LTC Paper

STRATEGIES AND TENURE IN AFRICAN LIVESTOCK DEVELOPMENT

by

Brent M. Swallow

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PREFACE

In recent years, policy toward rangeland tenure in sub-Saharan Africa has been based on one of two theoretical perspectives. The first is the "open access" model, which argues that overgrazing is inherent to communal use. Under "open access," there are no functioning property rights to the resource, and each herder uses the range without regard to the behavior of others. Adherents to this model are often drawn to the conclusion that overgrazing can be addressed only through radical "reforms" privatizing range tenure or giving states sweeping regulatory powers to police individual use. These policies have proved impractical or undesirable for a number of reasons.

The other theoretical perspective is the "common property" model, which states that individual use of common pastures can be, and often is, regulated by local institutions so that overgrazing does not result or is minimized. This latter school of thought has fostered a search in traditional arrangements for formal rules regulating range use, with the hope that the institutional arrangements surrounding such rules may provide appropriate models for regulating communal range use under contemporary circumstances. Unfortunately, the search has failed to turn up many cases of traditional management based upon formal decision-making bodies or control structures, at least along the lines suggested by common property theory.

In sum, available theories poorly model real world institutional arrangements or are not able to offer practical solutions to real world grazing-management problems.

In this Land Tenure Center paper, Brent Swallow offers a new theoretical perspective on rangeland tenure in sub-Saharan Africa, one which, I believe, addresses many of the inadequacies of existing models. Mr. Swallow concludes that many range tenure systems in Africa are best defined in terms of "coordination access" and "implicit contracts," in which pastoralists "coordinate mutually beneficial rangeland use without the existence of common property tenure systems." The success of these systems depends upon herders' basing their range use strategies upon information about the behavior of other herders and enforcing informal social sanctions against undesirable behavior.

In the process of developing his model, Mr. Swallow sorts through a wealth of theoretical and empirical material on African grazing systems. In so doing, he provides a valuable service to researchers and policymakers alike. His analyses go far toward explaining the inadequacies of past policy interventions. They point the way toward a productive re-evaluation of range and livestock policies in sub-Saharan Africa.

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Steven W. Lawry
Madison, Wisconsin
July 1990

EXECUTIVE SUMMARY

Donor agencies and African governments have implemented a variety of rangeland tenure instruments in efforts to achieve the objectives of increasing urban meat supplies, raising net exports of meat and live animals, conserving rangeland resources, and settling nomadic pastoralists. Rangeland tenure instruments are designed to achieve policy objectives through their effects on the behavior of individuals and groups of livestock owners. The consequences of those policy instruments depend upon livestock owners' strategies and the complex interactions between the instruments, the ecological system, and the social system. Prediction of the likely consequences of policy instruments requires an understanding of livestock owner strategies and those interactions. The goal of this paper is to contribute to that understanding.

Livestock Owner Strategies. An individual livestock owner's strategy is a set of conditional actions to be taken over a planning horizon. For the conditions that pertain at any time, a strategy defines one action that the livestock owner will pursue. The range of conditional actions depends upon the individual's objectives, his past actions and experience, and the constraints and opportunities afforded by the social and ecological systems. An individual's choice among possible actions depends upon social and ecological factors as well as the livestock owner's objectives, information, expectations of others' actions, and expectations of future conditions. A review of empirical evidence on livestock owner strategies supports the following conclusions.

1. Strategies depend upon past actions, expectations of the impacts of future random shocks, and the perceived risks associated with alternative actions.

2. The environments in which most livestock owners pursue their livelihoods are characterized by highly variable environmental conditions. The more variable the environmental conditions, the more mobile, flexible, and diverse are livestock owners' strategies.

3. Pastoralists use livestock products to secure subsistence and to generate cash income with which to purchase food, other consumer items, and capital assets.

4. There are emerging groups of large-scale commercial livestock owners in many countries. Because of their superior access to credit, markets, and political power, these commercial livestock owners are most likely to benefit from the introduction of new techniques and new institutions.

Types of rangeland tenure. Four tenure regimes have been described by previous analysts. State property, private property, and common property are tenure regimes in which the state, individuals, or groups of agents, respectively, have secure rights of access to future forage and water available on an area of rangeland. Open access is a non-property tenure regime in which

individuals or groups who achieve access to an area of rangeland ignore the consequences of their behavior on other rangeland users.

An additional tenure regime--coordination access--is developed in this paper to address a perceived gap between theory and empirical observation. Received theory implies that the absence of property rights is open access and that open access is likely to lead to consistent overuse and deterioration of resources. There is evidence to suggest, however, that pastoralists often coordinate mutually beneficial rangeland use without each agent holding secure access rights. In coordination access regimes, agents have no expectations that a social collectivity will sanction their access to or use of the resources. Rather, they expect that environmental and economic factors will dissuade strangers from future access. Those agents who achieve access will base their expectations of others' future actions upon the type of implicit contract that can be supported by the repeated interactions between agents.

Each of the property regimes can be supported by conventions, explicit contracts, or implicit contracts between resource users. A convention is an unenforceable norm of behavior. An explicit contract is an action that supports a desired agreement by making agents' future income levels contingent upon current actions. A legally binding contract is an example of an explicit contract. An implicit contract is an agreement supported by a set of credible threats of future punishment for current deviations from the agreements. Each party to an implicit contract follows strategies that are contingent upon information regarding the past actions of other users. If a user receives information that other users have disregarded the consequences of their actions--followed open-access strategies--then that user will follow a punishment strategy. If a user receives information that other users have acted in ways that account for the consequences of their actions--followed implicit contracts--then that user will have incentive also to follow a coordinated strategy.

In much of the literature on common property resources it is implicitly assumed that common property must be supported by explicit contracts. In this paper, it is shown that explicit contracts are necessary to support cooperative resource use in situations in which a group of independent profit-maximizing agents shares access to a resource for a single time period. Runge (1981) argues that the strategies of livestock owners sharing a common rangeland are generally interdependent and that convention may be sufficient to support coordinated resource use in such a situation. In this paper, the theory of dynamic games is drawn upon to develop the notion of common property based on implicit contracts. It is proved that there do exist circumstances in which independent resource users who share a common resource can achieve coordinated outcomes with implicit contracts.

Conclusions on Rangeland Tenure. A review of examples of state property, endogenous common property, common property innovations, private property, and open access supports the following conclusions.

1. It is generally some combinations of conventions, explicit contracts, and implicit contracts that provide users of African rangeland resources with secure expectations regarding the resource use behavior of other rangeland users.

2. Use of arid rangelands is often regulated and coordinated through tenure regimes for water resources.

3. Common property innovations can be successful in certain circumstances. In one example, coordination of livestock owners' grazing strategies developed as a secondary activity of a livestock owners' group.

4. Different types of rangeland tenure may operate at different levels of territorial organization.

5. Livestock owners are most likely to favor project activities that are designed in response to their objectives and constraints and object to attempts to regulate herd management directly.

6. Property relations supported by implicit contracts may be consistent with the flexible and mobile strategies followed by most African pastoralists. Mobility and flexibility may preclude legally binding explicit contracts but promote coordination based on information sharing, threats of punishments for deviant behavior, and loosely defined codes of behavior.

7. An ineffective state-property regime is likely to undermine local tenure regimes.

Implications for the design of rangeland tenure policy instruments. The empirical research supports the following hypotheses: (1) explicit contracts and implicit contracts can be equally appropriate solutions to the coordination problems faced by African pastoralists; and (2) policy instruments will be welcomed by livestock owners only if they are designed to improve their livestock herds, their coordination with other resource users, or their security of access and use rights to areas of rangeland.

If coordination and security of expectations are accepted as important objectives for tenure policy, then the following list of questions should guide the development of policy instruments.

1. Whose actions need improvements in coordination? Members of small herding groups? Different ethnic groups of pastoralists? Pastoralists and agriculturalists?

2. What is the point of conflict? Seasonal grazing areas? Watering points? Transhumant grazing routes?

3. At what times are the coordination problems the greatest? Drought years? Dry season?

4. What is the distribution of consequences of alternative policy instruments? Are there any policy instruments that can solve the coordination problem without negative consequences for any of the affected parties?

5. What is the distribution of transaction costs associated with alternative coordination regimes?

6. Is coordination consistent with national development and conservation objectives?

7. What factors currently contribute to the relative security or insecurity of livestock owners' expectations? Will policy instruments cause increased or reduced security?

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1. INTRODUCTION

Livestock owners in African countries have been frequent targets of development assistance and government policies over the past fifty years. Livestock and range development projects are often motivated by concern with "problems" of African livestock development. Low production per animal, poor-quality livestock products, low levels of meat exports, and degradation of rangeland are the most frequently cited problems. Donor agencies and national governments have adopted a number of policy objectives to address these problems. These objectives generally include a subset of the following: increase the availability of low-priced livestock products, particularly beef, in urban areas; raise net exports of meat and live animals; conserve or improve rangeland resources; settle and educate nomadic pastoralists. These policy objectives are defended as being consistent with long-term national development goals.

Governments and donor agencies utilize policy instruments in efforts to achieve their policy objectives. Policy instruments are often initiated as components of area-based livestock and range development projects that usually include technical, institutional, and organizational instruments. High-quality breeding stock, water provision techniques, and animal health practices are technical instruments. Rangeland tenure institutions and marketing regulations are institutional instruments. Marketing cooperatives and range management committees are organizational instruments.

Policy instruments are designed to achieve policy objectives through their effects on the behavior of individual livestock owners and groups of livestock owners. The behavioral consequences of a policy instrument depend upon livestock owners' strategies and the complex interactions between the instrument, the ecological system, and the social system. The designers of policy instruments require some understanding of livestock-owner strategies and those interactions in order to predict the likely consequences of alternative policy instruments. The purpose of this paper is to contribute to that understanding.

Rangeland tenure and livestock owner strategies are the foci of the report. Two categories of relationships are analyzed: the relationships between strategies and rangeland tenure systems, and the relationships between rangeland tenure systems and livestock owners, their animals, and the ecological

system. The paper proceeds as follows. In sections 2, 3, and 4, a number of concepts and models are developed based on existing and original conceptual research. In section 5, a mathematical model of livestock owner strategies and rangeland tenure is developed. Section 6 is a review of evidence on livestock owner strategies. Section 7 is a review of evidence on rangeland tenure systems. Conclusions and implications for the design of rangeland tenure policy instruments are presented in section 8.

2. PROPERTY, ACCESS, AND RANGELAND TENURE

2.1. Property Rights and Duties in Rangeland Tenure Systems

Right and duty are static social relations that are sanctioned by a collectivity of agents through its customs, laws, and judicial system. Right and duty involve individual agents, groups of those agents, and the expected behavior of both individuals and groups. An agent with a right has expectations of the ways that other agents will behave toward him and further expects that the collectivity will enforce that behavior and punish deviant behavior. An agent with a duty, on the other hand, knows that other agents expect certain behavior of him and anticipates that deviations from that behavior will be punished by the collectivity (Bromley 1989, pp. 44-45).

Property is a future income stream. A property relation is a social institution that describes triadic agent-property-agent relations. The social collectivity, or a designate of the collectivity, sanctions property relations in a property rights regime. Bromley (ibid., p. 205) distinguishes property rights regimes on the basis of the type of agent which is vested with property rights and duties:

> State property. Individuals have a duty to observe use/access rules determined by a controlling/managing agency. Agencies have a right to determine use/access rules.
>
> Private property. Individuals have a right to undertake socially acceptable uses, and have a duty to refrain from socially unacceptable uses. Others (called "non-owners") have a duty to refrain from preventing socially acceptable uses, and have a right to expect only socially acceptable uses will occur.
>
> Common property. The management group ("the owners") has a right to exclude non-members, and non-members have a duty to abide by exclusion. Individual members of the management group (the "co-owners") have both rights and duties with respect to use rates and maintenance of the thing owned.

A rangeland tenure regime may be a property rights regime. Future streams of income--property--are generated by forage and water produced in an area of rangeland. Agents who have property rights to access and use the products of a rangeland are party to property relations vis-à-vis other agents with property rights and duties. An agent with property rights to rangeland resources has the expectation that other agents will not hamper his access or certain uses of rangeland resources and the further expectation that the collectivity will protect his access and sanctioned use of the resources.

2.2. Non-property Rangeland Access

In addition to the three property regimes distinguished above, one additional tenure regime--open access--is commonly distinguished. There are no property rights or duties in an open-access regime. Each agent achieves access to the water and forage available in an area of rangeland by the physical presence of his animals on that rangeland. Agents have no expectations that a social collectivity will sanction their access to or use of the rangeland resources.

In this paper, a distinction is drawn between non-property rights regimes in which agents achieve open access and regimes in which they achieve coordination access to particular resources. The difference between open access and coordination access lies in the agents' expectations of others' behavior vis-à-vis the particular resources in question. In an open-access regime, each agent who achieves access ignores the consequences of his behavior on other agents who access the resource. In a coordination-access regime, each agent who achieves access follows a strategy that is contingent upon others' expected reactions to that strategy.

2.3. Contractual Dimensions of Tenure Regimes

Implicit in the preceding definitions of property and non-property tenure is the type of institutional arrangement that provides agents assurance about the expected behavior of other agents. Much of the literature on resource use under alternative property regimes assumes (1) that all property rights institutions are supported by explicit contracts which are enforced by the collectivity and (2) that all non-property rights regimes are open-access regimes in which there are no contracts between agents. In this paper, it is shown that conventions, explicit contracts, and implicit contracts are alternative institutional arrangements that can support property rights and non-property rights regimes. Further, it is argued that some combination of these institutions generally support rangeland tenure regimes in Africa.

A convention is a regularity in the behavior of a member of a population to which everyone conforms, to which everyone expects everyone else to conform, and to which everyone prefers to conform on the condition that others will also conform (Schotter 1981, p. 10).

An explicit contract is an action that supports a desired agreement by making agents' future income levels contingent upon current actions (Crawford 1985). A legally binding contract is an example of an explicit contract that is supported by the threat power of the collectivity. Explicit contracts that need not be supported by the collectivity are contracts involving hostages, collateral, or "hands-tying." These latter types of contract can be supported even in a Hobbesian "state of nature" in which there is contractual insecurity (Kronman 1985).

An implicit contract is an agreement--which does not require explicit communication between the contracting agents--that is supported by a set of credible threats of future punishments for current deviations from the agreement.

Each party to an implicit contract follows strategies that are contingent upon information regarding the past actions of other agents. If a party to an implicit contract receives information that others have disregarded the consequences of their actions, then that agent will follow a punishment strategy. If he receives information that others have behaved in ways that account for the consequences of their actions, then that agent will have incentive also to follow a coordinated strategy.

2.4. Organizational Dimensions of Rangeland Tenure Systems

The forms of the contracts that regulate access and use of resources are shaped by social organizations. The standard characterizations of private, state, and common property are based upon assumptions regarding the collectivities that define and enforce property rights and duties. State property systems require state collectivities that determine and enforce use and access rules. Private property-rights systems require collectivities that distinguish socially acceptable from socially unacceptable uses, sanction socially acceptable uses, and punish socially unacceptable uses. Common property-rights systems require collectivities at higher social levels that can enforce exclusion of non-members.

Three aspects of social structure are important to the organizational dimensions of rangeland tenure systems: (1) the social structure prevailing within a group of livestock-owning people, (2) the social and political relationships between groups of livestock owners and between livestock owners and other land users, and (3) the structure and strength of the overall national political system and its relation to local and customary political structures.

Schneider (1979) classifies East African pastoral groups along a continuum between hierarchical and egalitarian social systems. The customary rangeland property system in Lesotho was hierarchical: property rights to rangeland outside of village areas were granted by chiefs in exchange for social obligations. In contrast, the customary Maasai social system had both egalitarian and hierarchical elements. The Maasai system had a rigid hierarchy of social classes based on both gender and age, while social norms within classes stressed sharing and cooperative decision-making. Property over rangeland grazing was distributed through male age-sets and the tenure system was maintained through active group participation.[1]

Groups of livestock-owning people engage in a number of relationships with their neighbors that are directly related to rangeland tenure. In precolonial Maasailand, there were at least three types of group interaction. Between settlements there was significant sharing of grazing areas and fluid boundaries between grazing areas. Between sections there was a limited amount of sharing and frequent conflicts over rangeland. The pastoral Maasai had continual territorial disputes and conflicts with their non-pastoral neighbors (Jacobs 1975).

In much of West Africa the distinction between pastoralists and cultivators is drawn along ethnic lines. In Eastern Niger the Fulfulbe-speaking ethnic groups are primarily pastoralists while the Kanuric-speaking groups are

primarily agriculturalists. Throughout much of the year the relationship is peaceful and somewhat cooperative. The farmers gain from the manure dropped on their land, purchase milk and cattle from the pastoralists, and at times entrust their own animals to them. The pastoralists in turn gain access to crop residue, watering points, markets to sell dairy products and live animals, and markets for the purchase of staple crops. During harvest time and drought years, however, tensions rise. When cattle get onto unharvested fields, farmers charge that the cattle are allowed or prompted to wander. Pastoralists argue that farmers deliberately plant crops near grazing areas to attract livestock and introduce conflict (Awogbade 1986; Horowitz 1972).

One of the most important consequences of colonialism and postcolonial national governments for African pastoralists is that intergroup conflicts over rangeland resources are now often mediated by central political structures. The French colonial government of Niger undermined the hegemony of the Twareg and the Fulani pastoralists and changed the basis of the relationships between those groups and the agriculturalist groups in the area (Baier 1980). Pacification of Northern Nigeria by the British colonial government allowed Fulani pastoralists to gain access to grazing areas on the Jos Plateau (Awogbade 1986). The pastoral Maasai of Kenya and Tanzania had large territories expropriated by the colonial government for use by European and African agriculturalists. And in Western Niger, the government demarcates the **zone nomade** and the **zone sedentaire** and prohibits pastoralists from moving their herds into the **zone sedentaire** until after some officially established date; after that date there is no legal protection for livestock damage to unharvested fields (Horowitz 1972).

2.5. Endogenous Evolution of Rangeland Tenure Systems

Economists who advocate the economic importance of property rights take two positions regarding the evolution of property rights regimes. Demsetz (1967), Johnson (1972), and Posner (1977) argue that economic advance is fostered by private property and that customary institutions often hamper the development of private property. Private property is necessary for two important ingredients of economic growth—the development of markets and economic efficiency. Bromley (1989, p. 15) labels this the "property-rights view" of tenure evolution.

Alternatively, Ault and Rutman (1979) take the view that African property regimes have continually evolved in response to changes in economic constraints and opportunities. Bromley (1989, p. 16) describes this alternative view as follows:

> different forms of property rights (institutions) will require different levels of supporting infrastructure to define rights and duties, to demarcate boundaries, and to enforce the structure of

---

1. See subsection 6.1 for a further description of Maasai social organization.

> rights; and . . . therefore the economically appropriate structure, whether private property, state property or common property, is a function of the economic surplus available to support those differential costs.

Dahlman (1980) and Bromley (1989) agree that three factors take on primary importance in this alternative view of property rights: (1) the particular objectives of the decision group, (2) the role of technology, and (3) the transaction costs implied by alternative tenure regimes. Transaction costs include the costs of information, contracting, and enforcement of any exchange or bargain (Bromley ibid.). Williamson (1985) argues that transaction costs are an important measure of the efficacy of alternative governance or property rights structures. Everything else being equal, the preferred property regime is the one with minimal transaction costs.

3. PREVIOUS MODELS OF LIVESTOCK OWNER STRATEGIES AND RANGELAND TENURE

An individual livestock owner's strategy is a set of conditional actions to be taken over a planning horizon. For the conditions that pertain at any time, a strategy defines one action that the livestock owner will pursue. The range of conditional actions depends upon the individual's objectives, past actions and experience, and the constraints and opportunities afforded by the social and ecological systems. An action may comprise several variables under the livestock owner's control, including management practices, market transactions, and institutional transactions. Examples of management practices include herding, breeding, watering, and supplementary feeding. Examples of market transactions are exchanges and loans of live animals, animal products, feeds, and animal health inputs. Institutional transactions are actions taken by individuals to modify or maintain the institutional arrangements that define their management and market choice sets (Bromley 1989, p. 49). Examples of institutional transactions are actions taken to protect or challenge property rights and actions taken to change reciprocal obligations between members of a social group.

The foci of this paper are the relationships between livestock owner strategies and rangeland tenure systems. A limited amount of previous research has focused explicitly on those relationships. The following review of that research establishes concepts and models relevant to the models developed in section 4.

3.1. A Static Model of Open Access/Private Property

The economic model often used to illustrate the "tragedy of the commons" (Hardin 1968), or more accurately, the tragedy of open access, is a model first developed by Gordon (1954) and applied to rangeland situations by Simpson and Sullivan (1984), Jarvis (1984), and Sommerville and Kerr (1988). The simplest static version of the model is constructed as follows: Suppose that a group of N identical, profit-maximizing livestock owners shares a rangeland of fixed size for one forage-growing season. At the beginning of the season, each livestock owner chooses the number of identical animals (Xi) to keep on that rangeland. The price per unit of animal product (P) is fixed and known. The total cost of herding for each livestock owner is a function of the number of animals in that individual's herd. Each livestock owner knows that there is a linear relationship between average production of animal products (APP), the total number of animals on the rangeland (X), and the forage production potential of that rangeland (A). Each livestock owner also knows the relationship between herding costs per animal, the total number of animals on the rangeland, and the number of animals in his or her individual herd. The problem faced by each livestock owner in this situation is given in equations (1), (2), (3), and (4), and the first order necessary condition is given in equation (5). Second order conditions are satisfied by the assumed functional form of C(Xi).

$$\underset{Xi}{\text{Max}} \quad P * APP * Xi - Xi * Ci \tag{1}$$

$$\text{s.t.} \quad APP = A - S * X \tag{2}$$

$$\text{s.t.} \quad X = X1 + X2 + \ldots + Xi + \ldots Xn \tag{3}$$

$$\text{s.t.} \quad Ci = Ci(Xi) \quad \text{where } dCi/dXi > 0;\ dCi^2/dXi^2 < 0; \tag{4}$$

$$\text{fonc} \quad P * (A - S * X - S * Xi) - dCi/dXi = 0 \tag{5}$$

where P is price of livestock output;
APP is average product of livestock output per animal;
Xi is number of animals stocked by individual i;
X is the total number of animals;
Ci is the total cost of input to individual i;
A is a measure of rangeland potential;
S is a measure of rangeland stability.

The extremes of open access and private access are depicted in this model by varying the number of identical livestock owners assumed to be sharing the rangeland. It is useful to rewrite the first order necessary condition, equation (5), in terms of the proportion of animals held by the ith individual.

$$P * (A - S * X - S * k * X) - dCi/dXi = 0 \tag{6}$$

where $k = Xi/X$.

Private access is depicted in this model by setting $k = 1$, that is, by assuming that the ith individual owns all of the animals on the rangeland. The first order necessary condition can be rewritten as equation (7). That is, under private access the profit-maximizing livestock owner will add animals to the rangeland until net returns are maximized. Open access is depicted by setting $k = 0$, that is, by assuming that the ith individual owns a negligible proportion of the total number of animals on the rangeland. The first order necessary condition can be rewritten as equation (8). That is, under open access each of a large number of livestock owners will add animals until net returns are driven to zero. The tragedy of open access, therefore, is that total economic rents decline as the number of independent, profit-maximizing livestock owners sharing the rangeland increases (Weitzman 1974; Dorfman 1974).

$$VMP - dCi/dXi = 0 \tag{7}$$

$$VAP - dCi/dXi = 0 \tag{8}$$

The model is presented graphically in Figure 1. The curve labeled TR expresses total revenue, the product of average physical product (APP) and price, as a function of the number of animals grazed on an area of rangeland. The curve TCI similarly expresses total cost of input as a function of the number of animals. The static private-property equilibrium is at X_0 and the static open-access equilibrium is at X_1.

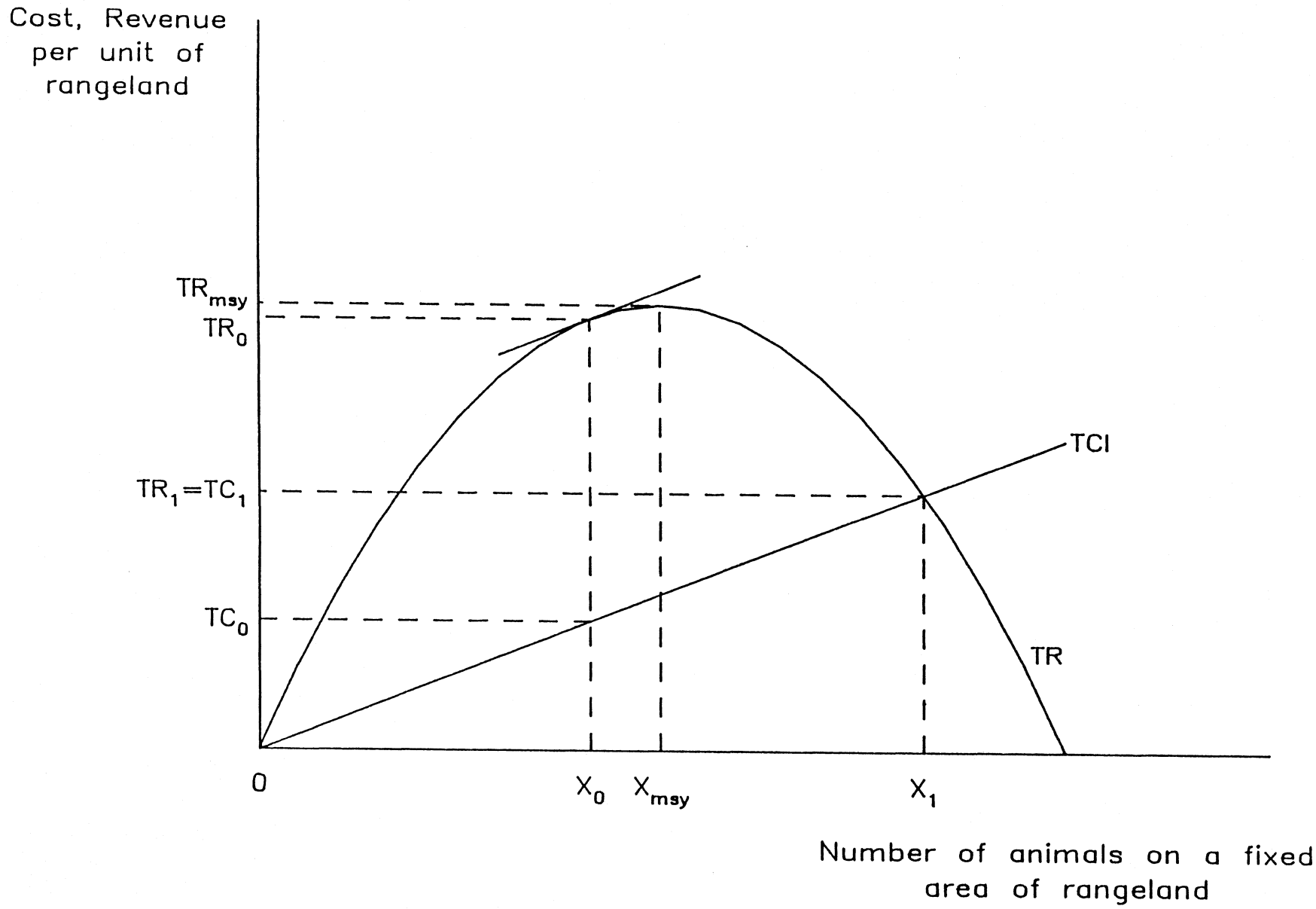

Figure 1: Gordon's (1954) Model of Stocking Rate Decisions

Source: Based on Conrad and Clark (1987), P. 88

3.2. A Dynamic Model of Open Access/Private Access

Suppose that the same group of N livestock owners shares access to a rangeland of fixed size for a large, but indefinite, number of forage-growing seasons. At the beginning of every season, each livestock owner chooses the number of identical animals to keep on the rangeland for that growing season. Again, price of livestock output (P) is fixed, and the cost of input is related to the number of animals held by an individual. In any particular growing season (t), there is a known linear relationship between average production of animal products (APPt), the total number of animals on the rangeland in that period (Xt), and the forage production potential of the rangeland in that period (At).[2] Year-to-year changes in forage production potential are a function of the current production potential and the number of animals on the rangeland that year.

The discrete-time optimal-control problem faced by a profit-maximizing livestock owner, who makes his decision independently of others, is to choose the number of animal units in his or her individual herd for each period (Xit) that maximizes the discounted net present value of future profits, subject to constraint. That is, the livestock owner chooses the vector $\underline{Xi}$ that maximizes equation (9) subject to equations (10) through (15).

$$\underset{\underline{Xi}}{\text{Max}} \sum_{t=0}^{\infty} B^t \, V(Xit, At, Xt) \tag{9}$$

$$At+1 - At = F(At, Xt) \tag{10}$$

$$A0 \text{ is given} \tag{11}$$

$$V(Xit, Xt, At) = [P * APPt - Ci] * Xit \tag{12}$$

$$Xt = X1t + X2t + \ldots + Xit + \ldots + Xnt \tag{13}$$

$$APPt = At - S * Xt \tag{14}$$

$$Ci = Ci(Xit) \quad \text{where } dCi/dXi > 0;\ dCi^2/dXi^2 < 0 \tag{15}$$

where B is the individual's factor for discounting future income;
P is the fixed per unit of livestock output;
Ci is the total cost of inputs to individual i;
Xt is the total number of animals stocked on a fixed area of rangeland in period t;

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2. The relationship between average production of animal products and the number of animals stocked on an area of rangeland has been the focus of a substantial amount of research by range scientists. From a review of experimental results, Jones and Sandland (1974), Sandland and Jones (1975), and Jones (1980) all concluded that "in the region of the response curve where pasture potential and not animal potential is limiting, gain per animal declines linearly with increases in stocking rate" (Jones ibid., p. 419).

Xit is the number of animals owned by individual i in period t;
At is a measure of rangeland potential in period t;
S is a measure of rangeland stability.

The Lagrangian and first order necessary conditions for the livestock owner's problem in this case are equations (16), (17), (18), and (9).

$$\underset{Xit,\ At}{\text{Max}} \quad \sum_{t=0}^{\infty}\{B^t\ V(Xit, At, Xt) + Lt+1\ (At + F(At, Xt) - At+1)\} \qquad (16)$$

$$P\ (-S * Xit + APPt) - dCi/dXi + B\ Lt+1\ dF/dXit = 0 \qquad (17)$$

$$B\ Lt+1 - Lt = -dV/dAt - Lt+1\ dF/dAt \qquad (18)$$

$$At+1 - At = F(At, Xt) \qquad (10)$$

where Lt is the co-state variable.

Equation (10) is the recovered adjoint equation. The co-state equation (18) defines the time path of the co-state variable. Equation (17) is the optimality condition. Independent profit-maximizing herd owners add animal units to their herds until the current value of marginal product of an additional animal unit equals the marginal cost of input plus the current marginal cost (less the benefit) of forgone future profits. That is, $dF/dXit > 0$ implies that additions to the individual's livestock herd increase future production potential and $dF/dXit < 0$ implies that herd additions reduce future production potential. Rangelands that require some grazing pressure to reduce brush encroachment or increase forage production would have $dF/dXit > 0$ for some levels of X.

Equation (19) expresses the optimality condition in terms of the total number of animals (X) and the proportion of the total held by the ith livestock owner (ki). As ki approaches one, depicting access by a single livestock owner, the VMPi for the individual approaches the VMP for the group of livestock owners. As ki approaches zero, depicting open access by many livestock owners, the VMPi for the individual approaches the VAP for the group. Even with ki very small, however, annual rents may be positive at the equilibrium stocking rate. The lower ki is, the more likely it is that dF/dXit is negative at the equilibrium stocking rate.

$$P(-S * ki * Xt + APPt) - dCi/dXi + B\ Lt+1\ dF/dXit = 0 \qquad (19)$$

Possible dynamic equilibria can be depicted on Figure 1. Consider a redefinition of total revenue and total cost of input functions to be total sustained revenue and total sustained cost of input. That is, if X_o number of animals is continually grazed on an area of rangeland, then the total revenue and total cost of input generated from that rangeland would stabilize at TR_o and TC_o. The maximum sustained total revenue is at X_{msy}. It can be shown that X_o is the dynamic private access equilibrium only in the case of a zero discount rate. With a positive discount rate, the private-access equilibrium

will be less than X_1 and may be greater than or less than X_{msy}. X_1 is the open-access equilibrium number of animals only if the discount rate approaches positive infinity.

3.3. Game-theoretic Foundations of the Open-Access Model

The open-access model has been formulated as a single-shot social dilemma game (Braver and Wilson 1986). Since first developed in the early 1950s, the social dilemma game (often called the prisoners' dilemma game) has come to epitomize situations in which rational decisions by individuals yield inferior social outcomes (Barry and Hardin 1982). Consider a game in which two livestock owners--Alpha and Beta--face a one-time problem in which both have to choose to graze a High or Low number of livestock on a fixed rangeland. The profits associated with the four possible outcomes (both choose Low; Alpha chooses Low and Beta chooses High; Alpha chooses High and Beta chooses Low; both choose High) are shown in the payoff matrix of Figure 2. The first element in each ordered pair is the payoff to Alpha; the second element is the payoff to Beta. If the payoffs are ranked as b > a > d > c, then the dominant strategy for both players is High. That is, whether the other player cooperates by choosing Low or deviates by choosing High, it is rational for each player to choose High. The outcome of rational choices by both livestock owners (d,d) is Pareto inferior. That is, both players would be better-off with the outcome (a,a).

FIGURE 2

Payoff Matrix for a Two-person Social Dilemma

		LIVESTOCK OWNER BETA	
		Low	High
LIVESTOCK OWNER ALPHA	Low	(a,a)	(b,c)
	High	(c,b)	(d,d)

where b > a > d > c and 2 * a > b + c [3]

3. The restriction that 2 * a > b + c ensures that the Pareto superior cooperative solution to a repeated prisoners' dilemma game (discussed in a later section) does not involve players' taking turns exploiting each others' cooperation.

It is argued that users of an open-access resource face a multiple-agent social dilemma. The dominant strategy for an individual livestock owner is to add animals to the rangeland until their marginal returns from adding an additional animal are zero, no matter whether the other livestock owners stint or follow the same rationale. The result of all livestock owners' following their dominant strategies is an equilibrium outcome that is socially inferior. That is, all livestock owners would be better-off if they all stocked fewer animals.

Runge (1986) depicts the multiple-agent social dilemma in a form that can be made consistent with the static open-access/private-property model presented in section 3.1. Suppose again that N identical livestock owners share a rangeland of fixed size for one forage-growing season. Prior to the beginning of the season, an economist calculates the open-access and private-access equilibria. His calculation is that XD is the number of animals that each identical livestock owner would stock on the rangeland in an open-access equilibrium (High) and that XC is the number of animals that each would stock to maximize rents (Low). The livestock owners' association has allocated XD number of grazing permits to each of the N livestock owners. At the beginning of the season, each livestock owner must choose to set his or her individual stocking rate (Xi) at either XD or XC level of stocking.[4] The dominant strategy for every individual livestock owner is to set Xi = XD. A Pareto-superior outcome would have each livestock owner setting Xi = XC.

Suppose that in this situation there exists some number $1 < h$ such that if h livestock owners each stock XC animals and the rest stock XD animals, those who stock XC would be just as well off as they would have been if all livestock owners had stocked XD. In game-theoretic terms, h is the minimum coalition that can achieve gains from cooperation. If $h \geq N$, then no one gains from cooperation unless all agents cooperate. If $h < N$, then some free riders could be tolerated, even though they gain more from cooperation than do the cooperators.

In Figure 3, the payoff to an individual player is plotted against the number of other players cooperating. Payoffs from two strategies are depicted. The function labeled High plots the payoffs to an individual player who chooses to stock the high number of animals. With no other players cooperating, the payoff to an individual player who deviates is zero. The function labeled Low plots the payoffs to an individual player who chooses to stock the low number of animals. With no other players cooperating, a cooperating player (who plays low) achieves negative payoffs. With k other players cooperating, the payoff to Low is zero. In the social dilemma, High lies above Low for all numbers of other cooperating players.

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4. The device of grazing permits assures that livestock owners who choose the lower stocking rate level can be assured that others will not stock even more animals. Runge (1981) implicitly assumes some such mechanism. Hardin (1968) argues that livestock owners who chose to stint will be taken advantage of by defectors.

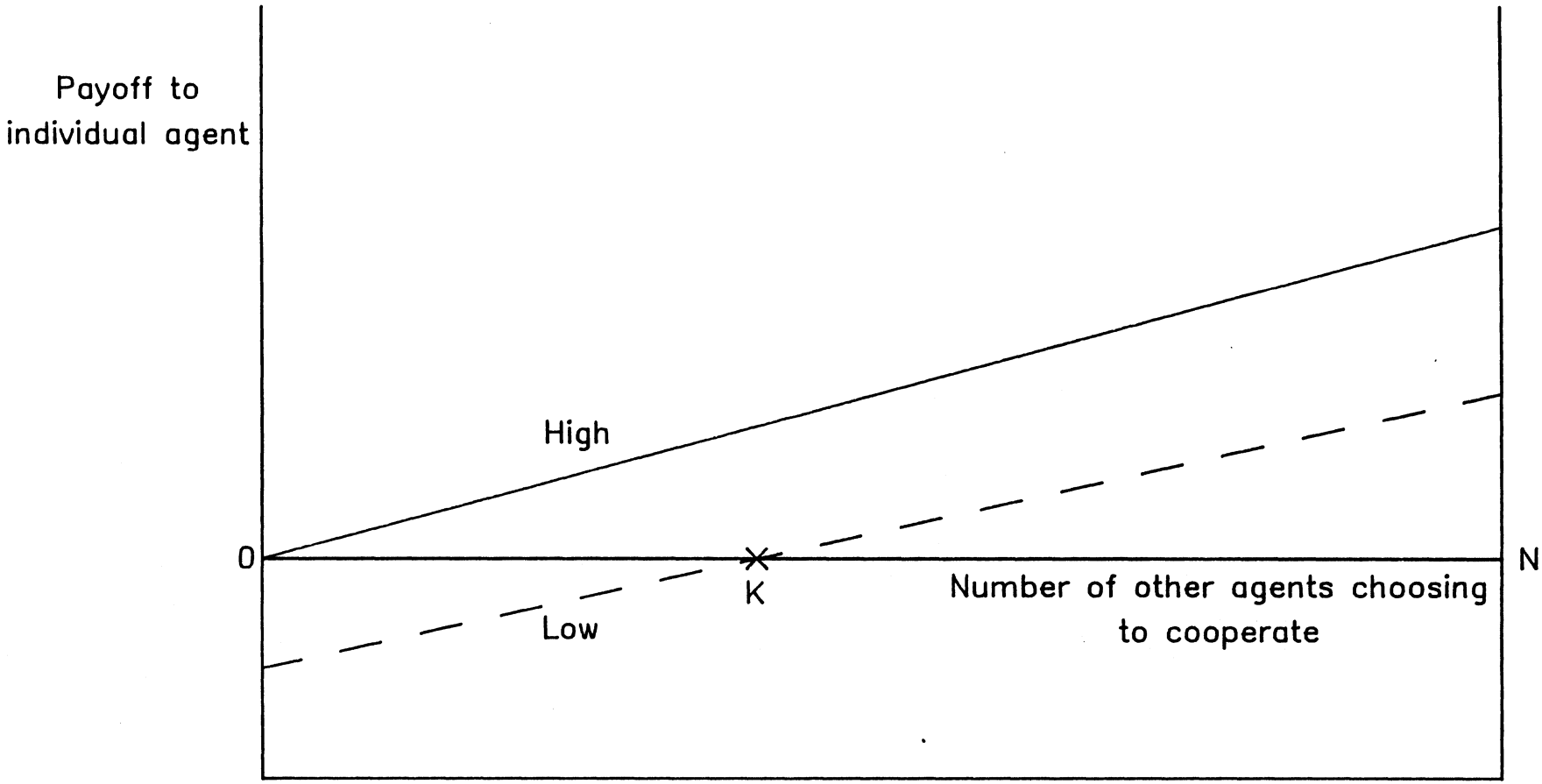

Figure 3: Graphical Depiction of the Multiple–agent Social Dilemma

Source: Runge (1986), P. 627

3.4. Property and Contracts in the Social Dilemma Models

In the single-period social dilemma, it is assumed that there are no future income streams. The outcome depends upon the type of contract that defines relationships between agents. Without an explicit contract between agents, a Pareto-inferior outcome is predicted. An explicit contract is necessary to support a Pareto-efficient outcome in those circumstances.

Agents in the dynamic social dilemma model are assumed to have rights to access resources in future periods but no property rights or duties vis-à-vis the other (N - 1) agents who also have that right. The open-access model is based on the assumptions that: (1) N is large, (2) all resource users ignore the consequences of their actions on others, (3) there are no binding contracts between agents, and (4) there are no conventions that provide assurance about players' expected behavior.

3.5. A Model of Interdependent Strategies

Runge (1981, p. 20) challenges the premise that users of a common resource face a social dilemma problem for three reasons.

> First, it fails to distinguish between situations of open access and those of common property, in effect arguing that they are the same. . . . Second, it treats the common property externality as a case in which the actions of each individual are taken to be independent. Third, because individuals are assumed to act independently, it abstracts from the crucial problem of each person's uncertainty regarding the actions of others.

The assumption that each individual takes independent action is crucial to the social dilemma formulation and, according to Runge, generally not valid for the case of resource users sharing a common resource. Users of common resources generally face interdependent decisions: the optimal action for each resource user depends on the actions of the other resource users. In this case, none of the resource users has a dominant strategy.

The case of interdependent choice is defined by Runge (1981) and Sen (1969) as an assurance problem. Each decision maker seeks assurance about the actions of others and, given that assurance, will choose to behave in a manner that produces a Pareto-efficient outcome. A two-person assurance problem is depicted in the payoff matrix shown in Figure 4.

In this formulation Alpha desires Low if Beta chooses Low and High if Beta chooses High. Likewise, Beta desires Low if Alpha chooses Low and High if Alpha chooses High. There is no Cournot-Nash equilibrium in pure strategies for this problem. That is, there is no combination of pure strategies which each player can choose to maximize his or her own payoff, given the strategy of the other player. In this situation players may follow mixed strategies or may choose to maximize their minimum payoff. The later strategy is called a maximim strategy. The result of both players' playing maximim strategies would

FIGURE 4

Payoff Matrix for an Assurance Problem

		PLAYER BETA	
		Low	**High**
PLAYER ALPHA	**Low**	**(b,a)**	**(e,c)**
	High	**(d,e)**	**(a,b)**

where b > a > e > d > c; b > (d+e)/2; and a > (c+e)/2

be Alpha choosing High and Beta choosing Low, and the outcome would be (d,e). Both (a,b) and (b,a) are Pareto-superior outcomes: both players would be better-off if they acted to achieve either outcome. Both players, therefore, have incentive to seek assurance about the actions of the other player. Conventions or explicit contracts are possible mechanisms for providing that assurance.

Runge (1986) formulated the multiple-agent assurance game in terms of the graphical model presented in section 3.3, above. In Figure 5, the payoffs to an individual player of following the strategies of Low and High are shown as functions of the number of other agents choosing to cooperate by playing Low. The crossing of the two functions at d depicts a situation in which neither Low nor High are dominant strategies for the individual. If a player has assurance that at least d other livestock owners will cooperate, then he will also choose to cooperate.

A sufficient condition for the interdependence of resource users' decisions is that others' choice variables enter non-separably into the benefit or cost functions of an individual. Runge (1981) follows Davis and Whinston (1962) in arguing that the costs to an individual using a resource are dependent, in a non-separable way, on the resource use of others. The static model presented in section 3.1 can be reformulated to depict a case of non-separable cost externalities. Recall that Ci was defined as the total cost of grazing Xi number of animals on a rangeland and was assumed to be a function only of Xi. If there are non-separable cost externalities, then Ci is a non-linear function of the number of animals held by each livestock owner sharing the rangeland.

$$C_i = C_i\ (X1,\ X2,\ \ldots\ ,\ Xi,\ \ldots\ Xn) \qquad (20)$$

Retaining the remainder of the formulation of the livestock owners' problem from section 3.1, the first-order necessary condition for the livestock owner's choice of Xi is given by equation (21).

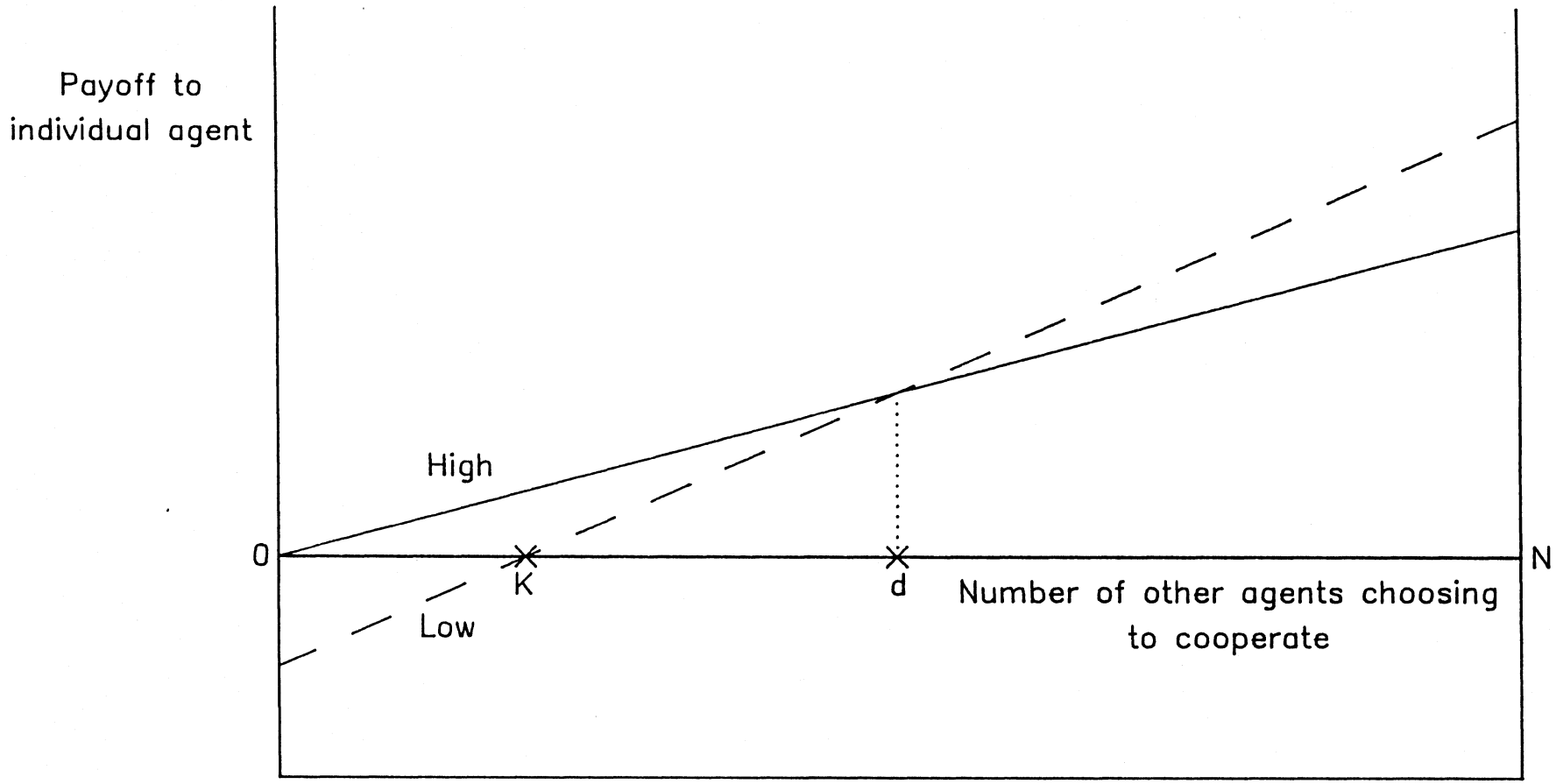

Figure 5: Graphical Depiction of the Multiple-agent Assurance Problem

Source: Runge (1986), P. 629

$$P * (A - S * X - S * Xi) - dC/dXi = 0 \qquad (21)$$

where dC/dXi is non-separable in Xj.

In this single-period assurance model, there are no future streams of income. In this situation an explicit contract will be sufficient, though not necessary, to support a Pareto-efficient outcome. A convention may be sufficient to provide the assurance about others' behavior that is required to support a Pareto-efficient outcome.

3.6. A Model of Opportunistic and Conservative Strategies

Sandford (1982) presents a framework for evaluating livestock owners' stocking-rate decisions given that rainfall, and thus available forage, has high year-to-year variability in most pastoral environments. Rather than make an assumption about livestock owners' motivations, develop a theoretical framework incorporating that assumption, and derive strategies based on that framework, Sandford (p. 62) begins by positing three alternative strategies. An opportunistic pastoral strategy is

> one which varies the number of livestock in accordance with the current availability of forage. Such a strategy enables the extra forage available in good years to be converted into economic output or into productive capital.

If the number of livestock is varied at the appropriate times--increased rapidly in good years and reduced rapidly in bad years so that no ecological destruction occurs--then the strategy is called an efficient opportunistic strategy. By contrast, a conservative strategy is "one which maintains a population of grazing animals at a relatively constant level, without overgrazing, through good and bad years alike" (ibid.).

Sandford simulates the consequences of these alternative strategies with different assumptions on rainfall variability and the level of risk allowable under a conservative strategy. On the basis of that analysis, Sandford (p. 70) concludes that

> very conservative (i.e., low risk) strategies have extremely high costs in all areas in terms of potential output forgone, and that in areas with very unreliable rainfall (high coefficients of variation) even moderately conservative strategies are very costly.

Sandford discusses ecological, social, political, economic, and attitudinal factors which will influence a livestock owner's choice of strategy. Everything else being equal, the greater the variability of rainfall, the smaller the area for seasonal migration, the greater the percentage of sheep and goats in the total herd, and the greater the opportunities for exchange, the more opportunistic the livestock owner's strategy will be. If livestock owners are motivated primarily by concerns about long-term survival and the

equity of the distribution of wealth and are less concerned about individual profit maximization, then they will tend toward following more conservative strategies.

3.7. Conclusions on Previous Models of Strategies and Tenure

The static and dynamic models reviewed in this section highlight the important role played by expectations in determining the outcome of interactions between agents sharing common access to rangeland resources. The social dilemma framework illustrates the possibility of a social dilemma solution even in a situation in which agents have access rights and duties that are sanctioned by collectivities. If agents have expectations that others will behave cooperatively, then the social dilemma can be averted. Expectations of cooperative behavior can be supported by explicit contracts (use rights and duties in common-property-rights regimes), conventions, or, as shown in the following section, implicit contracts.

4. THEORY OF INTERNAL IMPLICIT CONTRACTS

Sen (1969) and Runge (1981) argue that in the context of an assurance game, a convention between agents can support Pareto-superior outcomes without outside enforcement, even if all agents are individual profit maximizers and even if the game is played for only a single period. Ward (1989) shows that in repeated games, players may risk short-term losses to gather information regarding the preferences of other players. Axelrod (1984) argues that cooperative outcomes can be supported in repeated social dilemma games without the existence of an explicit contract. In those situations it is the threat of future retaliation for deviant behavior that encourages cooperation. A system of credible threats that supports a mutually beneficial outcome is called an implicit contract (Crawford 1985). Friedman (1971), Abreu (1986, 1988), and Lambson (1987) describe optimal implicit contracts.

4.1. Axelrod's Simulations of Implicit Contracts

Recall the two-player social dilemma game presented in section 3.3. Livestock owners Alpha and Beta face a problem of choosing whether to graze Low or High numbers of animals on a fixed area of rangeland. The payoffs associated with the four possible outcomes have been given in Figure 2. If the game is one-shot, then the dominant strategy of both players is to defect by playing High and the equilibrium has both players defecting and achieving a Pareto-inferior outcome. Both players would have been better-off if both had cooperated and played Low.

Suppose now that in every period that the game is played, there is a high probability that the same game will be repeated in the following period. At the end of each period both players can identify the actions of the other players, and at the beginning of each period they can recall the history of the game, including the actions of all players, and incorporate that information into their choice of action. Players discount future benefits and costs and do not have the option of exiting from the game.

This is the structure of the iterated two-person social dilemma game that Axelrod (1984) devised for his computer tournaments.[5] In each match contestants--that is, strategies in the form of computer programs submitted by contestants--paired off for play of the iterated social dilemma game. The tournaments were round-robin, every contestant played every other contestant once, and scores were cumulative. Axelrod held the tournament twice. The winner of both tournaments was a simple strategy called TIT-FOR-TAT.

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5. Axelrod ran two tournaments with slightly different rules. In the first tournament, the game was played 200 times in each match. Matches in the second tournament were of indeterminant length, with a high positive probability in every period that there would be a following period.

Axelrod concludes that the reasons for the success of TIT-FOR-TAT is that it is nice--it assumes cooperation in the first period and is never the first to deviate; it is retaliatory--deviations by other players are always immediately punished; it is forgiving--it reverts to cooperation after punishing deviant behavior for one period; and it is clear--its simple strategy can quickly be learned by opposing players.

How would one design a strategic setting to best promote the success and evolution of cooperative strategies? Axelrod (ibid., pp. 124-144) generalizes from his results to deal with this question. His suggestions: "make interactions more durable and more frequent" to increase players' subjective probability that they will encounter a player in a current game in the future; "change the payoffs" to increase the punishment for defection; "teach people to care about each other"; "teach reciprocity"; improve players' abilities to recognize players from previous interactions and to remember the relevant features of those interactions.

4.2. Critique of Axelrod

Other contributions to the game theoretic literature both challenge and validate Axelrod's analysis and the conclusions that have been drawn from it. Hirshleifer and Coll (1988) argue that special features of Axelrod's computer tournaments make their results relevant only for a small special set of all social situations in which individuals could gain from mutual cooperation. First, the social dilemma is the only game form that was considered. Other game forms (such as the assurance game) characterize many important social interactions.[6] Second, Axelrod considers only two-player matches. Olson (1965) and others suggest that the social dilemma situations are most problematic with large social groups. Third, TIT-FOR-TAT won Axelrod's computer tournaments by achieving high cumulative scores in round-robin contests with cumulative payoffs. Social interactions can also take the form of an elimination tournament. TIT-FOR-TAT is essentially never able to win in a one-to-one encounter. In computer tournaments in which the second and third of these assumptions were relaxed, Hirshleifer and Coll (1988) achieved results that cast doubt on the idea of a single optimum for all social dilemma situations.

Friedman (1971) and Abreu (1986, 1988) have proved the existence of perfect equilibria in repeated games in which players follow strategies that promote cooperative behavior on the basis of punishments for deviant behavior. That is, they have shown the conditions under which implicit contracts can exist in dynamic settings where they would not exist in similar static settings.

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6. Note that Runge (1981) deals with cooperation in the context of the assurance game and Ward (1989) analyzes the development of cooperative solutions when players are uncertain if they are in assurance, or prisoners' dilemma games.

4.3. Implicit Contracts Supported by Trigger Strategies

Friedman (1971, 1986) shows that under certain conditions it may be rational for players of repeated social dilemma games to follow punishment strategies in which cooperation is initially assumed and deviations by other players are punished. Friedman's trigger strategy contains an unforgiving punishment that is "triggered" by any deviation by any player. If another player deviates, a player following a trigger strategy will revert to non-cooperative Nash equilibrium behavior for all remaining periods of the repeated game. The following example, presented by Abreu (1988) as a case of duopolists in an infinite series of quantity-setting games, is useful for illustrating trigger strategies.

Suppose that livestock owners Alpha and Beta share use of a common rangeland for an infinite number of forage-growing seasons. Both seek to maximize the present value of their individual profit streams and both discount revenues and costs received in future growing seasons. During any season both Alpha and Beta must choose one of three discrete stocking levels: low, medium, and high. Nine discrete outcomes are possible in any season. Payoffs associated with each outcome are presented in Figure 6. High stocking rates by both livestock owners result in low average product per animal and negative profits to both. Low stocking rates by both players result in high average product per animal and the highest total profits. Call this the stinting outcome. Profits associated with each outcome are given in the payoff matrix of Figure 6. The first elements in the ordered pairs are payoffs to Alpha; the second are payoffs to Beta. The assumptions of symmetric profits and discrete strategies simplify the exposition.

FIGURE 6

Payoff Matrix Illustrating Trigger Strategies and Optimal Penal Codes

		LIVESTOCK OWNER BETA		
		Low	**Medium**	**High**
LIVESTOCK OWNER ALPHA	**Low**	10,10	3,15	0,7
	Medium	15,3	7,7	-4,5
	High	7,0	5,-4	-15,-15

The Nash equilibrium for the single-period game is (M,M) and both players receive payoffs of 7. That is, medium stocking by both livestock owners is the combination of feasible strategies at which each player maximizes her profits, given the strategy of the other player. In this situation, trigger strategies for the two livestock owners take the following form:

salpha = L if beta played L in all previous periods
M if beta played anything other than L in any period

sbeta = L if alpha played L in all previous periods
M if alpha played anything other than L in any period

These strategies can support the stinting outcome (L,L) as an equilibrium to the repeated game if the short-term gains from deviating from (L,L) are outweighed by the losses associated with reverting to (M,M) rather than continuing with (L,L). In this example, either livestock owner who expected the other to stock a low number of animals would maximize his single-shot payoff (deviate optimally) by playing M. The gain from deviating from the stinting outcome would be 15 - 10 = 5. The loss associated with the punishment would be the present value of the payoff to stinting less the payoff to future punishment. (Abreu discounts the payoff in the first period.) If the following inequality holds, then the cooperative outcome is supported as a perfect equilibrium.

$$5 <= B/(1-B) * [10 - 7] \quad (22)$$

where B = discount factor,
Vi(.) = repeated game payoff to player i associated with punishment.

Here V1(Nash) = V2(Nash) = B/(1-B) * 7, so equation (22) can be rewritten as equation (23). When B = 5/8, the players are indifferent between the stinting and the deviation outcome paths. For B > 5/8, the threat of the trigger-strategy punishment can support the stinting outcome path as an equilibrium. For B < 5/8, the threat of the trigger-strategy punishments imposed in the future cannot support the stinting outcome path.

$$5 <= B/(1-B) * 3 \quad (23)$$

The trigger strategy has been criticized on two grounds. First, Axelrod (1984) argues that it is too unforgiving of others' deviations. Friedman (1971) entered a trigger strategy in Axelrod's computer tournament that scored well against other cooperative strategies but poorly against uncooperative strategies. Axelrod contends that the ability of TIT-FOR-TAT to punish and then quickly forgive defections makes it superior to the trigger strategy. Second, Abreu (1988) proves that other strategies involving punishments for deviant behavior (penal codes) can be devised which support cooperative outcomes under a greater range of conditions. He proves that in an infinitely repeated game with discounting, it is possible to design a simple penal code that is an optimal penal code.

4.4. Implicit Contracts Supported by Optimal Punishments

Abreu (1988) provides the following definitions. A penal code is a vector of strategy profiles that specifies an initial path of cooperation and punishments for any deviation from the initial path or from a previously prescribed punishment. A simple strategy profile is defined by the initial path, N player-specific punishments (where N is the number of players) and the rule

that the punishment to a player is the same for any deviation. A simple penal code is a vector of N simple strategy profiles. An optimal penal code is a vector of N perfect strategy profiles, the ith element of which yields the ith player at least as low a payoff as does any other perfect equilibrium.

Abreu (ibid.) explains the logic of an optimal simple penal code for the example of the two livestock owners presented above. It turns out that Abreu constructed the example so that (Qalpha, Qbeta) is an optimal penal code for the livestock owners' game in pure strategies.

Qalpha = {(M,H), (L,M), (L,M), ... }

Qbeta = {(H,M), (M,L), (M,L), ... }

Consider the decision of Alpha--choosing to stint and enjoy the gains from repeated cooperation or deviate and bear the punishments imposed by the optimal penal code. By the assumption of symmetry, the decision of livestock owner Beta is identical. Suppose that B = 4/7. The optimal penal code is shown in equation (24) to be zero.

$$-4 * B + 3 * (B*B)/(1-B) = -16/7 + 3 * (16/49 * 7/3) = 0 \qquad (24)$$

That is, the penal codes' paths yield payoffs of zero to both players. The loss due to deviation, B/(1-B) * 10 = 12, is greater than the gain from deviation (which equals 5). For B = 4/7, therefore, the optimal penal code can support the stinting outcome as an equilibrium while the trigger strategy cannot.

Abreu (1986) analyzes optimal simple penal codes for the case of an oligopoly of quantity-setting firms. He found that under certain conditions, "a stick-and-carrot punishment exists that is an optimal symmetric punishment" (p. 198). A stick-and-carrot punishment is a two-phase punishment in which the outcome path reverts to the joint profit-maximizing path after one period of very severe punishment. Abreu's discussion (ibid., p. 206) of these results parallels very closely with Axelrod's discussion of the virtues of TIT-FOR-TAT:

> the most efficient way to provide low payoffs, in terms of incentives to cheat, is to combine a grim present with a credibly rosy future. In so doing, one simultaneously worsens the environment in which firms contemplate cheating today while providing them with an attractive non-deviation future.

An optimal stick-and-carrot punishment is an optimal version of TIT-FOR-TAT: it is optimally nice, optimally retaliatory, and, after a single period, optimally forgiving.

4.5. Information and Punishments in Internal Contracts

Axelrod (1984), Friedman (1971), and Abreu (1988) all rely on the assumptions of recognition and remembrance, that is, perfect and complete information. They all assume that defecting players could be traced and punished so

that cooperative solutions are supported by players' mutual fear of punishment for non-cooperative behavior. Schuessler (1989) relaxes these restrictive assumptions. He presents the results of computer simulations that suggest that cooperation may emerge in a situation in which players interact in two-player games with players randomly chosen from a large pool of anonymous players. At the end of each game, players may choose to continue the interaction or exit from the interaction and choose another player with whom to interact in the next game. Schuessler (ibid.) contends that this formulation accurately captures market-type situations.

Phlips (1988) examines the effects of imperfect information (lack of information regarding other players' actions) on solutions to repeated non-cooperative games between oligopolistic firms. His results can be generalized to any social dilemma problem, however. Imperfect information allows the possibility that deviations from cooperation will not be detected and punished. The reduction in the threat for deviant behavior reduces the set of likely cooperative outcomes. More perfect information will increase the set of likely cooperative outcomes and thus increase the possibility that an implicit contract will support a cooperative outcome.

4.6. Implicit Contracts and Coordination

The preceding discussion in this section shows that implicit contracts can support cooperative allocation of resources in situations in which agents have rights to access shared resources, rights to expect that only (N-1) other agents will share access to the same resource, but no rights regarding the resource use behavior of those (N-1) other resource users. Implicit contracts are shown, therefore, to be mechanisms other than explicit contracts or conventions that can provide agents with assurance regarding the expected behavior of other agents in a common property-rights regime.

These results can be extended to tenure regimes in which agents have "privilege" and "no right" to access resources in future periods, that is, access tenure regimes. In those situation, an agent who accesses a resource will base his current decisions upon his expectations of others' future behavior and upon his expectations of others' future access. If he expects unlimited access by new entrants--strangers--in future periods, then implicit contracts are unlikely to support cooperative behavior. The likely outcome is the open-access equilibrium. If, however, he expects there to be few new entrants, then implicit contracts may develop.

Several factors serve to restrict access to African rangelands. First, the patchiness of rangeland resources leads to plot-specific knowledge that is costly and difficult for new entrants to acquire (Scoones 1989; Binswanger, McIntire, and Udry 1989). Second, agents who achieve access to rangeland resources may not share important information on production and market conditions with strangers. Third, agents who repeatedly access an area of rangeland may use threat power to dissuade potential entrants. Threat power may be exerted in the form of military encounter or stock theft. Combinations of these and other factors may serve to give agents relatively secure expectations regarding others' future access. In those situations, implicit contracts may develop

that give agents assurance of others' expected resource use. Agents in those situations achieve coordinated access. The rangeland tenure regime is a coordination access regime.

5. MODELS OF LIVESTOCK OWNER STRATEGIES AND RANGELAND TENURE

Previous sections of this paper have provided descriptions of a number of concepts related to rangeland tenure and livestock-owner strategies. In this section, these concepts are integrated into a conceptual model of strategies and tenure. The model is constructed in a method similar to that employed by Sandford (1982). That is, a reduced-form model is specified directly. Variations of the model are specified for alternative rangeland tenure situations and alternative assumptions regarding the interpersonal strategic behavior of livestock owners.

5.1. Temporal Dimensions of Strategies

Dynamics. Analysts of livestock systems generally agree on the importance of modeling livestock-owner strategies as dynamic processes. Lorie (1947) first illustrated the importance of considering the dynamics of livestock production and marketing in the U.S. cattle sector. Jarvis (1974) developed the capital-asset model to explain the dynamics of Argentina's cattle sector. This model has been found appropriate for explaining the dynamics of livestock systems in Botswana (Ndzinge, Marsh, and Greer 1984), Swaziland (Jarvis 1980), and Zimbabwe (Rodriguez 1985).

Random processes. Sandford (1982) and Mace (1988) both accept the importance of modeling African livestock systems as dynamic. Both contend, however, that it is necessary to consider the effects that random dynamic processes have on those strategies. That is, livestock-owner strategies depend upon past actions and upon expectations of the impacts of future random shocks. Both Sandford and Mace identify rainfall as the most important random process affecting strategies. Other random processes are prices, diseases, government programs and regulations, and domestic political stability.

Risk. The existence of risk over time is an obvious implication of the dynamic, stochastic environment in which livestock owners pursue their livelihoods. Western and Finch (1986) and Franke and Chasin (1981) hypothesize that many aspects of the individual and group behavior of pastoralists are reactions to this risk. Their hypotheses can be separated into the effects of risk on individual strategies and the effects of risk on group institutions. Risk is hypothesized to affect individuals' decisions regarding the numbers and types of livestock held. Groups of livestock owners are hypothesized to maintain social institutions that allow sharing of animals between livestock owners affected by random shocks.

Mathematical expression of the temporal dimensions of strategies. Equations (25) and (26) are a preliminary mathematical model of the strategy of an individual livestock owner. Equation (25) indicates that the overall strategy of an individual i, S_i, is a vector of conditional actions for each of the T time periods in the planning horizon. Equation (26) indicates that the individual's conditional actions in each time period, $A_i t$, depend upon a vector

of previous actions taken by the individual, A_i t-j; a vector of the individual's expectations of future values of random variables, $E(\underset{\sim}{R}_{t+j})$; and a measure of risk preferences for the individual, $RISK_i$.[7]

$$\underline{S_i} = [A_i1, A_i2, \ldots, A_iT]' \tag{25}$$

$$A_it = A_it\ (\underline{A_i}\ t-j,\ E(\underset{\sim}{R}_{t+j}),\ RISK_i) \tag{26}$$

where $\underline{S_i}$ = strategy of an individual livestock owner, i, for a planning horizon of T periods;
A_it = conditional action of livestock owner i at time t;
$E(\underset{\sim}{R}_{t+j})$ = vector of expected future values of random variables;
$RISK_i$ = measure of risk preference for individual i.

5.2. Inter-agent Strategic Behavior

A number of important concepts related to livestock owners' strategies and rangeland tenure have already been identified in this paper. In this section, these concepts are related in simple mathematical models.

State property. If a rangeland is state property and the state specifies and enforces regulations on rangeland access and rangeland use, then the strategy of each livestock owner is dependent upon those regulations and not on the strategies of other livestock owners. The state property model is represented in equations (25) and (27), where $\underline{X}$ is a vector of regulations imposed by the state.

$$\underline{S_i} = [A_i1, A_i2, \ldots, A_iT]' \tag{25}$$

$$A_it = A_it\ (\underline{A_i}\ t-j,\ E(\underset{\sim}{R}_{t+j}),\ RISK_i,\ \underline{X}) \tag{27}$$

where $\underline{X}$ is a vector of state access and use regulations.

Private property. Private property refers to a situation in which a livestock owner has exclusive rights to access and use an area of rangeland, rights that are sanctioned and enforced by a collectivity. Duties of other property owners and non-owners are also enforced by the collectivity. The strategy followed by a livestock owner is independent of the strategies and actions of other livestock owners and dependent upon the restrictions imposed by the collectivity, $\underline{Z}$.

$$\underline{S_i} = [A_i1, A_i2, \ldots, A_iT]' \tag{25}$$

$$A_it = A_it\ (\underline{A_i}\ t-j,\ E(\underset{\sim}{R}_{t+j}),\ RISK_i,\ \underline{Z}) \tag{28}$$

where $\underline{Z}$ is a vector of access and use regulations or conventions.

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7. Two alternative measures of risk discussed by Anderson, Dillon, and Hardaker (1976) are the risk premium and the risk evaluation differential quotient.

Common property. What distinguishes common property from access regimes are the rights and duties of agents to access rangeland resources. Within the broad class of common property regimes, there are regimes in which agents ignore the consequences of their actions and regimes in which agents' expectations of resource use are supported by explicit contracts, by conventions, by implicit contracts, or by combinations of the three types of institutions. Common property regimes can also be distinguished by the type of agent who holds access rights and duties. Access rights may be assigned to individuals, households, villages, or ethnic groups, and within right-holding groups there is likely to be room for further strategic interaction between agents. Here four alternative types of common property regime are considered. The regimes are distinguished on the basis of the contractual form and the type of agent who holds property rights.

Common property supported by explicit contracts (or conventions) between groups and explicit contracts (or conventions) between agents. Rights and duties of property-owning groups are sanctioned by a collectivity of groups or by conventions; each group in turn sanctions and enforces rights and duties for its individual members. Strategies of individual members of common-property-owning groups depend upon access and use regulations defined by the collectivity, as in the case of explicit private property, and also upon access and use regulations defined by the group.

$$\underline{S}_i = [A_i 1, A_i 2, \ldots, A_i T]' \tag{25}$$

$$A_i t = A_i t\ (\underline{A}_i\ t-j,\ E(\underline{R}^{\sim}_t+j),\ RISK_i,\ \underline{Z},\ \underline{W}) \tag{29}$$

where $\underline{Z}$ is a vector of access and use regulations defined and enforced by the collectivity, and
$\underline{W}$ is a vector of access and use regulations defined and enforced by the property-owning group.

Common property supported by explicit contracts between groups and implicit contracts between agents. Rights and duties of property-owning groups are sanctioned by a collectivity of groups or by conventions; resource access and use by each group is in turn supported by implicit contracts between individual agents. Individual strategies again depend upon access and use regulations defined by the group. Individual strategies also depend, as in the case of implicit private property, on the form of the implicit contract between individual agents. If the implicit contract is supported by simple penal codes, than the strategy of an individual will be given by equations (27) and (30).

$$\underline{S}_i = [A_i 1, A_i 2, \ldots, A_i T]' \tag{25}$$

$$A_i t = A_i t\ (\underline{A}_i\ t-j,\ E(\underline{R}^{\sim}_t+j),\ RISK_i,\ \underline{A}_k\ t-1,\ \underline{Z}) \tag{30}$$

Common property supported by implicit contracts between groups and explicit contracts between agents. Property of groups is supported by implicit contracts between groups; each group in turn sanctions and enforces rights and duties of its individual members. The strategies of individual members depend upon access and use regulations defined by the group and, if the implicit contract is supported by simple penal codes, on recent actions of other groups.

$$\underline{S}_i = [A_i 1, A_i 2, \ldots, A_i T]' \tag{25}$$

$$A_i t = A_i t\ (\underline{A}_i\ t-j,\ E(\underline{R}\sim_{t+j}),\ RISK_i,\ \underline{G}_k\ t-1,\ \underline{X}) \tag{31}$$

where $\underline{G}k\ t-1$ is a vector of actions taken by property-owning groups.

Common property supported by implicit contracts between groups and implicit contracts between agents. Property of groups is supported by implicit contracts between groups; each group is in turn supported by implicit contracts between individual members. If all contracts are supported by simple penal codes, then individual strategies will depend upon actions taken by groups and individuals in the preceding period.

$$\underline{S}_i = [A_i 1, A_i 2, \ldots, A_i T]' \tag{25}$$

$$A_i t = A_i t\ (\underline{A}_i\ t-j,\ E(\underline{R}\sim_{t+j}),\ RISK_i,\ \underline{G}_k\ t-1,\ \underline{A}k\ t-1) \tag{32}$$

Open access. The consequences of open access on livestock-owner strategies have been developed in the presentations on the static and dynamic models of open access. In these models it is assumed that each livestock owner follows the strategy that maximizes his payoff, assuming that the strategies of the other livestock owners sharing the rangeland are independent of his own strategy. Mathematically this is captured by incorporating others' actions as additional independent variables, $\underline{A}_k$ it, and assuming them to be constant. Equations (25) and (33) are the mathematical model specified for the open-access case.

$$\underline{S}_i = [A_i 1, A_i 2, \ldots, A_i T]' \tag{25}$$

$$A_i t = A_i t\ (\underline{A}_i\ t-j,\ E(\underline{R}\sim_{t+j}),\ RISK_i,\ \underline{A}_k\ it) \tag{33}$$

where $\underline{A}_k$ it are fixed strategies of all other livestock owners in period t.

Coordination access. Agents in coordination access regimes do not have access rights to rangeland resources. Coordination access is, therefore, neither common property nor open access. Agents in coordination access regimes have expectations about others' future access and use of common resources that are sufficiently secure to support implicit contracts between the agents who access the resources at any time. If livestock owners in a coordination access regime follow optimal penal codes--that is, if they impose harsh short-term punishments for deviant behavior--then their strategies will depend only upon the most recent actions of the other livestock owners. This model is depicted in equations (25) and (34).

$$\underline{S}_i = [A_i 1, A_i 2, \ldots, A_i T]' \tag{25}$$

$$A_{it} = A_{it}\ (\underline{A}_i\ t-j,\ E(\underline{R}\sim_{t+j}),\ RISK_i,\ \underline{A}_k\ i\ t-1) \tag{34}$$

6. EVIDENCE ON LIVESTOCK OWNER STRATEGIES

In the remainder of this paper the concepts and models developed in previous sections are employed in an analysis of evidence from studies of livestock owner strategies and rangeland tenure. A synthesis of the evidence on livestock owner strategies is presented in this section. In section 7, the applied research on African rangeland tenure is synthesized.

6.1. Livestock owner objectives

Analysts of African livestock systems seek to specify objective functions as simple representations of livestock owners' motivations, ethics, and values. Specific objective functions are proposed for the purpose of predicting future actions and responses to alternative policy instruments. Unfortunately, objective functions are difficult to validate or invalidate. Different objective functions often predict similar actions. For example, Doran, Low, and Kemp (1979) propose that cash needs determine the marketing behavior of Swazi cattle owners. Jarvis (1980) argues that the econometric results they presented to support that proposition actually validate Jarvis's capital-asset model of livestock production and marketing.

Economic models of livestock owner strategies frequently assume that livestock owners seek to maximize the profits generated from the production and sale of livestock and livestock products (Runge 1981; Stryker 1984). A closely related objective is the maximization of the net present value of one's livestock herd (Jarvis 1980; Ariza-Nino and Shapiro 1984; Rodriguez 1985; Ndzinge, Marsh, and Greer 1984). Other objectives often postulated, particularly regarding pastoralists in arid areas, are ensuring survival, reducing risks of calamity, and maximizing the number of people who can be sustained on a given resource base (Grandin 1985; Swinton 1986; Cossins 1983; Franke and Chasin 1981).

6.2. Livestock Owner Management and Market Strategies

A number of analysts have attempted to distinguish strategies followed by African livestock owners. I discuss management and market strategies in this section and institutional strategies in section 7.

The role of livestock in agro-pastoral risk-minimization strategies. Swinton (1986) postulates that agro-pastoral households in Niger seek to maximize the probability of meeting subsistence requirements and minimize losses in the event of a production failure. Risk-minimization strategies followed by agro-pastoral households are "crop diversification, the mixing of crop and livestock enterprises, inter-cropping, staggered plantings, and planting large land areas" (p. 124). Loss-limitation strategies are: forgoing non-essential forms of consumption, increasing non-farm income-generating activities, and

managing the accumulation and depletion of productive assets in ways that maintain future productive capacity. Livestock play very important roles in the asset-management strategies of Nigerien agro-pastoral households. Livestock are widely distributed, liquid, and potentially the most productive asset held by agro-pastoral households in Niger (ibid., pp. 124-135).

Mobility, breeds, and species. Mobility is postulated as a strategy adopted by pastoralists to maximize production and ensure survival from drought conditions. In East Africa, localized forage deficits are a consequence of the seasonal, patchy, and variable rainfall pattern. Mobility increases the intake of the most productive forage on the range; it varies according to the species and breeds of animals herded.

The environment occupied by the Ariaal pastoralists of northern Kenya is characterized by highly variable rangeland conditions, ranging from desert plain to highland valleys and plateaus. Great mobility is necessary to take advantage of this variety of conditions. The Ariaal enhance their mobility by keeping herds of camels, cattle, and goats. Camels are well suited to desert environments, while cattle are better suited to conditions in the mountain valleys. Many Ariaal households maintain separate herding units for cattle and camels to take advantage of these different characteristics (Fratkin 1986).

Western and Finch (1986) show that the mobility of the pastoral Maasai is enhanced by the breeds of their cattle. The pastoral Maasai follow two herding practices during the dry season: some herders use rangeland distant from watering points and trek their animals to water on alternative days; others use rangeland closer to watering points and water their animals every day. These alternative management practices are viable because of the physiological characteristics of the zebu cattle owned by the Maasai. In particular, experiments conducted by Western and Finch on a sample of zebu steers indicate that the animals' metabolic rates adjust to their foraging, watering, and trekking regime. Animals that traveled longer distances walked more slowly and had lower metabolic rates than animals that covered shorter distances. In addition, the animals were found to regain weight rapidly with improvements in nutrition. Western (1982) estimates that the mobility of the Maasai and their animals in the Amboseli region of Kenya allows a 50 percent higher utilization of available forage than would be possible with less mobile breeds of cattle.

Herd size. The fact that African livestock owners suffer periodic losses of animals due to drought-induced malnutrition and disease has been suggested as evidence of overstocking consistent with Gordon's model of open access. Sandford (1982) and Western (1982) argue that relatively high stocking rates are not evidence of open access but rather reflect opportunistic herding strategies. Opportunistic strategies are designed to "track the changing annual production more closely, avoiding the high mean annual wastage in order to gain a higher food chain efficiency" (Western 1982, p. 199). In addition, more animals at the beginning of a drought may increase the probability that some animals will survive.

Diversification of livestock species. Most pastoralists maintain diverse herds of cattle, sheep, goats, and, in some instances, camels or horses. Herd diversity allows a greater offtake of vegetation than would be possible with a

single species (Western 1982). In addition, livestock species have different reactions to environmental conditions. Fratkin (1986) found that diverse herds of cattle, sheep, goats, and camels have allowed the Ariaal of northern Kenya to adapt to ecological changes more quickly than their camel-keeping Rendille neighbors. McCabe (1987) found that drought conditions that affected the Kenyan Turkana in the 1980s caused the greatest losses of cattle, lowest losses of camels, and intermediate losses of sheep and goats. Dramatic improvements in environmental conditions increased cattle numbers at the fastest rate and camels numbers at the slowest rate.

Multiple product livestock enterprises. Swift (1982, p. 163) characterizes pastoralists' production strategies as "milk production-oriented strategies." By following these strategies,

> traditional nomadic pastoral economies are capable of supporting a considerably greater number of people on the land than are the meat production-oriented "modern" strategies of commercial ranching enterprises that are often intended by government planning to replace them.

Grandin (1988b, p. 6) notes the importance of milk production among the Maasai, but suggests additional production goals including meat production and cash income.

> Maasai goals of production can be summed up as: (1) a year-round supply of milk for home consumption, (2) occasional supplies of meat/fat, (3) animals to sell to generate desired cash income, (4) animals to use for social purposes, e.g., gifts, loans, and bridewealth, and (5) herd accumulation for long-term survival and security (for oneself and one's children) and to be a cultural success.

The range of livestock products utilized may be greatest among agropastoralists. Swallow et al. (1987) found that Basotho livestock owners kept mixed herds of cattle, sheep, goats, horses, and donkeys that produced a variety of marketed and subsistence products. The most important products of cattle are milk, draft power, meat, dung for fuel, and hides. Most important sheep and goat products are wool, mohair, meat, and skins. Most important horse and donkey products are transport, draft power, and meat.

Consumption of products from wild animals. Wildlife are important sources of protein for pastoralists in many areas of Africa. In Botswana and Zaire, most of the meat consumed is from wild animals (Krostitz 1979, cited in Simpson and Evangelou 1984). Wild animals provide an emergency source of food among the Ariaal of northern Kenya (Fratkin 1986). In the past, Maasai pastoralists hunted wild animals directly and traded for meat from wild animals with Ndorobo hunters and gathers (Grandin 1985).

Trade of live animals and dairy products. African livestock owners engage in a variety of local and long-distance trading networks. West African pastoralists became involved in trans-Saharan trading networks as early as the

fourteenth century. Control of the trans-Saharan trade was a cornerstone of the political and economic hegemony of the nomadic Twareg in the nineteenth century. Twareg and Fulani pastoralists of the Sahel have been important suppliers of animal products for urban areas in Nigeria, Ghana, Cote d'Ivoire, Cameroon, and Liberia since the beginning of the twentieth century (Baier 1980).

Pastoralists throughout Africa are now very heavily involved in market and barter transactions in which livestock and livestock products are exchanged for a variety of subsistence and luxury products, including, most importantly, cereals and sugar. Swift (1986) estimates that Twareg and Fulani pastoralists market between 39 and 59 percent of the animals they produce and rely on cereals for between 24 and 59 percent of their annual caloric intake. Twareg and Fulani agro-pastoralists rely on cereals for between 65 and 85 percent of their total caloric intake. Grandin (1988b) estimates that pastoral Maasai women and children get 25-30 percent of their caloric intake from maize and sugar.

Pastoralists exchange both livestock and livestock products. Marketings of dairy products by pastoralists vary greatly across Africa. Fulani women of the Jos Plateau in northern Nigeria regularly sell fresh milk and butter. Income earned from these milk sales is sufficient for many households to meet incidental household expenditures, and cattle are sold only to meet extraordinary expenditures (Awogbade 1983). In the South Darfur region of Sudan, revenue from the sale of dairy products comprised an average of 40 to 45 percent of the 1984-85 incomes of a sample of Baggara and Fulani pastoralists (Kerven 1987). Over the 1982-84 period, milk sales comprised 30-35 percent of the income of a lineage of Baggara that Michael (1987) studied in South Kordofan, Sudan. In contrast, milk sales comprised only 5 percent of aggregate income on the Maasai group ranch investigated by Grandin (1988b). However, Grandin found that poorer Maasai households collected and sold higher proportions of the total milk produced by their cows.

Local trading networks between pastoralists and agriculturalists are ubiquitous in West Africa. Best known of these trading relations are the complex relationships that develop between Fulani pastoralists and Hausa agriculturalists. In the most complex situations, Fulani pastoralists gain access to crop residues, dry-season water, cereals, and products produced by agriculturalists' animals. In return, agriculturalists receive dung dropped on their fields, caretaking of their animals, and livestock products (Baier 1980).

Agro-pastoral production and sedentarization. The Somali pastoralists of northeastern Kenya have suffered extremes of both war and drought since Kenya gained its independence in 1964. Those whose herds have been hardest hit by these harsh conditions have been forced to revert to irrigated agriculture to survive (Merryman 1987). Little (1985) found two groups among the Il Chamus of the Baringo area in Kenya that have became more sedentary during the recent droughts—the relatively wealthy and the relatively poor. Wealthy households have been able to shift some of their wealth from livestock into irrigation agriculture while poor households practice agriculture to meet basic needs for survival.

Off-farm income. A survival strategy that is particularly important during times of drought is migrant wage income. Sperling (1987) documents a

history of steady increase in the importance of income from migrant labor among Samburu pastoralists in northern Kenya. Wage labor allows relatively wealthy Samburu households to maintain and expand their livestock holdings and relatively poor households to sustain families in rural areas that would otherwise not be viable.

6.3. Static factors affecting strategies

This section summarizes the previous analyses of the relationships between ecological factors, social factors, and livestock owners' strategies. Social factors examined include wealth and customary social institutions. Ecological factors include climatic conditions, hydrological conditions, characteristics of the forage base, livestock diseases, and rangeland topography.

Wealth. Grandin (1988b, pp. 19-20) examined the effect of livestock wealth on pastoral dairy production in Maasailand. She found that households with few cattle--little wealth--collect most of the milk produced by their cows for consumption and sale. Households with many cattle--more wealth--were able to leave a larger proportion of their cows' milk for calves. The amount of milk left for calves in turn affects calf survival rates, growth, and age of maturity.

Avoidance of customary social relations. Hunter (1987) documents how Basotho rapidly entered into the production of wool and mohair during the late nineteenth century. Merino sheep and Angora goats represented attractive investments for common Basotho with surplus cash earned in South African mines and railways. Although ready markets existed for wool and mohair, the new breeds were especially attractive because they were not included under the customary **bohlanka** patron-client obligations. Merino sheep and Angora goats could be owned outright by common Basotho, and income from the sale of wool and mohair belonged exclusively to their owners.

The variety of important ecological variables. Western (1982) contends that the most important ecological variables affecting livestock owners' strategies are diseases, amounts and variability of rainfall, level and variability of temperature, competition by wild ungulates, and destruction by wild predators. He argues that these variables affect mobility, species composition, and certain herd-management activities.

The limits of ecological determinism. Fratkin (1986) suggests that major differences in management, market, and institutional strategies can occur between groups experiencing similar ecological conditions. Fratkin's comparison of the Rendille and Ariaal ethnic groups of northern Kenya led him to conclude (p. 284) that:

> Ecological concepts . . . are important in the analysis of social adaptations to particular environments. . . . However, ecological differences between Rendille and Ariaal herding environments in and of themselves do not explain differences in Rendille and Ariaal social organization. . . . More important to their production strategies are the variables of social organization that enable them to utilize the resources of their environment.

6.4. Dynamic factors affecting strategies

Livestock owner strategies are dynamic in two respects: (1) they specify actions for each period in the owner's planning horizon, and (2) changes in certain conditions cause livestock owners to switch from one strategy to another. Factors causing switches between strategies are discussed in this section.

Risk and change in social relations. Starr (1986) argues that changes in the social hierarchy in Niger since the colonial period have increased the risk to which poorer livestock owners are exposed. This increased risk caused owners of small livestock herds additional hardship during the 1968-73 Sahelian drought and, since the drought, has prohibited them from reentering full-time pastoralism.

Absentee herd ownership. Little (1985) presents evidence of increasing absentee ownership of livestock by non-pastoralists in Botswana, Kenya, Somalia, Cameroon, Mali, and Niger. In the El Chamus area of central Kenya, Little found local businessmen and private farm owners to be taking increasing advantage of formerly common-property grazing areas. He argues (p. 132) that "the blame for some of the overstocking and apparent overgrazing in the location may lie more with non-pastoralists and part-time herders than with the pastoralists themselves."

Competition with cultivators. The competition between pastoralists and agriculturalists is particularly severe in West Africa. Groundnut (peanut) production is continually expanding northward, pushing the limits of the agricultural zone before it. As a result, dry-season grazing areas have been expropriated and seasonal migration routes disrupted (Franke and Chasin 1981; Horowitz 1979).

Introduction of new production techniques. The techniques that have had greatest impacts on African pastoralists are water provision techniques. Swift (1977) describes the impact of new water-provision techniques--boreholes and water tanks--in arid areas of Somalia. The increased availability of water has extended the grazing season and thus caused increased resource pressure in areas previously used only for wet-season grazing. In addition, the new water sources are available to those who can pay rather than to those who have customarily utilized the rangeland. The result has been a disruption of the established rangeland tenure regime in many areas and the establishment of new classes of commercial livestock owners. New common-property institutions have not developed.

Behnke (1988) describes a more recent phenomenon related to the introduction of new water-provision techniques in Somalia. Land in areas around certain deep wells has been the object of increased demand for forage production and intensive feeding. This increased demand has stimulated the private enclosure of rangeland.

Commercialization of livestock production. Closely related to the new water-provision techniques in Somalia has been an increased commercialization of livestock production. Since 1950 there has been a rapid increase in the

numbers of live cattle, sheep, and goats exported from Somalia. According to Swift (1977), this increase in exports has been accompanied by the emergence of a class of successful livestock traders and a deterioration in traditional reciprocity and rangeland-access institutions. Similar trends are occurring in Botswana (Lawry 1988).

The importance of nonlivestock income and heterogeneous livestock interests. Lawry (1988), studying a grazing association at Sehlabathebe, Lesotho, found that the association members who cited livestock as their principal source of household cash income were those who were generally the most active members of the association. In addition, he noted that livestock ownership was concentrated in the 50 percent of households headed by resident males. Households with small numbers of livestock--mostly female-headed households--utilized the animals for the production of subsistence products only and were relatively uninterested in the grazing association.

6.5. Concluding comments on livestock owner strategies

A number of tentative conclusions on African livestock-owner strategies can be drawn.

1. The environments in which most livestock owners pursue their livelihoods are characterized by highly variable environmental conditions.

2. The more variable their environmental conditions, the more mobile, flexible, and diverse--"opportunistic," in Sandford's terminology--livestock owners' strategies must be.

3. Flexibility and diversity characterize all aspects of livestock owners' strategies--management practices, market transactions, and institutional transactions--in highly variable environments.

4. While most pastoralists rely on their own production of milk and meat for a large proportion of their food, few if any depend exclusively on livestock products. Both milk and meat are important sources of income to many pastoralist groups.

5. Groups of large-scale commercial livestock owners are emerging in many countries. Because of their superior access to credit, markets, and political power, these commercial livestock owners are most likely to benefit from the introduction of new techniques and new institutions. They are also more likely to disregard the consequences of their actions on customary institutions.

6. Problems of coordination will increase with greater diversity of uses and users.

7. EVIDENCE ON RANGELAND TENURE SYSTEMS

In this section I examine examples of rangeland tenure regimes drawn from a variety of settings in sub-Saharan Africa. I attempt to distinguish these regimes by the type of agents with use and access rights and by the type of institutional arrangement that mediates interactions among agents.

7.1. Endogenous common-property regimes

Tenure regimes that are most easily recognized as common property are those that are supported by explicit access and use contracts and/or conventions between groups and between individual agents. Here I draw a distinction between common property regimes that emerge as endogenous responses to social, ecological, and technical factors and common property regimes that are developed by external development planners and imposed on a particular group or collectivity of resource users. The former type I call endogenous common-property tenure systems; the latter I call common-property tenure innovations. Endogenous customary and contractual common-property tenure regimes are reviewed in this section, and common-property tenure innovations are reviewed in the section that follows.

The dina code in the Niger River delta, Mali. Nomadic Fulani herders first entered the inland Niger River delta in the fourteenth century. In the seventeenth century, the Fulani achieved political control of the delta and established the semiautonomous state of Macina. Early in the nineteenth century, Cheikou Ahmadou established hegemony over Macina and codified the dina system of property rights to the forage and the agricultural and fisheries' resources of the delta. Three reasons are cited for the development of the dina: (1) to decrease the level of conflict over the resources of the delta by instituting a system of property rights and duties with regard to the area's resources, (2) to settle the nomadic herders and thus foster the spread of Islam, and (3) to aid the collection of livestock taxes (Riddell 1982; Lawry 1989).

Property rights and duties defined by the dina were sanctioned and enforced by the authority of the Fulani state. The code defined property rights and duties of the Fulani clans of Macina, through which individuals had access and use rights. The leaders of each clan allocated grazing rights among groups of herders, the dates at which the groups entered and exited the delta, the transhumance routes to and from the delta, and the relationships between groups. Groups with grazing rights in the delta were able to gain reciprocal access to other groups' rangeland; access was usually accompanied by a payment of some sort. Groups without grazing rights were required to make substantial payments in order to gain access.

The advent of French colonial rule weakened the hegemony of the Fulani and thus the political basis of the dina. In 1960, the government of newly independent Mali claimed ownership of all resources in the delta, though as

yet the government has not established state property over the delta (Lawry 1989). Increasing differentiation among herders, resulting partly from the effects of prolonged drought, has further undermined social relations that support the **dina**. Relations among, and between, property-owning groups have weakened (Moorehead 1989).

The Borana common-property system, Kenya and Ethiopia. The Borana of southern Ethiopia have been able to sustain a balanced relationship between people, livestock, water, and rangeland. This relationship has been maintained through strict regulation of human reproduction, a transhumant grazing system, and a common property regime for water resources.

Few restrictions exist on rangeland access: all Borana livestock owners have the right to graze livestock anywhere on Borana rangelands. The rangeland resource is regulated through a limited number of wells located at relatively wide intervals across the rangeland. Wells are the most important watering points for Borana livestock, and the difficulty and expense of constructing new wells has kept their number relatively constant.

Each well is considered the property of a particular Borana clan. A council of well-users has overall authority for each well, with a "father of the well" supervising daily operations. Withdrawing water from the well is very labor intensive, requiring between ten and twenty-five people to lift the water hand-over-hand to the surface. Access to wells is based on clan membership and on the livestock owner's position in the well council. Users contribute labor in proportion to the number of animals they graze.

A number of aspects unique to the situation of the Ethiopian Borana makes their social organization an effective common-property tenure system. The limited supply of well water places an upper limit on the number of livestock that are grazed on the Borana rangelands while the amount of labor available to the household restricts the number of livestock that any household can herd and thus provide with water. The complexity of the management and operation of the wells requires that Borana livestock owners maintain close cooperative relationships (Helland 1982).

The situation of the Ethiopian Borana stands in sharp contrast to the situation of the Kenyan Borana. Famine relief and irrigation projects initiated in Kenya's Isiolo District since the early 1970s have had largely detrimental impacts on the Kenyan Borana and their systems of property rights (Hogg 1983, 1987).

Common property and coordinated access among the pastoral Maasai, Kenya and Tanzania. The pastoral Maasai occupy an area of 16,000 square miles in southern Kenya and a contiguous area of 24,000 square miles in northern Tanzania. Today there are approximately 164,000 pastoral Maasai in Kenya and 62,000 in Tanzania (Jacobs 1975). Here the traditional Maasai property-rights system is described as an example of an endogenous common-property system. Later sections will describe recent attempts to transform the endogenous system through an exogenous common-property innovation called the group ranch.

Traditionally the pastoral Maasai were divided into approximately twelve sections (**olosho**), each subdivided into localities (**enkutoto**). Within

each locality, groups of several polygamous families lived in small, semi-permanent settlements called **inkan'gitie**. Contacts between sections were minimal in normal years, with conflict over resources only occasionally resulting in battles between sections. Common-property resource management occurred at the level of the locality. The council of elders of each locality sanctioned and enforced the property rights of the individuals within its locality. Individual families gained rights to access common resources by long-term residence and active participation in the local age-set activities of the locality (Jacobs 1980).

Within each locality, access and use of rangeland resources was mediated through contractual common-property regimes that were sanctioned and enforced by the council of elders. The access rights of each locality were maintained by less explicit contracts between sections. The access rights of sections were maintained by implicit contracts supported by threats of future retaliation. Indeed, a case could be made that the warrior or **moran** age-set was maintained by each Maasai locality to support these implicit contracts.

Propositions on customary common-property regimes. The analyses presented in this section support the following propositions:

1. Economic and political developments at the national and international levels affect the social and political bases of local common-property regimes. Assertion of state ownership and increasing differentiation of resource users has disrupted the **dina** and other common property regimes in West Africa (Lawry 1989; Moorehead 1989), while the introduction of new water-provision techniques has led to the deterioration of water-based common-property regimes in Somalia and Botswana. Famine relief and irrigation projects have undermined the common property regimes of the Kenyan Borana, just as a variety of external and internal forces have weakened customary property regimes in Maasailand.

2. Endogenous common-property regimes are generally supported by combinations of conventions, explicit contracts, and implicit contracts between groups and between individuals. For example, the nineteenth-century **dina** code defined property rights and duties that were sanctioned and enforced by the authority of the Fulani state. The Fulani state regulated common property rights and duties of Fulani clans that in turn defined access and use rules for clan members and non-members. Individuals within common-property-owning groups worked out various explicit and implicit contracts to coordinate their mutual access and use of resources.

3. The Maasai system relied on explicit contracts at the level of the locality and implicit contracts at the level of the compound.

4. Unique geographical and ecological characteristics of the inland Niger River delta limit generalizations from the experience of the **dina** code.

5. Rangeland property rights are often mediated through the most limiting factor of production such as dry-season grazing or available well water. For the Borana, the limiting factor is well water.

7.2. Common-property tenure innovations

The common-property tenure innovations reviewed in this section were conceived by development planners and implemented as components of livestock and rangeland development projects. In each case a great enough degree of success has been achieved that the innovations continue to function in some form. The term "common property" is used very loosely in some of the cases.

Pastoral units as common property innovations in Senegal.[8] According to Bromley and Cernea (1989), "one of the more successful [World] Bank experiences with common property management has been the Eastern Senegal Livestock Development Project." This project covers an area of approximately 1 million hectares of rangeland in the eastern part of Senegal. Rangelands in the area had been subject to traditional common-property systems, but these systems had deteriorated until the rangeland had effectively become open access at the time the project began.

During the first phase of the project (1976-1983), 53 pastoral units were established in the area. Each pastoral unit was comprised of 8 to 10 small villages and 1-2,000 thousand people. The pastoral units collaborated with the project in the delivery of supplemental feed and veterinary supplies and served as collective credit guarantors. Loan repayment rates were excellent. Throughout Phase I, however, little progress was made toward the development of common property tenure.

It was during the project's second phase (1984-1988) that the pastoral units began to assume common-property rangeland management as a secondary activity. In 1984, legislation was passed that permitted the pastoral units to become legal entities and allowed them to register group title to local grazing areas. The pastoral units began to administer grazing rotations to coordinate the grazing and watering activities of their members as well as agricultural and livestock activities in the area (Associates in Rural Development 1989).

Group ranches in Kenya's Maasailand. The Maasai group ranch was conceived by development planners as an organizational framework for radically altering Maasai livestock-production practices and social institutions. The stated policy objectives of the group ranch intervention were to: increase the amount of beef marketed to the urban areas, protect Maasai rangeland from further encroachment by its agro-pastoral neighbors, and regulate herding practices and stocking rates to prevent rangeland degradation.

The group-ranch development plan called for the following: (1) the adjudication of trust land into group ranches large enough to include adequate dry-season and wet-season grazing areas but small enough to facilitate management by elected committees; (2) the registration of permanent members of each

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8. Attempts have recently been made at establishing pastoral associations in Zaire, Senegal, Central African Republic, Burkina Faso, Niger, Mali, Mauritania, Chad, and Cameroon (Sihm 1989).

ranch who would then be excluded from other ranches; (3) the allocation of grazing quotas and maintenance of "conservative" stocking rates; (4) the development of shared facilities financed through group loans; and (5) the democratic election of ranch management committees to manage operations on each ranch (Grandin 1988a).

The first phase of group ranch development began at the time of Kenyan independence in 1963. At that time the Maasai felt politically and economically vulnerable and were concerned about the protection of their property rights. Under the Swymmerton Plan, registration of individual freehold title had begun to take affect in other areas of Kenya, and several parcels of Maasai grazing land had been demarcated into individual parcels. Maasai concern for the protection of their property rights prompted many groups of Maasai to welcome the new group-ranch innovation as a way of securing legal title to their rangelands. The first group ranches that were registered also received assistance in infrastructure development. By the early 1970s, fifteen group ranches, with an average size of 17,000 hectares, and sixty individual ranches, with an average size of 600 hectares, were adjudicated and registered. By 1981, 65 percent of Kajiado and Narok Districts had been adjudicated into group ranches and individual ranches. By 1986, the proportion registered as individual and group ranches had reached 80 percent. (Grandin 1988a; Evangelou 1984; Bekure and ole Pasha 1986; ole Pasha 1986).

Ole Pasha (1986) and Bekure and ole Pasha (1986) note three positive developments that have resulted from the group ranch innovation. First, group ranches have been effective in establishing the property rights of the Maasai to the rangelands of Maasailand. Second, group ranches have contributed to the sedentarization of the Maasai, though ranch members often cross ranch boundaries with their animals, and this increased sedentarization has allowed greater access to education and health services. Third, water sources and dips constructed during the first phase of the development have contributed to the management of individual herds. The most serious problem of the group ranches noted by ole Pasha and Bekure and ole Pasha is the lack of effective management. Management committees either have been ineffective or have reverted to customary authority structures.

Opinions on the relative success or failure of the group ranch vary greatly. Galaty (1980, p. 169) argues that the group ranch has been a successful innovation because of its limitations:

> for in the cracks and crevices of its organization, Maasai may be able to make it work through their own system. What it promises them is the security and the time to generate innovations appropriate to their needs without the inevitable anomie of national neglect or the demoralization and disenfranchisement of direct government intervention.

In contrast, the cracks and crevices of its organization are viewed by Hopcraft (1981) and Evangelou (1984) as being the greatest problems inherent in the group ranch organization. Transition to a market economy based on efficient market transactions and individual control of commodities and resources is

necessary, according to Evangelou, before Maasailand will make its maximum contribution to Kenya's national development.

Analyses by Grandin (1988a), ole Pasha (1986), and Bekure and ole Pasha (1986) indicate that there are strong moves to subdivide group ranches into individual ranches. Bekure and ole Pasha (1986) note four reasons for this movement to subdivision. First, Kenyan government policy favors individual tenure throughout the country. Second, there is no effective management of group ranches. Third, because people gain access to group ranch resources only through the heads of their households, young Maasai are not registered as property holders and feel that subdivision would allow them individual title. Fourth, many group ranch members believe that individual deeds to ranch land would be sufficient collateral to enable them to gain access to credit from the Agricultural Finance Corporation. Those who oppose subdivision cite four reasons. First, subdivided ranches would generally be too small to support the type of production practices that are most appropriate to the variable ecological conditions in Maasailand. Second, transferable individual-title deeds would be alienated to non-Maasai. Third, individual title would promote increased cultivation and thus increased soil erosion. Fourth, individual ranch boundaries would further reduce the mobility of the Maasai.

Grazing associations as common property innovations in Lesotho.[9] Three grazing associations have been initiated in Lesotho since 1978. Experiences of the two most successful are reviewed here.

The Ongeluk's Nek Grazing Association became operational in 1980 with the support of the EEC-funded Mphaki Livestock Project. The 4,200-hectare area used by the grazing association is unfenced but easily distinguished by elevation and topography. Membership is open to anyone who pays the relatively high annual membership fees, and grazing is restricted to cattle. The association hires three herders who graze all of the animals as a single herd during the summer months. The association was registered as a cooperative in 1985, but its rights to exclusive use of the rangeland have not been legitimized by either formal or customary law (Lawry 1986).

The association has encountered significant trespassing problems by non-members and members alike, and attempts to introduce a rotational grazing system have failed. There have been complaints about the quality of herding and the management committee's administrative procedures; the project and the management committee have experienced a series of disagreements. Despite these problems and increases in the annual membership fee, however, the membership of the association has continually increased. By 1985, the association had 119 members with 702 cattle, and new applicants have had to be refused membership. Members generally appreciate shared herding as a way of reducing expenses and gaining access to relatively good summer grazing (Roeder 1985; Lawry 1986).

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9. Grazing associations have been promoted elsewhere in Southern and Eastern Africa. Bennett, Lawry, and Riddell (1986) describe the grazing associations that developed in Somalia, and Cousins (1987) describes grazing associations in Zimbabwe.

However, the association has not, as was planned, established common property tenure in the grazing area. Rather, it has become something of a "club" providing cattle-herding services to its members.

The Sehlabathebe Grazing Association was established in 1982 by the USAID-funded Land Conservation and Range Development Project as a mechanism for livestock owners to participate in the development of the rangeland area. The area allocated to the grazing association, 30,720 hectares, includes village grazing areas, cattle-post grazing areas, and eleven villages. Residents of the eleven villages have been granted exclusive grazing rights to the area--a concept project personnel have labeled "controlled" communal grazing (Weaver 1986). The enforcement of exclusive use by local residents resulted in an immediate reduction in the number of livestock grazing in the area. The consequent decrease in competition for forage has led to the recuperation of the rangelands and improvement in the condition and productivity of local animals. Unfortunately, the welfare gain enjoyed by residents in the range management area has been accompanied by a loss to those who had their grazing rights extinguished without compensation.

The area's chief, project, and grazing association have been quite successful in discovering and punishing those who trespass into the area. The grazing association has been far less effective, however, in enforcing rules on local livestock owners. The association's executive committee has been unwilling to adopt management rules and punish the deviant behavior of local residents. Frustration with the executive committee has resulted in the project staff's playing an increasing role in the active management of the association. As of August 1986, it was the project manager, not the executive committee, who directed the range riders, set the dates for grazing rotation, and administered the finances of the association (Lawry 1988).

According to Lawry (ibid.), the idea that the grazing association would become more self-reliant and willing to regulate its members' behavior was based on an overestimation of the willingness of individual livestock owners to cooperate. Lawry suggests that several factors reduce the aptitude of Basotho livestock owners to follow the cooperative management practices prescribed by the project. First, livestock owners are heterogeneous in objectives, resource constraints, and management ability. Second, intensive control over community resources has not been a main objective of endogenous social institutions. As a result, there are few negative social consequences for those who violate management rules or even for those who engage in livestock theft (Shoup 1987). Third, "because remittances are the most important form of income, local resource condition is not of compelling economic interest for most households. Subsistence for the great majority of households is purchased at the shop with cash earned in the mines" (Lawry 1988, p. 272). Fourth, many elements of the management plan are justified by project management on ecological grounds but have not been shown to be economically viable. Individual livestock owners will need to have strong, long-term economic reasons for pursuing a management strategy that cannot be justified economically over the short term.

Comments on common property innovations. Livestock and rangeland development projects, with common property as one of the stated objectives, have

been initiated in most African countries. Unfortunately, the record of project failures is much longer than the list of successes. The cases reviewed have been among the most successful, and several comments on these cases can be made:

1. Rangeland tenure organizations are more likely to succeed when directly involved in livestock improvement and when consistent with endogenous social institutions.

2. In areas where pastoralists compete with agriculturalists for property rights, common property innovations may be welcomed by pastoralists as a means of securing customary property. In those areas the same pressures may prompt pastoralists to demand private title deeds.

3. Common property management may develop as a secondary role of pastoral associations primarily engaged in other activities.

4. There is no evidence of any grazing association having success in directly regulating the numbers of livestock held by members. Some successes are recorded of grazing associations that coordinate members' access to grazing areas.

7.3. Coordination access regimes

Pastoral Fulani rangeland tenure in the Sahel. The rangeland tenure system of the pastoral Fulani has been described by a number of analysts in terms very similar to the notion of implicit common property developed in this paper. Since the late nineteenth century, the pastoral Fulani in Mali and Niger have had no central political organization, no social sanctions, and no institutions for defining and enforcing rangeland rights. According to Stenning (1959, p. 59):

> None of [the] forms of social groupings had, or has, any *de jure* rights to ownership of pasture, water, or cattle tracks enforceable either by the sanctions of Pastoral Fulani society, or those of the alien political entities within which the Pastoral Fulani move. The nomadic movements of Pastoral Fulani are a constant adjustment to the changing demands of the natural habitat and the fluctuating pressure of the social environment.

Horowitz (1979, p. 67) notes that Fulani livestock owners are relatively independent and free to make individual resource use and management decisions.

> Many development documents exhibit a "take me to your leader" optic; they advise getting the approval of traditional chiefs for any proposed changes, under the assumption that the rest of the community will follow along. Few pastoral societies are in fact so hierarchically organized. On the contrary, the more likely situation is that there is no individual who has the authority to tell any other member of his community how the latter should handle his animals. Many

> pastoral societies have no centralization of managerial decisions relating to access to grazing lands and water, and therefore to herd size, composition, and movements.

According to Riesman (1978, pp. 27-28) this loose social organization and lack of a property regime facilitates best use of the variable forage and water resource base of the Sahel.

> The nomadic Fulani, as well as most of the semi-sedentary ones, seem to be anarchic in their political organization. Their chiefs act as guides, arbitrators, and spokesmen for extended family groups that tend to move about more or less together. These chiefs have no real powers of coercion over their followers, nor can they make binding agreements on their behalf. . . . It is important to understand that both Fulani political organization and their love of independence contribute significantly to the Fulani ability to take advantage of the economic resources of the Sahel. . . . We have seen that the land is best utilized when people and cattle spread out to the maximum degree, and for this to happen people have to be relatively independent of one another, able to make their own decisions and take their own risks.

An overview of African pastoralist systems. From a review of empirical studies of African pastoralists, Niamir (1989) distinguishes between what she calls active and passive coordination of herding units. Active coordination refers to situations where herding units follow formal and informal rules created and recognized by a group of herding units. Niamir offers "choreography of movements" as evidence of passive coordination. That is, passive coordination refers to situations where "no formal agreements are made between tribes but where coordinated movements result from the wish to avoid other tribes" (p. 40). Groups of livestock owners maintain passive coordination through informal rules.

Niamir (1989) suggests that passive coordination occurs in almost all cases where groups of pastoralists share access to a rangeland. In contrast, she notes (p. 42) that "it is rare to find active coordination, based on formal and informal agreements, among different tribes." The examples of coordination access she cites are the Messeriya, Dinka, and Nuer of Sudan; the Moors and Fulani of western Africa; and the Fulani and Rufa's al-Hoi of Sudan.

Propositions on coordination access. The following propositions are based on the empirical research reviewed in this section and on the theoretical analysis presented earlier in the paper.

1. Coordination access regimes are consistent with the "opportunistic" strategies followed by most African pastoralists. The severe and variable ecological conditions extant on African rangelands demand that pastoralists use flexible production practices. Mobility increases the probability that agents will have future encounters and thus the likelihood of successful implicit contracts.

2. Punishments for non-cooperative behavior vary from increased resource competition, as under open access, to armed conflict. The latter, such as occurred among Maasai sections, can be regarded as severe punishment. By intensifying the penalty for defection, occasional armed conflict can increase the likelihood of successful implicit contracts.

7.4. State property regimes

The examples presented in this section indicate that government assertion of ownership often serves to undermine local common-property management with the appearance, but not the reality, of government management and control. The result may be de jure state property but de facto open access (Bromley and Cernea 1989).

State property in Senegal. In 1964, the Government of Senegal passed a law that nationalized all unregistered land. Individual citizens are now granted only use rights to land. One of the reasons for the passage of this law was to circumvent customary property regimes in which certain people were classified as nobles and others as slaves. The new land law was intended to help those individuals, regardless of social class, who wanted to employ more modern production practices (Riddell 1982).

To date, land nationalization has had relatively little impact on pastoral property relations, though greater impacts are likely to occur in the future. Common property regimes may be undermined by the state assertion of property rights. In the area of the East Senegal Livestock Development Project, nationalization may have had some positive consequences by reducing the power of the established elites and providing legal processes for the redefinition of rangeland rights.

State ranches in Tanzania. In the late 1960s and early 1970s, the World Bank supported three types of ranches in Tanzania: ujamaa, National Ranching Company, and District Development Corporation. A total of eighteen National Ranching Company ranches and four District Development Corporation ranches were put into operation. President Nyerere's rationale for state ownership of these ranches was that it would be necessary for the state to supply cattle for export, tourism, and domestic consumption while the nation was transformed into a socialist society. All ranches were run by the government: the National Ranching Company ranches were operated by the national government, and the District Development Corporation ranches, by district governments. A series of financial and managerial problems caused the rapid bankruptcy and closing of the national ranches; the district ranches were somewhat more successful (Bennett, Lawry, and Riddell 1986).

State property in the Niger River delta, Mali. The dina common-property tenure system was undermined by French colonial rule and the 1960 declaration of state ownership of all natural resources. As the power of the dina declined, no new property system developed. Some areas of the Niger River delta now have characteristics of open access. These areas have come under increased stress from herders, fishers, and rice producers. The level of conflict between users is high, and the resource base is deteriorating

(Lawry 1989). In some areas of the delta, powerful groups and individuals--founding lineages, merchants, retired soldiers--have been able to use their greater access to credit, capital equipment, and labor to establish exclusive access to the most productive resources (Merryman 1989).

Comments on state property regimes. The examples presented in this section support three conclusions regarding state property of rangeland.

1. Many African countries proclaim state ownership over all land, but in very few cases is this de jure situation consistent with the de facto situation (Riddell and Dickerman 1986). Often the proclamation of state ownership has no effect on the users of rangeland.

2. Where states declare de jure rights to resources and attempt to exercise property rights de facto, there is every likelihood that the only result will be an undermining of local common-property rights over the resource, with no effective tenure system replacing it (Bromley and Cernea 1989). In general, the colonial and independent governments of African states have neither the administrative capacities nor the political mandates to sanction and enforce property regimes over rangeland resources. Claims of state ownership of rangeland resources can actually reduce users' rights over those resources.

3. There are few examples of government-operated enterprises that compete successfully with privately owned and operated enterprises.

7.5. Private Property Regimes

Individual tenure among the Kipsigis of Kenya. The Kipsigis occupy an area of approximately 1,000 square miles in western Kenya. Prior to the arrival of Europeans, the Kipsigis relied primarily on sedentary livestock production for subsistence. Millet and vegetables were grown on small, fenced plots using shifting cultivation techniques. Land in the area was highly productive and relatively abundant. No stringent land property regime was necessary.

The productivity of the land attracted European settlers to the area; by World War I, areas to the north, northeast, and southwest had been alienated to individual European settlers. Kisii and Luo territorial boundaries limited Kipsigi expansion in the other directions. In this limited area, population growth eventually prompted the adoption of new production techniques, and local tea estates provided large markets for maize produced by the Kipsigis. The introduction of the plow allowed expansion of production.

The competition between agricultural and pastoral production provided the impetus for changes in the customary land-tenure system. In particular, land cultivators traditionally bore the responsibility for fencing their plots to keep livestock out. A few large cultivators challenged this institution by leaving their plots unfenced and fencing their own grazing areas. This shifted the responsibility for fencing to livestock owners. Within a few years, these practices had been widely adopted and incorporated into the property rights structure of the Kipsigis (Manners 1974).

Private ranches in Kenya's Maasailand. Individual title to Maasai rangeland was first granted in the years immediately preceding the 1963 Kenyan independence. After independence, the Kenyan government and the donor agencies supported group ranches and discouraged the development of individual ranches. Nevertheless, by 1981, 300 individual ranches had been adjudicated in Kajiado District. Adjudication of more individual ranches and subdivision of group ranches is the trend in Maasailand. Grandin (1988a) notes that in many areas, group ranches now exist only in name. In Kajiado District, 29 of 52 group ranches have passed resolutions to subdivide their ranches. In other areas, powerful individuals have been granted their own ranches within the boundaries of established group ranches.

Individualization of rangeland is consistent with national individualization of arable land and with current economic and social trends in Maasailand. The decrease in average settlement size, for instance, from 6.2 households in the 1950s to 2.7 in the 1970s, reflects the more individualistic economic and social structures. The Maasai are also turning more frequently to cultivation as a means of diversifying their income sources, a trend which is consistent with their decreased mobility. Although the establishment of the group ranch boundaries has contributed in a minor way to this decreased mobility, more important have been the peoples' desires to register individual titles to areas of land. These desires have been stimulated by the title registration occurring elsewhere in Kenya, the lack of success of group ranches, and the relatively large size of previously registered individual ranches. But the resulting dispersion of domestic residences has resulted in a deterioration of the linkages between households and between settlements, so that individual homesteads now generally maintain fewer, but closer relationships (Grandin 1988a).

Semienclosed pastoralism in Somalia. Enclosure of rangeland in the Ceel Dheer District of central Somalia is based on land law that supports the enclosure of cultivated land. This property rights structure has developed in a situation in which livestock mobility is essential, yet most agricultural land is located along trek routes and thus requires protection from livestock. The introduction of deep wells has increased demand for land in areas surrounding the wells. Following construction of the wells, an increasing number of agriculturalists expanded their enclosures to include land for grazing and for forage production. Once this large-scale enclosure had begun, others had little choice but to follow (Behnke 1988).

Individual leaseholds in Botswana. The Tribal Grazing Lands Policy of 1975 was introduced by the president of Botswana with the following statement:

> Under our communal grazing system it is in no one individual's interest to limit the number of his animals. If one man takes his cattle off, someone else moves his own cattle in. Unless livestock numbers are somehow tied to specific grazing areas no one has an incentive to control grazing (Government of Botswana, Tribal Grazing Land, as quoted in Bennett, Lawry, and Riddell 1986, p. 110).

The Tribal Grazing Lands Policy was motivated by the assumption that rangelands were open access and needed to be brought under new property regimes.

Two property regimes were proposed: commercial ranching areas, where grazing rights were to be granted to small groups or individuals; and communal grazing areas, where people would be taught better management techniques. Enactment of the Tribal Grazing Lands Policy has given a small class of wealthy cattle producers private access to large areas of formerly communal rangeland. No significant change in grazing pressures has occurred in the remaining communal areas. At the same time, the construction of boreholes has expanded cattle production into new areas. No institutional or organizational support has been given to maintain the common property system in the communal areas (Bennett, Lawry, and Riddell 1986).

Comments on private property regimes

1. Private property remains rare among African pastoralists but is becoming increasingly common among agro-pastoralists. The Kipsigi and Somali examples are cases in which private property to rangeland has developed in response to the establishment of private property rights to cultivated land. The pastoral Maasai's desire for private property is partly a reaction to external conditions and partly an expression of dissatisfaction with the group ranch innovation.

2. The expansion of private property is likely to have negative consequences for the poorest segments of the population. Those who register individual titles are likely to be the most wealthy, educated, and politically powerful households in the community. Poorer households suffer when their common property rights are extinguished by individual adjudication. They also suffer from the deterioration of customary social institutions that frequently accompanies the privatization of property. Deterioration of customary social institutions reduces income transfer from wealthy to poor households and increases the risk exposure of the poorest households (Graham 1988).

7.6. Open-Access Tenure

Open access is distinct for the attributes it lacks rather than for the attributes it possesses. There are no sanctioned social authorities that define and enforce the rights of individuals or groups to income streams generated by the resource. And each resource user ignores the consequences of his or her behavior on other resource users.

Open access in the Niger River delta, Mali. The Niger River delta has been used as an example of four tenure types in this section. The **dina** code was cited as an example of a customary common-property tenure regime. In 1960, the **dina** was legally replaced by state ownership. Current observations suggest that many areas of the delta are, de facto, open access. In this situation, economically powerful individuals and groups in the delta have been able to establish effective private access to the most productive resources of the delta.

Well construction and open access. The construction of new livestock-related infrastructure has the potential to change common-property and coordination-access regimes into open-access situations. Horowitz (1979, p. 53)

describes how the development of new boreholes in the Sahel resulted in open access:

> These deep wells changed the transhumant orbits of many herdsmen, concentrating vast numbers of animals on the narrow tracks linking the diesel-powered pumps, and disrupted conventional land use arrangements which had been previously obtained. In a well-documented case, Bernus (1974) shows how the Illabakan Twareg of Niger petitioned to have the pump turned off, because the new source of water, available to any and all comers, had overcharged the terrain and severely exacerbated relationships between Twareg and Fulani.

Objection to state construction of boreholes also exists in Somalia (Swift 1977). A drilling project in the Central Rangeland Development Project was stopped twice due to threats from local pastoralists. When drilling was continued a third time, a well driller was shot (Ray Brokken, personal communication, December 1989).

Comments on open access. Open-access tenure is the most difficult tenure system to identify. Most rangelands in Africa have been characterized as open access at some time by at least one analyst. In some cases this characterization has been based on misunderstandings of the distinctions between open access and common property. In other cases the open-access label has resulted from inadequate or incorrect interpretation of information. In some sense, then, open access is a "default" tenure category. When there are no explicit contracts or conventions and no evidence of systematic coordination between livestock owners mediated through implicit contracts, the regime is, by default, described as open access.

8. CONCLUSIONS AND IMPLICATIONS FOR THE DESIGN OF RANGELAND TENURE POLICY INSTRUMENTS

Donor agencies and African national governments have pursued a variety of objectives designed to address the "problems" of African livestock development. The policy instruments implemented to achieve these objectives have often included a rangeland tenure component. Some conceptual framework--explicit in some cases, implicit in others--has been used to link rangeland tenure instruments with policy objectives. Past conceptual frameworks, in particular the "tragedy of the commons" interpretation, have supported the implementation of rangeland tenure innovations that have been, at best, ineffective.

Recent advances have been achieved in three research domains relevant to African rangeland tenure. The first is the area of common property and interpersonal strategic behavior. It is now well established in the conceptual literature that overexploitation and abuse of resources is not a necessary result of multiple users sharing the same resource. The second area of advance is the foundation of analytical results regarding the social and ecological environment and the motivations and actions of African livestock owners. The third area concerns conceptualizations of the interrelationships between rangeland tenure, livestock owner strategies, and the environment. Dynamics and risk have received increased attention.

This paper has aimed at integrating past research and contributing new concepts and frameworks to assist in the design of future rangeland-policy instruments in Africa. An important original contribution of the paper is the development of the theoretical distinctions between property maintained by alternative contractual forms by resource users. Secure expectations of others' behavior may be supported by explicit contracts, conventions, or implicit contracts. Explicit contracts are necessary to support property relations if resource users are involved in a single-period social-dilemma game, conventions may be sufficient if resource users have assurance preferences, and implicit contracts may serve to support property relations in a repeated social-dilemma game.

Another important contribution of this paper is the distinction between open access and coordination access. Coordination access is proposed as an addition to the three tenure types typically identified in the conceptual literature: state property, private property, and common property. Coordination access describes a tenure regime in which a group of resource users achieves coordinated resource use without the assertion of property rights. Parties to a coordination access regime expect that future access to the resource will be restricted by information asymmetries and by the threat power of those who currently use the resource. Current users also have the expectation that the future behavior of others may be based upon implicit contracts, which will support mutually beneficial behavior through the system of credible threats of punishment for deviant behavior.

A review of research on livestock-owner strategies and rangeland tenure supports the following propositions:

1. Most tenure regimes for rangeland resources in Africa are supported by combinations of conventions, explicit contracts, and implicit contracts.

2. Coordination of resource access and use is an important byproduct of common-property tenure regimes.

3. Registration of title to particular plots of rangeland is most important for high potential areas where livestock owners consider themselves to be economically and politically vulnerable.

If security of expectations and coordination are considered to be important objectives for tenure policy in African countries, then the following list of questions should guide the development of policy instruments:

1. Whose actions need improvements in coordination? Members of small herding groups? Different ethnic groups of pastoralists? Pastoralists and agriculturalists?

2. What is the point of conflict? Seasonal grazing areas? Watering points? Transhumant grazing routes?

3. At what times are the coordination problems the greatest? Drought years? Dry seasons?

4. What is the distribution of consequences of alternative policy instruments? Are there any policy instruments that can solve the coordination problem without negative consequences for any of the affected parties?

5. What is the distribution of transaction costs associated with alternative coordination regimes?

6. Is coordination consistent with national development and conservation objectives?

7. What factors currently contribute to the relative security or insecurity of livestock owners' expectations? Will policy instruments cause increased or reduced security?

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