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The Challenge of the Commons: The Allocation of Nonexclusive Resources

William Magrath

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ABSTRACT

This paper examines the forces that determine the allocation of resources which are not subject to completely private ownership, nonexclusive resources. The paper develops the distinction between common property, in which collective action controls resources use, and open access where individual decision making prevails. It is shown that open access regimes are inefficient, but that, although potentially unstable, common property regimes can generate satisfactory outcomes. Policy interventions and socio-economic factors that influence the successful management of nonexclusive resources are reviewed from both theoretical and resource perspectives.

THE CHALLENGE OF THE COMMONS -- THE ALLOCATION OF NONEXCLUSIVE RESOURCES

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I. INTRODUCTION

1. An important feature of many economically significant natural resources is that they are, or at least may be, nonexclusive. That is, their use or ownership by one individual need not preclude their use or ownership by others. Nonexclusivity may result from the physical properties of the resource making control by one individual difficult or costly, such as air quality. Or it may result from legal, cultural, or political circumstances in which certain types of resources are not deemed appropriate for private ownership, such as grazing land, water, or forest resources. There may, indeed, be instances in which common ownership of nonexclusive resources arises as a low cost institutional innovation.

2. Economic theory argues very strongly that the absence of fully articulated and enforced property rights will lead to free riding and to inefficient resource allocations resulting in social losses. And, in fact, recent experience in many countries, particularly developing countries, seems to support this view. In theory, prevention of these losses requires the imposition of controls on resource use, the establishment of exclusive property rights, or a combination of the two.

3. However, the theoretical condemnation of nonexclusive resource regimes actually applies only to a certain class of these resources, which are referred to here as open access resources. This is because the behavioral basis of these theories does not deal with the possibility of group action to avoid social losses. When these models are enriched to allow for the emergence of group action, the prediction of inefficient outcomes does not necessarily continue to hold.

4. Moreover, it can be argued that such collective action, which is referred to here as common property management, is not uncommon. In line with this alternative view, since cooperation may be generated among co-owners/users, the explanation of environmental degradation lies in the forces that eroded the capability for collective action. Such forces could include colonialism, the growth of market exchange, population growth, and technological change. The success of policies to alter the management of nonexclusive resources such as irrigation water, woodlands, groundwater, and rangelands, depends critically on the relevance of these views. On the one hand, measures such as taxes, controls, and other incentives applied from outside the community are appropriate for promoting efficient use of open access resources. On the other, developing (or rehabilitating) systems of group decision making are appropriate first steps for dealing with common property problems.

5. A great deal of emotion is generated by discussions of common property, common property management and open access. In most societies there are few economic resources over which some sort of ownership claim is not made. These claims may be individual, collective, may be made by governments and are not infrequently in conflict. It is the strength of these claims, different perceptions of their validity, and qualms about

their distributional implications that cause controversy. Economic theory can not validate or legitimate any particular system of ownership or distributional scheme. It can however indicate the outcomes that are likely when ownership is nonexclusive and suggest the additional conditions that are required to positively influence those outcomes.

6. The results of the open access literature are often misrepresented and/or misunderstood as advocating privatization as the only remedy for nonexclusive resource problems (Runge 1981; Wade 1985; Cycon 1986) and as being in some sense contradictory to common property approaches. In fact, the policies of many developing countries and development agencies do rely on privatization, as do some writers on open access (Hardin and Baden 1982). However, there are also a large number of other policies that are consistent with both open access and common property theory. Open access theory points to relatively specific interventions, such as taxes and quotas, that can be used to manage nonexclusive resources, while common property theory deals with the broader conditions that make the introduction of specific interventions possible and which help to indicate the social level at which management operates. Case studies of a range of successful and unsuccessful attempts at nonexclusive resource management indicate a number of important features that tie together these two approaches. These include: an awareness of resource scarcity; a "centralized" capability for investment planning coupled with "decentralized" management; a means of exchanging information between users and managers; and the presence of an accepted system of management that combines authority and responsibility.

7. This paper is a preliminary discussion of these issues. The emphasis is on the contribution of the economics literature in providing a framework for analysis of nonexclusive resource problems. Although nonexclusive resources can legitimately be defined to include the general environment, thereby making pollution an example of a nonexclusive resource problem, pollution problems are not considered in detail here. The treatment of resources is intentionally abstract, but resource examples are used where appropriate to illustrate specific issues. The presentation makes liberal use of mathematical notation. Readers uninterested or unfamiliar with this style will find that the key arguments are fully explained in the text and that most or all of the arithmetic can be skipped or skimmed with no loss. It is included here for the sake of precision and as a guide to further reading. The next two sections provide a brief discussion of open access resource use. Section II examines behavior under open access and contrasts the results with a formal model of optimal resource management, and Section III considers issues related to the size of the social costs due to open access. Section IV turns to the question of common property management. It summarizes some key aspects of property rights and the distinction between open access and common property resources. Section V discusses theoretical and practical issues involved in the choice of management tools to deal with open access problems and Section VI looks at the management of common property resources. Section VII concludes by suggesting possible conditions for successful nonexclusive resource management and by outlining directions for further research.

8. The remainder of this section attempts to both summarize the implications of the analysis which follows and set the stage for it. The main objective is to develop somewhat further, and provide a framework for thinking about three prototypical property rights regimes: common property, private property and open access. There is usually great imprecision in the terminology used to describe the allocation of nonexclusive resources. Unfortunately, the distinctions are not trivial and confusion is common. Therefore this paper attempts to be consistent in the use of language, and departures from this standard, which are sometimes required for appeals to intuition, are usually indicated by quotation marks.

9. The easy way to think about those regimes, and unfortunately, the way in which most thinking proceeds is to visualize a one-dimensional continuum going from pure open access all the way to private property, with common property somewhere in between (Figure 1). While in some sense it is true that private property is the "opposite" of open access, this simple view is misleading, because as is discussed at length below and in the sections that follow, there are other more important qualitative differences between these regimes. Perhaps more important however, is that this linear construct provides little insight to the operational problems of selecting and promoting institutional or technical innovations aimed at resolving the resource allocation problems that seem to go along with physical or technical nonexclusivity.

10. Property rights regimes are institutions that serve the purpose of coordinating expectations. Just as there are no perfectly exclusive or nonexclusive resources, only resources over which exclusion is more or less costly, no property rights regime provides perfect coordination. In fact, the basis of the "commons dilemma" is two-fold; physical nonexclusivity combined with poorly coordinated expectations, usually called free riding. Nonexclusivity provides the opportunity for free riding. The cause of free riding, however, is not nonexclusivity but rather the absence of institutions that control the pursuit of individual maximization. In other words, high costs of exclusion are a necessary, but not sufficient condition for the "tragedy of the commons", nonexclusivity must be linked with unbridled pursuit of private objectives.

11. To illustrate this approach Figure 2 plots the costs of exclusion against the costs of coordination. In the positive quadrant the three property rights regimes are arrayed. For any particular resource or system of resources the combination of costs suggests the likely property rights regime. For those resources, such as arable land, where the costs of exclusion are relatively low and the costs of coordination are relatively high, we expect to observe private property. For resources with higher costs of exclusion, we expect to see either some form of common property or open access, depending on the costs, in some particular setting of coordinating actions and expectations. As both kinds of cost rise, as might be the case with international fisheries or, possibly, open range land, we expect to observe open access.

Open Access ⟷ Common Property ⟷ Private Property

Figure 1. The Conventional Approach to Non-exclusive Resource Regimes

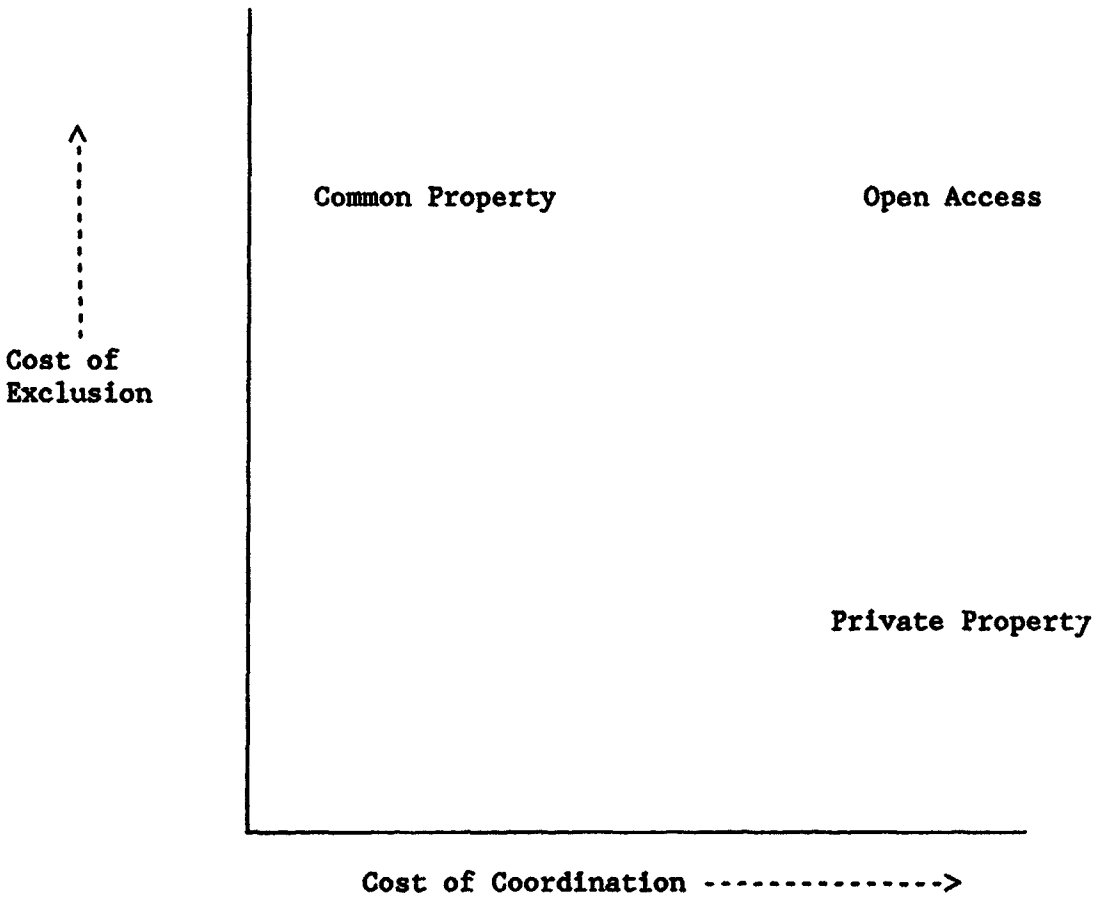

Figure 2. The Interaction of Technical and Social Factors to Generate Property Rights Regimes

12. Aside from providing a logically consistent way to array the three property rights regimes, Figure 2 is also suggestive of the problems facing policymakers as they seek to resolve the problems of open access. While there are no definite boundaries between the property rights regimes, there are policies and measures that can be implemented to shift relative costs to favor one institutional regime over the others. For example, technical change or subsidized pricing of inputs to exclusion can decrease the costs of exclusion and facilitate the shift from open access resource or common property toward private property. Similarly, efforts at community development and empowerment, such as might result from providing for "political entrepreneurs" (see section VI), may lower the costs of coordinating expectations. The model also suggests that there should be no a priori bias for policy to favor either common or private property. Rather, resource development policy should be aimed simply at reducing the size of the area in Figure 2 that is prone to open access. An important proviso to this is that the costs of exclusion or coordination are likely to be incurred and perceived differently by different individuals and groups. For example, the option of privatizing range resources via enclosure, will be more attractive to those who are relatively well off and have better access to credit for financing for fencing.1/

13. The distinction between exclusion and coordination costs is not completely clear. Obviously the two need not be independent nor can relevant costs always be unambiguously assigned to one category or the other. The point of the distinction is to focus attention on the social and physical dimensions of the nonexclusive resource problem, no more. We are now in a position to explore the allocational implications of particular nonexclusive resource regimes.

II. The Standard Open Access Problem

14. We begin our detailed discussion of nonexclusive resources by focussing on the exploitation of a particular class of these resources: those characterized by open access. As indicated above and as detailed in the following sections, not all nonexclusive resource systems behave as open access ones. However, models of open access do reveal the issues that are central to the concerns of policymakers, appear to be in broad agreement with the circumstances surrounding environmental degradation in many countries, and are mathematically tractable in ways that alternative approaches to nonexclusive resources are not.

15. The now classic example of the open access resource that has received the most attention from economists is the fishery. With only minor revisions, the models described here can address a variety of resources including rangeland, groundwater, irrigation systems, and wildlife. The problem involves a lake capable of supporting a population

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1/ See Anderson and Hill (1977) for a discussion of the advent of barbed wire fencing in the American west.

of economically desirable fish and an industry of fisherman. Access to the lake for fishing is uncontrolled. The resource allocation questions that arise include: How big will the fishing industry be? How big should it be? How is the size of the fish population affected by the management of the lake? Is the fishery sustainable?

The Fishery Without Time or Management

16. Because the fish population is governed by a biological growth function, a complete description of the fishery requires consideration of intertemporal issues. However, considerable insight, especially into the open access mode of exploitation, can be obtained from a static model.2/ 3/ Suppose that the fishery under consideration is small relative to the market for fish so that price is given exogenously. Similarly, fishermen (and their equipment) can obtain employment in other pursuits at some constant wage.

17. Total costs and revenues in the fishery are shown in Figure 3. Total revenue rises with output at a constant rate given by the price. Cost, on the other hand, at first rises more slowly and then more rapidly than revenues. This, of course, is the usual case of production with one variable input. For example, in order for output to increase, at some point additional effort is required to find the last few fish; boats interfere with each other and so on. Nonexclusive resources, however, are distinct from the usual case because these rising costs are felt across firms. The crowding effect as output rises is a technological externality; the actions of some firms raise costs for others without compensation. It is this kind of externality that characterizes open access resources and which accounts for social welfare losses. In Figure 3, the optimum level of output is Y^* where the rent earned by the fishery resource is maximized. Y^* is not an equilibrium level of output, because potential entrants to the industry are attracted to the available rents. Under open access each fisherman acts irrespective of the externality he imposes and output rises to Y_{oa}, or where total cost equals total revenues. Each fisherman earns just enough to keep him from leaving the industry but there is no return to the resource itself. Thus, equilibrium in the open access resource is given by:

2/ In this model and what follows, we make several assumptions: aside from the fishery itself, all other markets function perfectly; there is a full set of contingent claims markets (risk is fully insurable); and, the current and intertemporal distribution of income is acceptable.

3/ For a discussion of the static open access model in greater depth see Haveman (1973); for a fuller discussion of the timeless fishery see Gordon (1954), Scott (1955), and Gould (1972).

$$TC = Y\ C(x) = P\ Y = TR \tag{1}$$

or

$$C(x) = P \tag{2}$$

where C(x) is the average cost of harvesting Y units of fish with fish population X and where P is the price of fish. Y_{oa} constitutes an equilibrium because at levels of output above Y_{oa} the marginal fisherman is incurring losses, while below Y_{oa} there continue to be rents available. The problem for policymakers is to design a system of incentives or enforcement that leads efficiently to output level Y* (possible approaches are discussed in Section V). First, however, we can introduce other issues to make the basic model more realistic.

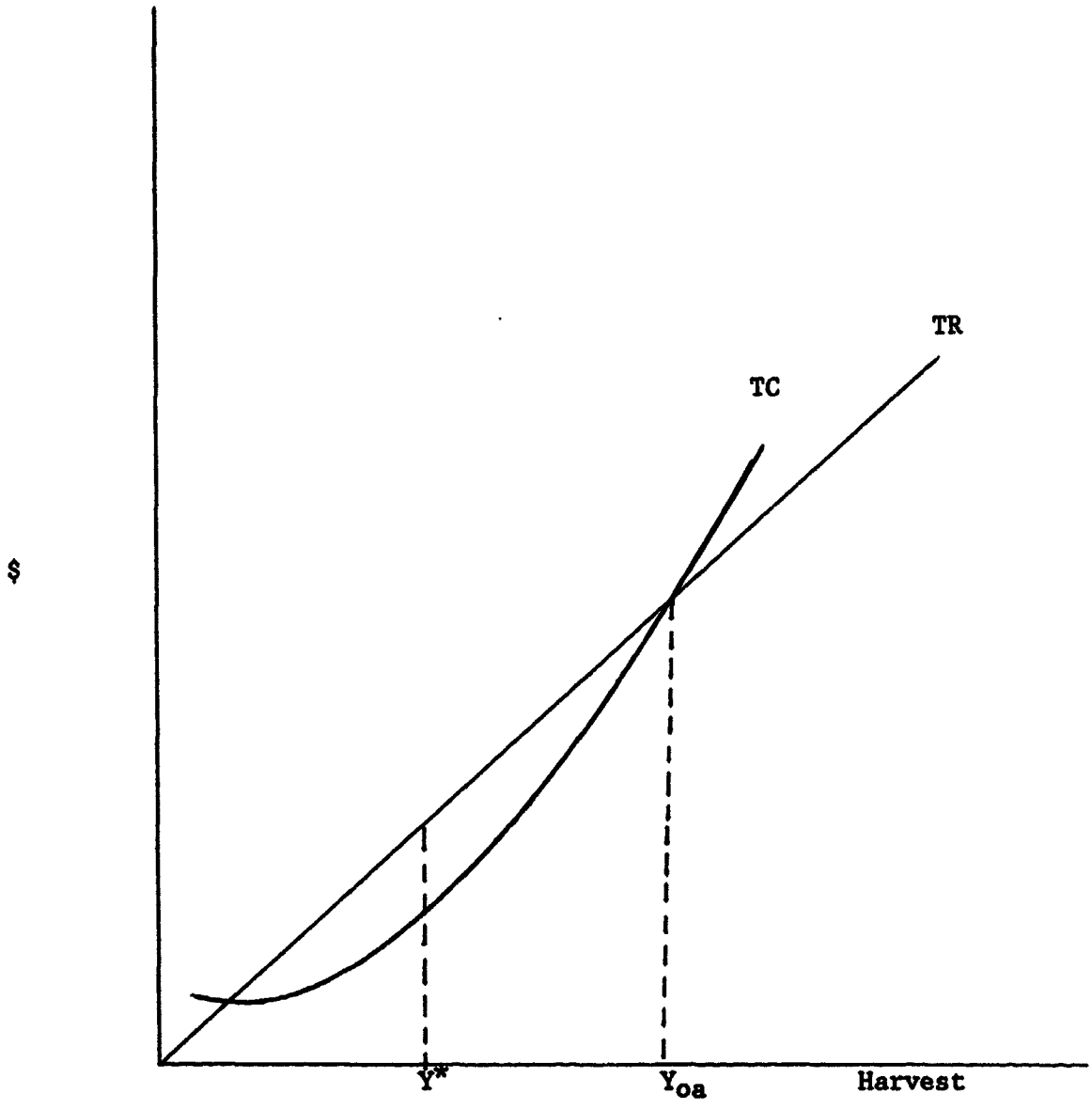

Figure 3. Equilibrium in the Static Open Access Resource

A Simple Dynamic Model of the Fishery4/

18. Time is important in the fishery in two respects. The potential existence of rent and the appropriate disposition of that rent over time is one concern. The other is the fact that the resource stock will grow over time, potentially adding to the value of the resource. To deal with these issues, a richer model is needed that considers time preference, resource growth, and a more detailed picture of costs. It is also convenient if we assume that the fishery is being managed by a sole owner or government agency. After seeing how such a fictional owner would optimally manage, we can more easily contrast this to the open access result. The sole owner construct is formally equivalent to both centralized planning and to pure competition with fully enforced property rights (see Levhari, Michener, and Mirman 1981).

19. Assume that the rate of change in the fish population is the natural growth rate F(x) less the rate of harvest Y_t:5/

$$dx/dt = F(x) - Y_t \qquad (3)$$

The harvest level is related to the population size and to the level of effort E. For simplicity assume:

$$Y = G(x) \quad E \qquad (4)$$

We continue to assume that the harvested price of fish is constant P and that a unit of effort costs c. At any instant in time the current revenue of the sole owner will be:

$$R = PY - cE$$

$$= [P\ G(x) - c]\ E \qquad (5')$$

Defining

$$C(x) = \frac{C}{G(x)}$$

$$R = [\ P - C(x)]\ E\ (G(x)) \qquad (5'')$$

$$= [\ P - C(x)]\ Y \qquad (5''')$$

The overall objective of the sole owner, however, extends over time and with a discount rate of r can be written:

$$\text{Max. } V = \int e^{-rt}\ [P - C(X)]\ Y\ dt \qquad (6)$$

That is, maximize the present value of revenue less costs, where harvesting costs at time t are a function of the population level at time t. Note that there is no value attached directly to the fish population. The only

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4/ The reader uninterested in the formal mathematics of renewable natural resources can skip or skim this section.

5/ This exposition follows that developed by Clark (1976).

way in which the population enters the objective functional is via its contribution to the level of harvest and harvest cost. Any other value to be derived from the fish population (scientific, genetic, ethical, etc.) is explicitly set at zero. If such values are relevant, equation (6) would need to be modified (as an example see Hartman, 1976). Accepting this limited objective, the sole owner chooses Y(t) subject to the constraints:

$$X(t) > 0 \tag{7}$$

$$Y(t) > 0 \tag{8}$$

We can solve this problem by first substituting $Y = F(x) - \frac{dx}{dt}$ which gives:

$$\text{Max. } V = e^{-rt} \; [\, P - C(x)] \; [F(x) - \frac{dx}{dt}] \; dt \tag{9}$$

This is a problem in the calculus of variation and is solved by satisfying the Euler Condition.6/ The Euler equation for equation (9) simplifies to:

$$F'(x) - \frac{C'(x)\; F(x)}{P - C(x)} = r \tag{10}$$

which can also be expressed as:

$$\frac{d}{dx} \; [P - C(x)] \; F(x) \; \frac{1}{r} = P - C(x) \tag{11}$$

20. The economic interpretation of equation (11) is straightforward. The sole owner should seek the steady state harvest, and by implication the steady state population, such that the present value of a marginal change in the population (the left hand side) is just equal to the current value of realized rent (P - C(x)). In other words, there is a trade-off between the harvest of an additional fish in any current period and allowing the fish to remain in the water thereby adding to future yields. At the optimum the two contribution are equal in a present value sense.

21. Now, to compare the open access solution with the optimal solution, note that as r approaches infinity the left hand side of equation (11) vanishes and we are left with equation 2:

$$C(x) = P \tag{2}$$

6/ The variational problem is to maximize (x,t,x)dt subject to x > 0; it can be shown that the optimal choice of x is given by satisfying the Euler Condition / x = d /dt /dx (see Kamien and Schwartz,1980). Throughout this paper second order conditions are assumed to be met.

Open access regimes neglect the future value of resource growth and behave as if the discount rate were infinite!7/

22. It is important to note that satisfying equation (10) while maximizing the objective functional, does not guarantee infinite sustainability. In other words, in this framework the sole owner may find it "optimal" to exhaust the resource or to drive a species to extinction. A number of authors explore the conditions under which extinction is optimal (see Brown 1974; Clark 1973, 1976: Berck 1979). We do not pursue these issues here other than to observe that the forces leading to extinction will generally work faster under open access than under optimal management and that open access regimes while not necessarily leading to extinction, may lead to it when optimal management would permit sustainable use of the resource.8/

Summary

23. In this section we have presented two simple models of natural resource management. The first, which explicitly ignores intertemporal issues, describes open access resource use. The individuals who engage in harvest do so irrespective of the crowding costs that they inflict upon each other. This technological externality results in an equilibrium in which total costs are equal to total revenues. The social loss from this situation arises because harvesting effort could be reallocated to other pursuits where marginal returns would be higher. It is also likely that resources will be over-exploited due to open access use.

24. Because growth is a critical aspect of resource management, the second model considers dynamic issues. Optimal resource management can be shown to consider growth rates and time preference in addition to the costs and returns that appear in the timeless model. For optimal management the present value of marginal, and not average, costs and benefits must be equated.

25. Finally, the open access equilibrium is very directly related to the optimal management plan. Specifically, the open access regime and the sole owner will produce according to the same rule if the discount rate is

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7/ As Demsetz (1967) writes in a slightly different context,"[open access] means that future generations must speak for themselves. No one has yet estimated the costs of carrying on such a conversation." It is left as an exercise for the interested reader to explain why the sole owner is not better off setting price equal to marginal cost in the current period.

8/ If sustainability is an important social consideration, it is possible to add a constraint requiring $x > x_{min}$ to the system of equalities and inequalities (6)-(8). Solution of the expanded problem would yield a shadow price equal to the cost (if any) of requiring that the population not fall below that level.

infinite. In other words, open access resource users behave as if future costs and benefits are irrelevant.

26. Up to this point we have demonstrated that social losses occur from open access use. Because we have dealt with general growth, cost, and revenue functions, we are not able to specify the real significance of these losses. In the next section we consider how the forms of these relationships influence the magnitude of social and environmental costs.

III. THE COSTS OF OPEN ACCESS REGIMES

27. This section explores a number of issues related to the size of social welfare losses under open access. As shown in the previous section, such regimes are likely to dissipate resource rents via overcrowding and undervaluing of future costs and benefits. However, the quantitative significance of open access regimes is dependent on a number of factors including: the physical/biological properties of the resource; the opportunity cost of harvesting effort; and the rate of time preference. We proceed by considering the components of the natural resource management models described in Section II, and the ways in which they act and interact to establish the actual level of social cost. Note that the costs of open access can include economic, environmental, as well as other costs. While in principle many environmental and other costs can be valued in economic terms it is often useful to consider them directly.

28. Returning now to the formal models of resources management described in Section I, we consider in greater detail the role of various parameters in determining the economic costs of open access regimes. These economic losses are, of course, simply the present value of the difference between the returns to optimal management and the returns to open access exploitation. Losses result from reduced yields, excessive costs, abbreviated life of the resource, or some combination thereof. Their magnitude in turn depends on specific combinations of growth rates, cost functions and time preference. Formal indicators of the importance of these factors could be obtained by first combining the optimal management model with the open access model to form a loss function and then calculating differentials with respect to various changes. For our purposes it will be more useful to consider, individually and non-mathematically, alternative specifications of the management problem and its parts.

29. The resource growth function can play an important role in determining the costs of open access exploitation. However, the properties of the growth function varies from resource to resource. Where growth of the resource is dependent on its current size, such as with many species of fish and wildlife, excessive levels of harvest can lead to declines in the population. A common formulation of biological growth functions is the logistic or sigmoid growth curve in which population size is an "S" shaped

function of time. In terms of growth as a function of population size the general logistic is an inverse parabola (see Figures 4 and 5). The tendency of excessive harvest to lead to population declines is one of the central concerns of environmentalists with regards to open access resources. Falling population size has two major effects. One is a general tendency for an increase in costs of harvesting, and the other is the increased risk of completely exhausting the resource or driving a species to extinction (making harvest costs infinite). This also relates to harvesting costs (see below).

30. The danger of declining population size is greatest for species such as large mammals, that have lower fecundity and which rely upon high survival rates to reach adulthood. Species producing large numbers of offspring which require little care, and for which survival to adulthood is largely determined by environmental factors, are less subject to serious depletion problems. A nonbiological example of the latter type of resource is groundwater in which the rate of flow of water into an aquifer is essentially independent of its current stock.

31. The growth function of certain, perhaps all, species displays a characteristic known as "critical" depensation. Depensation refers to the presence of an inflection in the lower tail of the growth function. Critical depensation is shown is Figure 6, at some positive levels of population size the rate of growth is negative. This could be the case for large marine mammals with large ranges. Once the population falls below some size the density of breeding adults is too low to generate growth. In the absence of artificial measures to restore growth, once the population size of a critically depensated species falls below K_0 in Figure 4, extinction will result.

32. As suggested above, the size of the resource stock is often related to the cost of harvest. In addition, harvest costs depend on other factors such as alternative employment opportunities and technology. As usual, the relevant consideration in determining social loss is the opportunity cost of harvesting effort. Where opportunity costs are low, as might be the case with subsistence fisherman in remote areas without alternative employment, the true social cost of crowding externalities may be low.

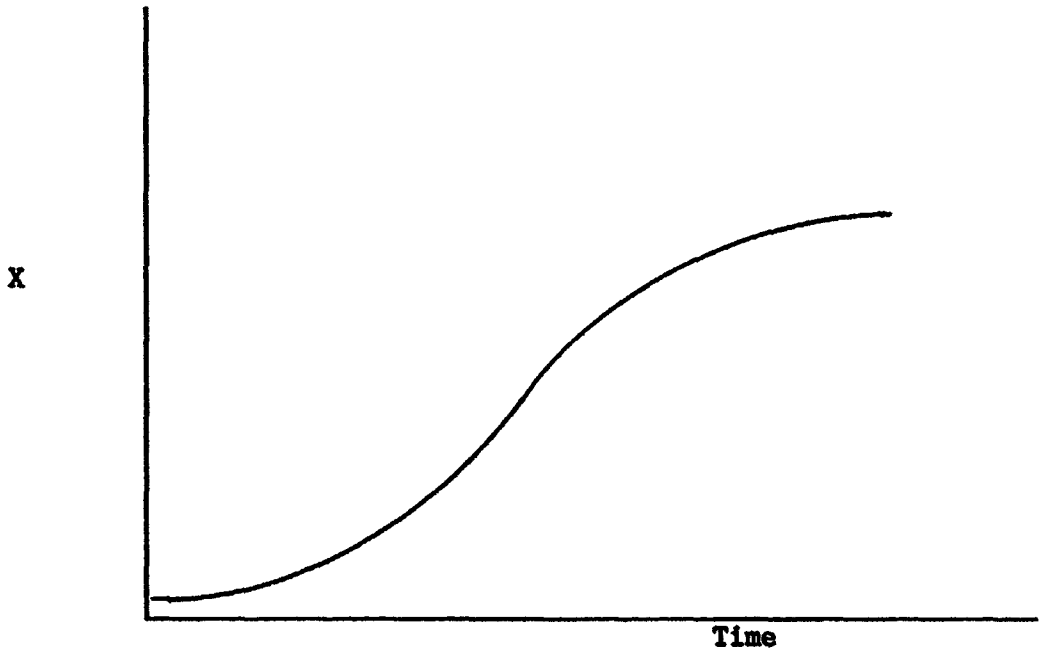

Figure 4. Logistic Growth as a Function of Time.

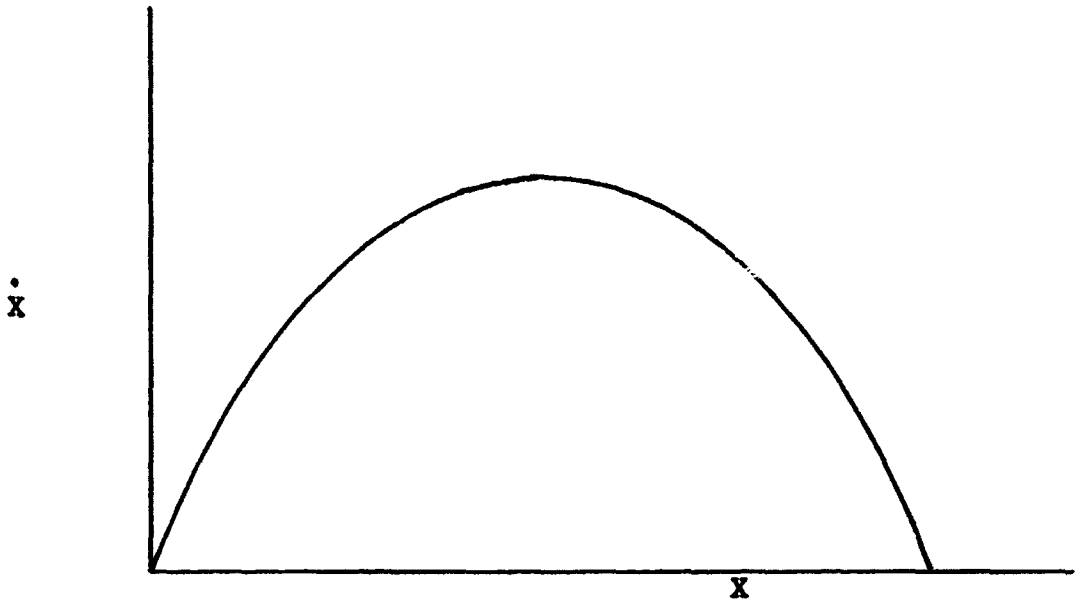

Figure 5. Logistic Growth as a Function of Resource Stock

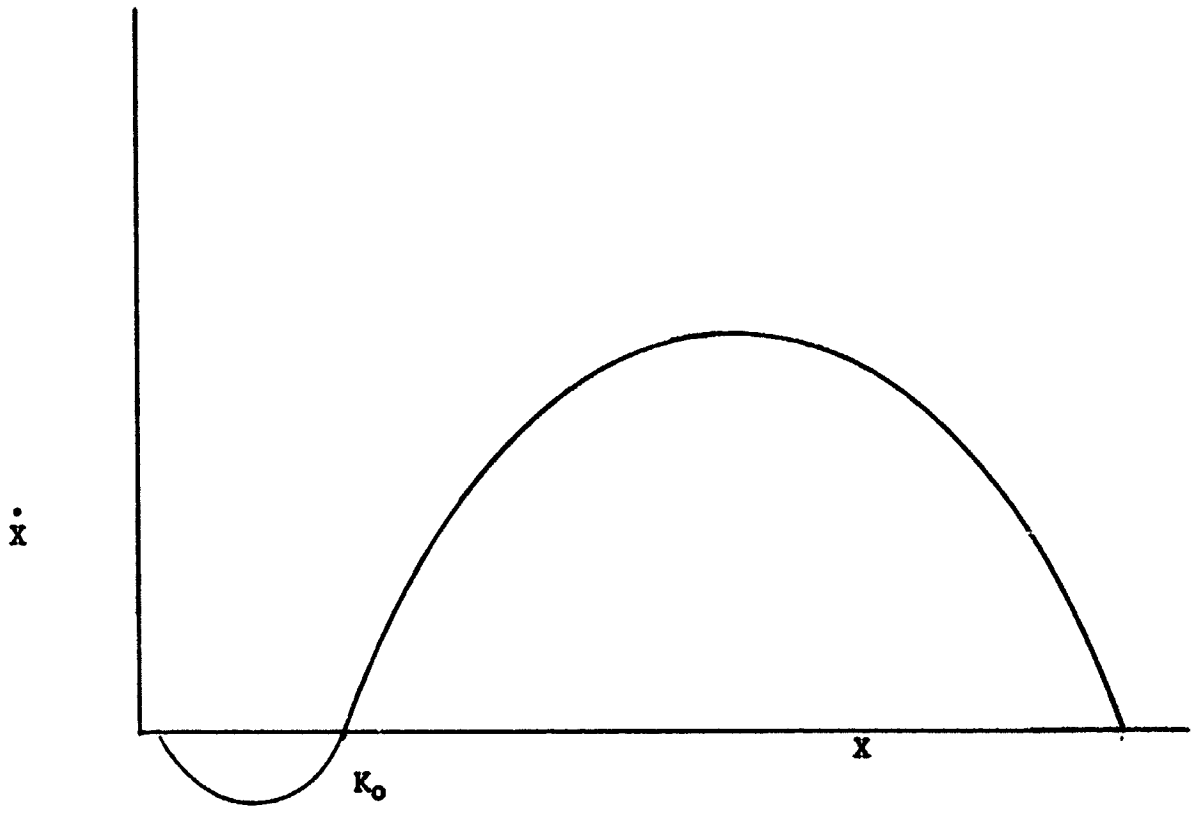

Figure 6. Critical Depenration

33. In terms of Figure 3, the absence of alternative employment means that the cost curve has not, in fact, turned upward and met total revenues. In the absence of a stock effect (depletion of the resource) when effort is costless, open access regimes do not seem to improse social costs. Fixed capital investment in harvesting equipment is another example of irrelevant costs.

34. Clark, Clarke, and Munro (1979) provide an in-depth examination of management when harvesting technology involves fixed and variable inputs. In their model they derive an optimal trade-off between the depreciation of overinvestment in fixed capital and the dynamics of the resource stock. The economic interpretation of their model is that if harvesting capital is fixed, its use is costless. Therefore, the trade-off between the use of harvesting effort generating current income and the maintenance of the reproducing natural stock shifts in favor of current exploitation. Their findings are relevant to the introduction of management over an open access and overcapitalized resource, and the significance of fixed capital depends critically on the depreciation rate. The general tendency for harvesting costs to vary inversely with population size tends to limit social losses from open access. Providing that depletion of the resource stock causes harvesting cost to rise high enough to choke off new entrants, there will be some upper limit to crowding. This same tendency may work to limit open access from resulting in species extinction.

35. With respect to harvesting costs, the overall relationship between the prices of inputs to harvesting and of output price plays a key role in determining the level of social cost due to open access when there are stock related effects. When output prices are high relative to costs, output from both open access and optimal management will rise. However, open access regimes, because of the implicit infinite discount rate, will ignore future values and expand output too much. The size of the population stock will fall too rapidly and future harvesting costs will be higher than optimal. Uncertainty about price can lead to a situation in which open access harvest is actually less than the optimal harvest. This will occur if price is highly variable and/or if risk aversion is great (Anderson 1982).

36. An often neglected aspect of open access regimes (and possibly of other nonexclusive resource regimes) is that they serve to reduce and bias investment incentives for technological change. The usual public good problem that frequently accounts for underinvestment in agricultural research and development exacerbated by the fact that individuals have relatively even less of a stake in technological improvements in the resource base. In addition, the incentive that remains favors development and adoption of technology that more efficiently (from the individual's point of view) captures the nonexclusive resource. This suggests that technological change in fisheries is more likely to be embodied in improved boats and gear, and that changes in pastoral technology would include changes in animal breeds and even species as opposed to pasture improvement. The weakness of incentives to develop a sound technical

packages for nonexclusive resources may be one reason for the limited success of projects to improve nonexclusive resource use.9/

37. Finally, the social discount rate is related to the present value of losses due to open access. As shown in Section II, open access regimes behave as if the discount rate were infinite, while optimal management requires a conscious trade-off between current and future costs and benefits. The higher the social rate of discount, the lower the social losses from open access.

IV. ALTERNATIVE APPROACHES TO NONEXCLUSIVE RESOURCES

38. The theory presented in Sections II and III is a widely accepted representation of the behavior of open access resources. It does not follow, however, that all resources not subject to private property will fall prey to the evils described above. Evidence abounds showing that resources have, in many times and places, been effectively utilized under common property regimes.10/ In many ways the management of common property is an example of the economic problems associated with the provision of public goods and other forms of collective action. In this section we explore the notion of common property management. We first review the key characteristics of private and public goods. Common property is approached as an institutional mechanism for the control of nonexclusive resources that display varying degrees of "publicness". Examples from the game theory literature are used to illustrate some of the features of common property management. We then consider the difficulty of differentiating common property resources from open access resources and identify some of the factors that seem to accompany the collapse of community management systems.

Private Property, Public Goods, and Common Property

39. The models developed in the last section revolved around the use of privately owned harvesting resources (effort) to capture from nature, another resource. That resource, in our case fish, only assumed value when captured by a private party, who could then claim exclusive rights to it. Nonexclusive resources are not always subject to this simple rule of capture. To analyze alternative rules (institutions) it is useful to consider explicitly the concept of property and specifically the public good aspect of many nonexclusive natural resources.

9/ Montague Yudelman called my attention to the weaknesses of technical packages for pastoral rangelands.

10/ An alternative view of some of these examples is that the apparent success of "traditional common property regimes" is actually a result of low levels of demand for resources, i.e., in the absence of economic scarcity.

40. The notion of property involves "a bundle of rights in the use and transfer of natural resources" (Ciriacy-Wantrup and Bishop (1975) p. 714) and importantly, the right and ability to exclude the exercise of those rights by others. Examples of these rights include the rights to consume, to preserve, to sell, to lease, and to bequeath. Private property typically confers all of these rights to a specific party, an individual, a firm, or unit of government. Goods held under pure private property regimes, pure private goods, are allocated among individuals (1,2,3,...i...s) in an economy according to the relation:

$$X_j = \sum x_j^i \qquad (12)$$

The total amount of the jth private good in an economy (X_j) is the sum of the amount consumed by consumers 1 through s. Pure private goods are efficiently allocated by competitive markets.

41. Nonexclusive resources are those resources which for various reasons of technology, law, culture, or economics are not appropriated by individuals. The extreme case of nonexclusive resources are pure public goods (Samuelson 1954, 1955), where the consumption of all individuals in the economy is identical. Thus:

$$X_n = x_n^i \qquad i = (1,2,3,...s) \qquad (13)$$

The distinction between public and private goods is illustrated in Figures 7 and 8. In Figure 7, individuals A and B's demand curves for private goods are aggregated by horizontal summation. In Figure 8, individual demands curves for public goods are aggregated by vertical summation. Because A's consumption does not obstruct B's consumption, aggregate willingness to pay for any quantity of the public good is higher than for the private good.

42. Provision of public goods by private market, while possible, generally will not provide optimal quantities. First, in the context of Figure 7, suppose individual A ignores B and arranges his own purchase of the good at say Q_A*. By the definition of a public good, B receives exactly the same level Q_A*. In the aggregate, the optimal quantity is clearly not Q_A*, but rather Q* where marginal social willingness to pay equals marginal social cost. The same result would hold if individual B chose first. More importantly, neither A nor B will voluntarily reveal their true preferences for the public good if they believe that the amount that they pay will be related to the preference they reveal. Both A and B, and in the more general case all s consumers, will have an incentive to free ride, and make no contribution to purchasing the good. Rather they will consume whatever quantity is forthcoming.11/

43. Pure public goods are probably rare. The consumption of most goods can be more or less limited to certain individuals, although spillovers

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11/ Varian (1984) discusses techniques that can be used to elicit truthful revelation of preferences.

will be important for some goods. A more general and useful formulation of equation (13) is suggested by Krutilla and Fisher (1985) to be:

$$X_n = X^i{}_n \qquad i = (1,2,3,\ldots s) \qquad (13)$$

$$X_A = aX \qquad 0 \leqslant a \leqslant 1$$

$$X^B = bX \qquad 0 \leqslant b \leqslant 1 \qquad (14)$$

Where the lower case letter indicates the proportion of the good consumed by a given individual for pure public goods $a = b = \ldots = s = 1$, and for pure private goods $a = b = \ldots = s = 0$, except for one individual whose proportion equals 1. Krutilla and Fisher further emphasize the limitations of the public good concept for analyzing natural resource problems. They point out that many conventional public goods services are provided under conditions such that rivalry between consumers is present, similarly many private goods and services can be provided without diminishing the amount available to others, and that the degree of publicness of a good is related not only to its technical characteristics but also to the assignment of ownership rights.

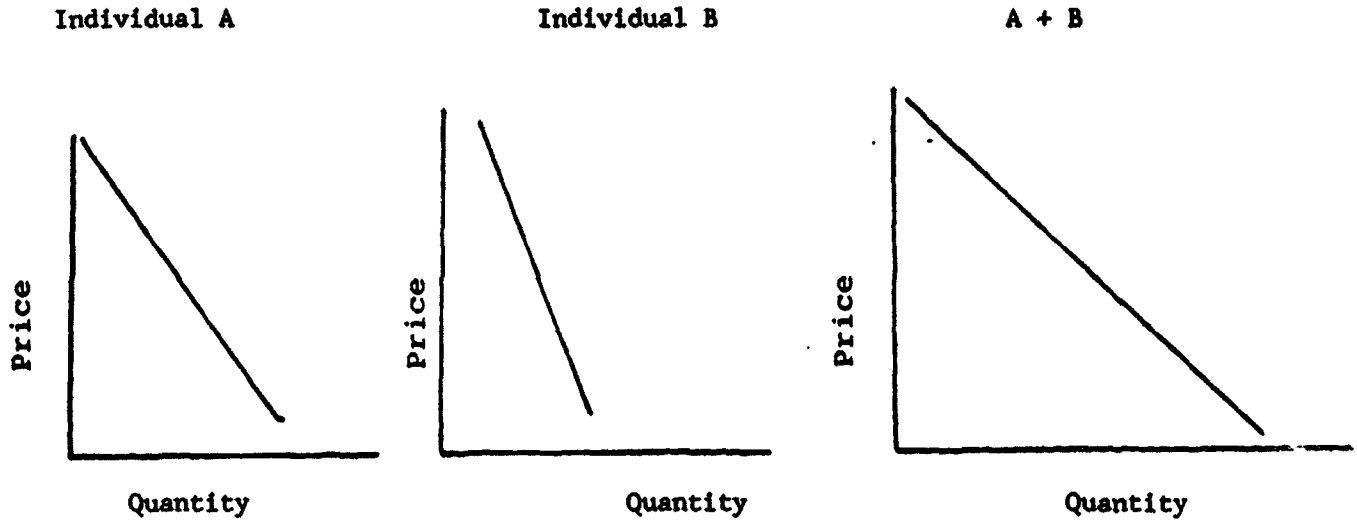

Figure 7. Aggregation of Individual Demand Curves for Private Goods

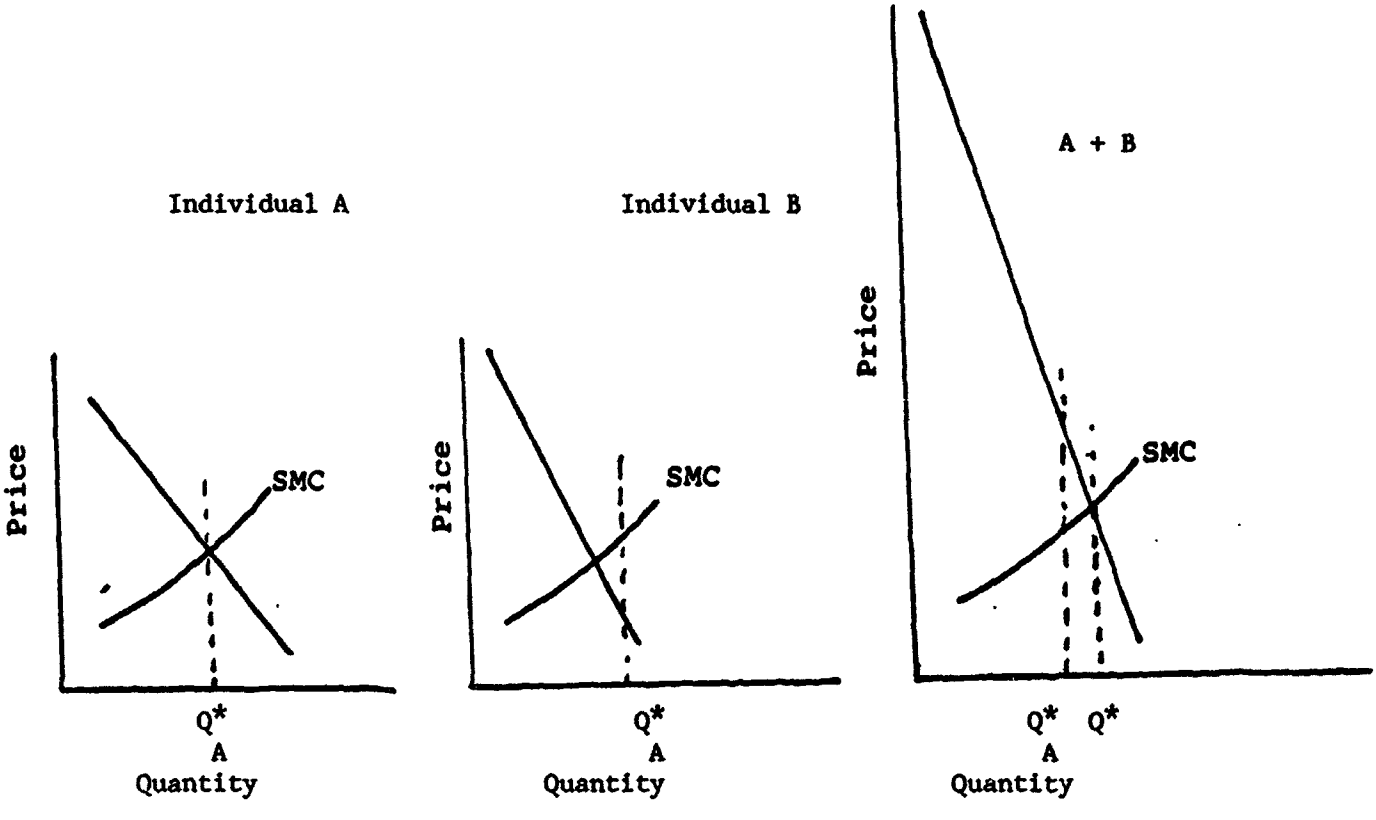

Figure 8. Aggreation of Individual Demand Curves for Public Goods

44. We can define common property resources as those nonexclusive resources in which some number of owners are co-equal in their use rights.12/ Membership in the group of co-owners is typically conferred by membership in some other group, generally a group whose central purpose is not administration of the resource per se (tribe, clan, village). Consequently, individual co-owners do not hold rights of transfer. Moreover, co-ownership does not necessarily confer use rights to equal quantities per unit time on the various co-owners. Discussions of the operations of common property resources systems (e.g. Ciriacy-Wantrup and Bishop (1975); Bromley and Chapagain (1984); Brokensha and Riley (1979); Sahlins (1972); Chayanov (1966)) necessarily involve consideration of a whole array of social relations precisely because resource allocations are so deeply "imbedded" in the social fabric (Polanyi 1944).

45. In contrast to nonexclusive resources held under such a common property regime, are open access resources, the formal modeling of which, is discussed above. Open access resources are those for which there is not a defined group of co-owners who exercise use rights and exclude others from exercising such rights. It is the absence of a system for exclusion that characterizes these resources and leads to the (misnamed) "Tragedy of the Commons." Open access resource systems operate in relative isolation from broader social systems; private inputs are utilized to capture private benefits from the resource. Consequently, relatively realistic models can be developed that do not give particular attention to nuances of the social context.

Isolation and Assurance

46. The implications of divorcing resource allocation decisions from the broader social setting is illustrated by comparing the isolation and assurance problems in game theory. The isolation paradox, also referred to as the "Prisoners Dilemma", is frequently cited as the basis of the "Tragedy of the Commons", or what was described above as the open access problem (Goodwin and Shepard 1979). The prisoner's dilemma is as follows: Two prisoners are being held for interrogation; the prosecutor has evidence of their guilt in a minor crime and strongly suspects their guilt on a more serious charge. They are each given two options: deny all charges, or admit to the more serious charge and testify against the other. If both prisoners refuse to confess, the prosecutor will be limited to the evidence already in his possession and both prisoners will receive short prison terms (say 1 year) for their minor offenses. If only one prisoner confesses and "turns State's evidence", he will go free and the other will be sentenced to life imprisonment. However, if both confess and turn states evidence on each other, they will both be sentenced to fifteen years. The "rewards" to the game are summarized in Table 1.

12/ This interpretation follows Ciriacy-Wantrup and Bishop (1975).

Table 1: The Prisoner's Dilemma

		(Second Prisoner) Deny	Confess
(First Prisoner)	Deny	(1,1)	(life, 0)
	Confess	(0, life)	(15, 15)

47. In Table 1 the combination (confess, confess) is dominated from the perspective of each individual; each would prefer some other outcome. Nevertheless, it is a stable equilibrium. Any agreement among the prisoners for denial has a built-in incentive for defection.

48. Instead of two prisoners, consider a group of pastoralists grazing their herds on common pasture, each deciding on whether to increase the size of their herd. A small increase in the size of each herd has negligible negative effect on the range resource but positive returns to the individual herdsman. A large increase in the total herd size (as would result from all herds increasing), however, will have a negative effect on range quality and will result in lower returns to all pastoralists. If each herdsman chooses to ignore the effect of his increasing his herd on range quality, the same pattern of dominance and inferior equilibrium will result. Stinting has very much the character of a public good, and each herder has an incentive to free ride. Even with communication between players the internal dynamics of the game result in an inferior outcome. An agreement to cooperate, if one is reached, continues to have an incentive for defection. Thus, the only useful policy options are externally applied controls. This is an analogous result to the model of open access described in Section II, and appropriate control mechanisms are described in Section V.

49. Runge (1981, 1983, 1986), however, has argued that the representation of pastoral management decision-making as a prisoner's dilemma masks important considerations. He proposes that community management of natural resources involves strategic interdependence between players such that a cooperative game, the "assurance problem" is a more appropriate representation.

50. The assurance analogy to the prisoner's dilemma is "the battle of the sexes" in which a couple face the choice of entertainments and companionship (Sen 1967). One partner prefers the dog races to the ballet, the other the reverse. Both, however, prefer to accompany the other rather then to go to their preferred event alone. A battle of the sexes payoff matrix is displayed in Table 2.

Table 2: The Battle of the Sexes

		(Second Partner)	
		Ballet	Dog Races
(First Partner)	Ballet	(1, 2)	(-1, -1)
	Dog Races	(-1, -1)	(2, 1)

51. In contrast to the prisoner's dilemma this game has two stable equilibria: both go to the dog races or both go to the ballet. Once an agreement is made there is no incentive to defect, unless a new agreement is made with the other player. The problem is obtaining assurance of the other player's actions. Runge argues that conceiving of community resource management as an assurance problem has several advantages: it displays that coordinated action can arise between the players without being imposed from outside; it emphasizes interdependence among the players and the possibility of multiple stable outcomes (including free riding); and it emphasizes the uncertainty regarding the actions of others and the costs of reaching new agreements.

52. The distinction between isolation and assurance is formally related to the separability of the players' cost functions (Runge 1981) and to the ability of the players to reach stable agreements. In essence, separability refers to the manner in which the actions of one player influences the payoff to the other. For example, externalities typically involve a generator(s), and a victim(s); the behavior of both together will generally determine the size of the externality. Where this is the case the externality is said to be nonseparable. Only where there is separability, is individual strategy always dominant.13/

53. The structure of the assurance problem is also such that once an agreement has been made, defection is no longer an attractive strategy. Runge uses the assurance problem to support the argument, made by many others without reliance on game theory justification (Ciriacy-Wantrup and Bishop 1975), that community management of natural resources is a viable institutional arrangement. While some evidence seems to support the assurance problem view of traditional systems (NAS 1986) there also appear to be forces that, by altering the relative rewards and penalties for

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13/ More formally, separability implies additivity in the players expected total payoff function. At the margin, where optimal decisions are made, the impact of an additive element vanishes. In a more general form of the payoff function, the derivative of the opposing player's choice will be non-zero. Baumol (1976) discusses the implications of nonseparability and argues that separability is much more likely the exception than the rule. In actual situations the operative question is whether the "degree" of nonseparability outweighs transaction costs.

cooperation and defection, serve to transform these systems into prisoner's dilemmas. Perhaps more important than the assurance-isolation issue per se are the facts that the games that the resource users play are multiperson and repeated. We turn next to recent developments in repeated and multiplayer games and then to several case studies of traditional community resource management. Finally we conclude this section by identifying some of the forces that seem to accompany the collapse of community management systems, returning to the questions of the possibility of reintroducing community management in Section VI.

Repeated and Multiperson Games

54. Single-play, two-person games which predict an absence of cooperation may not provide good indications of how users of nonexclusive resources will actually behave. Resource use almost always involves groups significantly larger than two, and users generally interact over extended periods of time. Theoretical, experimental, and empirical studies of multiperson games (also called n-person games) and of repeated games suggest that cooperation can emerge under a wide variety of circumstances.

55. Multiperson games differ from two-player games in several important respects. In a two-player game, individuals are either masters of their own destiny or share control with their partner/opponent. In non-trivial n-person games, any one player's control of the situation is much reduced. I sues of strategy, ethics, and expectations play much larger roles. In a series of experiments Marwell and Ames (1981) found that defecting in single-play prisoner's dilemmas is less than might be predicted by theory alone. In games played for small sums of money with a variety of participants (high school, colleges and graduate students) substantial (but less than optimal) sums were consistently donated toward the provision of public goods. In what is now becoming an (in)famous result, graduate students in economics provided the least for the public good. Interviews with participants suggest that notions of fairness were related to levels of contribution toward the public good. Experiments by Sweeny (1973) suggested somewhat more modest contributions toward public good provision, but still significantly greater than zero.

56. Bromley and Chapagain (1984) devised a similar, but hypothetical bidding game to Marwell and Ames' to investigate the free riding tendencies of Nepalese farmers. They offered farmers the opportunity to divide a Rs 100 windfall (roughly an average family's annual taxes) between private consumption and a village investment that would be matched by the national government and that would earn a 10 percent rate of return. Respondents stated that, on average, they would contribute Rs 49.29 to the public good with the remainder reserved for private investments. This percent level of contribution is quite similar to those obtained by Marwell and Ames (1981) (although they did not invoke the promise of government subsidy). Both sets of authors interpret these results as failing to support the hypothesis that free riding is natural behavior. Both studies also elicited respondents' judgments as to the "fairness" of various levels of contributions, and claim that ethical considerations play a substantial role in determining an individual's contribution.

57. While it seems likely that ethical considerations play an important role in public good provision, the extent to which either study provides a good indication of levels of contributions toward public good provision is unclear. The net payoffs to contributing players in the Marwell and Ames experiments were lower than had they simply taken the private payoff. Had the game been repeated, it seems plausible to expect that, regardless of ethical considerations, contributions would decline. The hypothetical game in Nepal is subject to the same problem. Instead of the 20 percent return that each family would have received with full participation and the government subsidy returns to contributors would have been slightly over 13 percent (presuming that all families in the sample shared equally). Again, it is unclear if this level of return would be sufficient to sustain cooperation. In addition, Binswanger's comparison of interview and gambling experiments results suggests caution in accepting conclusions based on interviews (see also Barker 1984). Nonetheless, other recent developments in the theory of public good provision, such as reciprocity rules (Sugden 1984), also suggest that the belief that free riding is morally wrong may be important in understanding levels of contributions for public good provision.14/ While experiments with multipurpose games suggest important divergences from predictions based on purely theoretical views of games, the same is true of repeated or iterated games. In repeated games, even without nongame communications between players, there are opportunities for learning, teaching, punishment and reward. Participants can observe the results of early plays and adjust their strategies accordingly.

58. Axelrod (1984) has explored the types of strategies that lead to cooperative outcomes in prisoner's dilemmas. His approach to studying prisoner's dilemmas is to ask what strategies a player should employ in such a game. In part he bases his analysis on insights from tournaments in which computer programs embodying different sets of rules repeatedly play prisoners' dilemmas. The programs, which were prepared by a variety of game theory experts and computer science specialists, were played pairwise against each other and were given payoffs consistent with those in Table 1.

59. The programs varied in complexity, and embodied strategies such as random defections, unconditional defection or cooperation, and probabilistic attempts to discern opposing strategies. Despite the presence of these elaborate strategies, the winning program had the simplest structure: on the first play cooperate, and on every subsequent play do exactly what the opponent had just done. In other words, the program,

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14/ Sugden's reciprocity principle is: consider an individual who is a member of a group of which all others contribute at least x toward a public good. The individual chooses the level of contribution he wishes all other members would make. If this level is not less than x, he is then under an obligation to reciprocate with a contribution of at least x.

named TIT FOR TAT, would retaliate against defection and return cooperation.

60. In addition to noting the success of the TIT FOR TAT strategy, the tournament highlighted several other aspects of successful strategies.15/ The highest scoring strategies had the property of never being the first to defect. The extent to which a strategy was forgiving was also associated with success. One relatively unsuccessful program would cooperate until its opponent defected and would thereafter always defect. TIT FOR TAT, on the other hand, would return to cooperation (forgive) immediately after its opponent had also returned to cooperation.

61. Based on these observations and other analyses, Axelrod advances several propositions dealing with the emergence of cooperation in iterated prisoner's dilemmas. Among them are: that if the rate of time preference is sufficiently low there is no strictly dominant strategy, including unconditional defection,16/ that the threat of and the willingness and ability to retaliate against defections is vital to the emergence of cooperation, and, perhaps unfortunately, that the only strategy that is always stable is for everyone to always defect.

62. The most intriguing aspect of Axelrod's work, however, is his application of the principles garnered from computer tournaments to the explanation of cooperation in real world prisoner's dilemmas. According to Axelrod, an extreme example of the emergence of such cooperation is the live-and-let-live system in trench warfare in World War I. He argues that trench warfare, in which pairs of combat units faced each other for extended periods of time, had the structure of a repeated prisoner's dilemma. At any instant each side can shoot to kill (defect) or deliberately seek to miss (cooperate). Each side is best off if its opponent cooperates (misses) while it defects (kills), and everyone is worse off if both sides defect. Despite efforts to the contrary by military superiors, Axelrod quotes reports from the front lines showing numerous instances of mutual cooperation. Moreover, the structure of this cooperation developed without direct communication or collusion, and was policed internally by a system remarkably like TIT FOR TAT. A soldier described the system,

> "If the British shelled the Germans, the Germans replied, and the damage was equal: if the Germans bombed an advanced piece of trench and killed five Englishmen, an answering fusillade killed five Germans." (Belton Cobb, 1916)

15/ In Axelrod's analysis success is judged in terms of an individual's own payoff.

16/ Note the divergence from the single-play prisoner's dilemma in which detection is always dominant.

Another example:

> It would be child's play to shell the road behind the enemy's trenches, crowded as it must be with ration wagons and water carts, into a bloodstained wilderness . . . but on the whole there is silence. After all, if you prevent your enemy from drawing his rations, his remedy is simple: he will prevent you from drawing yours. (Hay 1916, pp. 224-25)

63. While cooperation would break down, due to miscalculations, pressures from superiors, etc., mutual restraint was also common and violations of the tacit agreement were retaliated and forgiven as would be prescribed by the TIT FOR TAT strategy.

64. An important dimension of cooperation in repeated prisoner's dilemmas, that emerges from Axelrod's and others' analyses is that sustained cooperation appears to alter the players' payoffs. In the process, the prisoner's dilemma comes to look like something else. As Runge (1982) has noted, this something else is similar to an assurance problem. Conversely, the widely noted deterioration of nonexclusive resources in developing countries may represent the conversion of an assurance problem into a prisoner's dilemma. We turn next to examples of sustained use of nonexclusive resources under alternative property rights regimes and then to examples of situations that seem to lead to a decay of the system.

Nonexclusive Resource Use: Res Communes or Res Nullius?

65. Whether particular resources are owned by everyone (common property), or owned by no one (open access), is key to understanding the structure, function, and performance of the resource allocation system. Unfortunately, when resources are not subject to private control, it is not always clear whether nonexclusivity is an institutional innovation that serves to manage scarcity or the result of a lack of economic scarcity. Ciriacy-Wantrup and Bishop (1975) acknowledge that, at least at some levels of development, some resources are not scarce. They call these "ubiquitous" resources and "institutions regulating their use and allocation are not needed before that stage of economic development is reached."

66. Ciriacy-Wantrup and Bishop (1975, p. 724) are sanguine about the ease with which institutions to regulate resource use arise, once scarcity develops. Demestz (1967) also argues that property rights develop out of situations of scarcity. However, Demsetz also implies that the

difficulties and costs of negotiations may require long time periods and that those property rights that do develop will be biased in the direction of exclusivity.17/

67. Marshall Sahlins (1972) describes hunting and gathering groups as the "original affluent societies" because the resources on which they subsist are easily available from the environment. Further, "access to natural resources is typically direct -- 'free for anyone to take' -- even as possession of the necessary tools is general and knowledge of the required skills common."

The Changing Commons

68. The transition from community resource management along the lines of the assurance problem to an open access prisoner's dilemma represents a change in the way in which resource are allocated. But it fundamentally reflects changes in the way in which individuals in a community relate to each other and to their environment. These changes may relate to the general development process, but their effects on resource management will vary according to the economics and technology of the resource in question, and by social and political factors; the collapse of community management is not an inevitable result of development process.18/

69. Analysts have suggested a number of factors that lead to failure of common property systems. These include: population growth; the growth of market economies' colonialism and centralized government; environmental stress such as climate changes and drought; and technological change Ciriacy-Wantrup and Bishop (1975) are particularly severe in their indictment of the market economy and contact with western culture. They argue that such contact leads to resource depletion in two ways. First, the intruder may directly mine the resource base (they use the example of the American bison). Second, they perceive a fragility in traditional societies with respect to adapting to cash markets.

> "The scenario usually involves the hunters and gatherers overusing their resources in order to acquire market products. Equally significant in many cases was the introduction of taxes to be paid in cash. Cash could only be acquired with overuse of resources in order to obtain a marketable surplus." (Ciriacy-Wantrup and Bishop, p.718)

17/ Although Demsetz does not exclude the notion of common property resource management as used here, in general his usage of communal ownerwship is closer to what we have called open access. His description of American Indian property rights in land, which he refers to as private property, bears closer resemblance to the present usage of common property.

18/ see Noronha (forthcoming) for a rigorous discussion of this and related issues.

Kisangani (1986) describes the effect of colonial rule on the decay of traditional systems of exploitation of the Zairian elephant population. Traditionally, low levels of demand for elephant meat (relative to the elephant population) were met by a trading system by reciprocity between pygmy hunters and settled agriculturalists. The introduction of commercial trade for ivory and European political control upset this system and led to a situation very much resembling open access exploitation. Demsetz (1967) presents a different view of the property rights effect of trade in wildlife. He argues that the commercialization of fur trading led to the development of property rights in land among American Indians, where previously land had been held under open access. With respect to the enclosures in Great Britian that accompanied the industrial revolution, Ciriacy-Wantrup and Bishop add, "here also the result was a weakening of the village system and dispossession of the peasantry. The peasant was transformed from a co-equal owner on the commons with secure tenure to a landless worker on the feudal estate. This is the true 'tragedy of the commons'."(p. 720)

70. Picardi and Seifert (1976) describe the collapse of the Sahelian rangeland resource as coming about through the interaction of demographic, technological, and climatic factors. According to their description, a relatively long period of higher-than-average rainfall was combined with population growth resulting from the introduction of public health measures, and an expansion of herd size that resulted from the introduction of deepwell watering technology. When rainfall levels went below average, the resource base could not continue to support the expanded use level. Cruz (1981) attributes overfishing in the San Miguel Bay of the Philippines to the introduction of small motorized fishing boats and shallow draft "baby trawlers". The role of the small fishing boats is particularly significant because their use was subsidized by a low interest government loan program.

71. Brokensha and Riley (1984) ascribe forest depletion in parts of Kenya to changes in land tenure brought about by a government sponsored land adjudication program. The introduction of formal land titling appears to have undermined established rules of access and promoted over harvesting. A similar situation is described by Bromley and Chapagain (1984) in Nepal. Artz, Norton and O'Rourke (1986) describe the imposition of French colonial rule and subsequent centralized government as playing a role in the decline of traditional control of Moroccan grazing land.

Jodha (1983, 1985) describes the decline of common property resources in Rajasthan, India as coming about through population growth, mechanization, and technological change. More important, he argues, was the redistribution of land following independence. This undermined the system of extensive grazing and shifted the region's comparative advantage toward an unsustainable crop agriculture. The dismantling of feudal authorities, who exercised taxing authority over use of marginal lands was not accompanied by the introduction of new political authorities willing

and able to exert similar controls. Village panchayats were neither authoritarian nor bold enough to take measures which would anger their constituents.

V. TOOLS FOR THE MANAGEMENT OF NONEXCLUSIVE RESOURCES

72. The deviation of resource use patterns between open access regimes and optimal management suggests a role for government intervention to resolve inefficiencies. In fact, a large number of interventions have been suggested and implemented in an attempt to improve the use of nonexclusive resources in developed and developing countries. The design of some of these mechanisms flows out of the type of the formal resource allocation models described above, and tries to produce incentives or sanctions that will lead open access regimes to the sole owner optimum. Others are designed to alter the underlying distribution of property rights, so as to actually create a sole owner. Still others are intended to reach goals other than maximization of net present value (for example, preservation of species, indefinite sustainability, income distribution, or fairness). Finally, there are attempts to introduce or revive systems of community resource management. In this section we present a brief review of some key examples of specific policy tools for the management of open access resources. Not considered are how to design and establish institutions capable of exercising such control. In Section VI we return to issues related to the development of common property management.

Taxation

73. The classic economist's recommendation for the elimination of a deviation between social and private costs and benefits is a Pigouvian tax. Not surprisingly, this has been applied to open access resource management. The logic of taxation schemes is to raise the private costs of entry (or, equivalently, to lower the benefits) to the point where individual action will result in the socially optimal level of resource use. Recall that the open access resource generates no rents because of overcrowding and resource depletion. In order for the taxation authority to bring about the maximization of net present value of the resource, it can be shown that the authority should adopt the tax policy that results in the maximization of the present value of tax revenues. Thus, the authority captures all the rent generated by the resource. As long as the underlying behavior of resource users is unchanged, they continue under the tax to exhaust all privately appropriable rents. Because the displaced effort can be reallocated to other pursuits earning at least its opportunity cost, the tax is potentially Pareto-preferred.

74. For the static open access resource the effect of taxes on harvest and on inputs is shown in Figure 9 and 10 respectively. In Figure 9 a per-unit harvest tax is imposed. This has the effect of lowering private revenue to curve TR-t. The optimal tax will lower private revenue until it crosses the total cost curve at Y*. In Figure 10 a tax is imposed on harvesting inputs. The effect is analogous; private total costs now rise

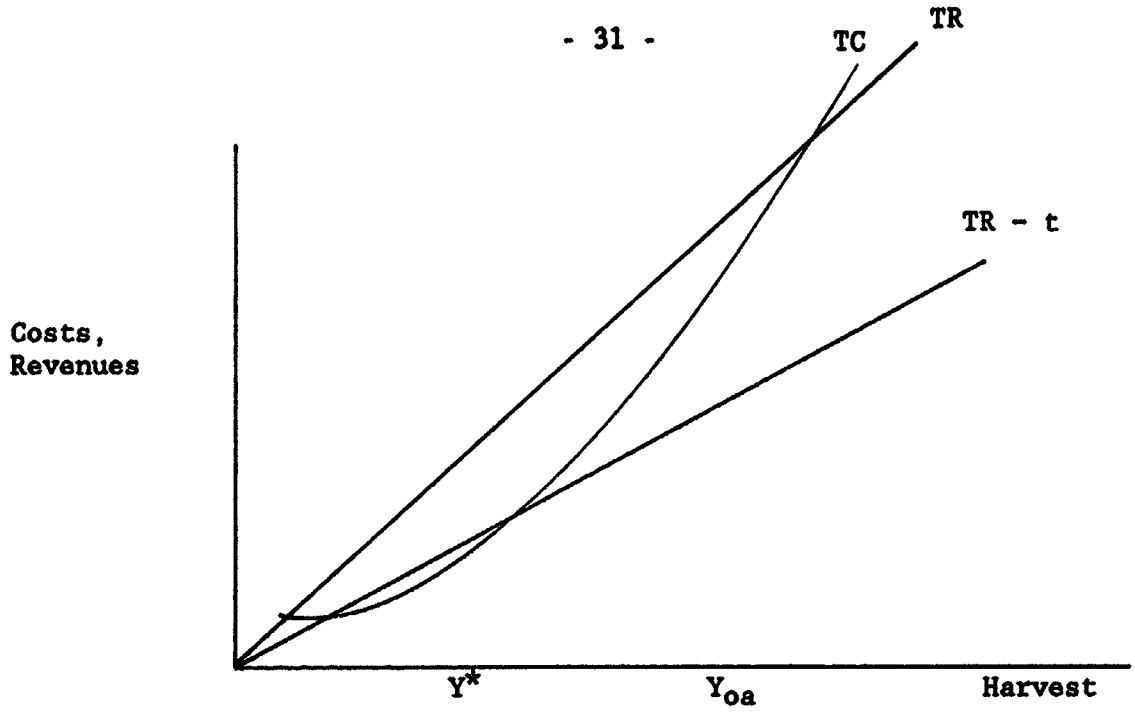

Figure 9. Effect of a Tax on Harvest

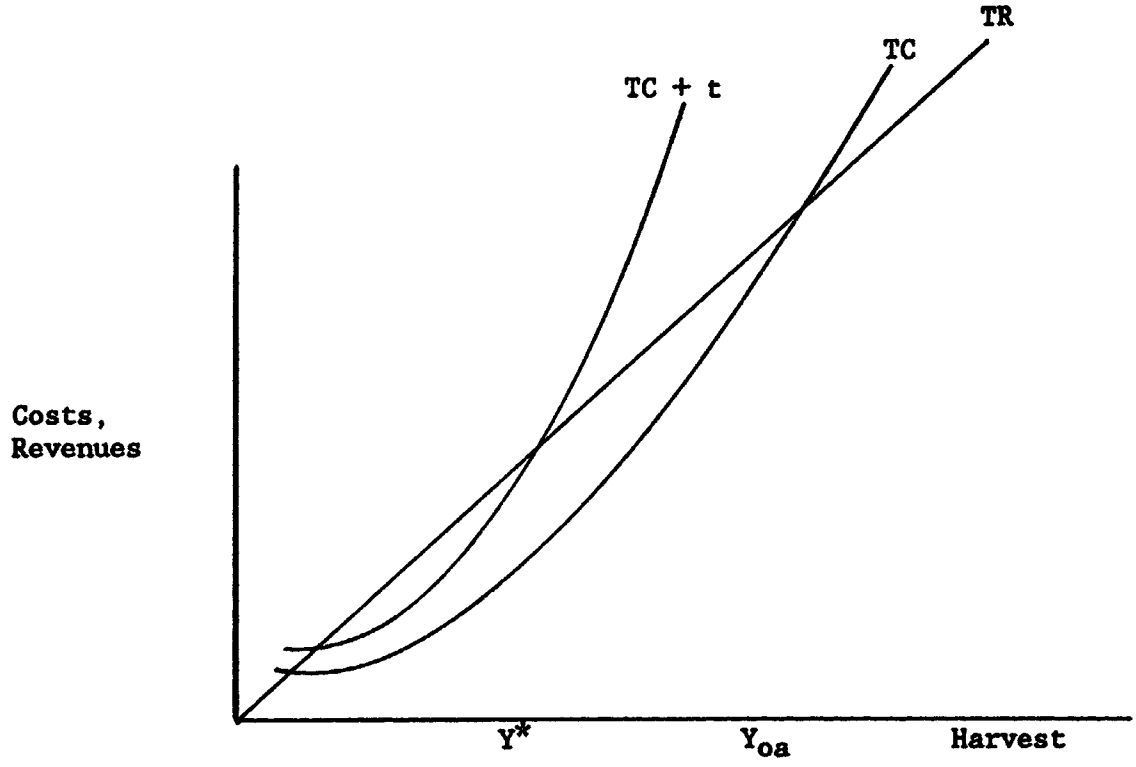

Figure 10. Effect of a Tax on Effort

more rapidly and cross total revenues at Y*. Both taxes generate the same tax revenue equal to the length of the segment between costs and revenues without the tax focus on two related issues. The first is: How, in terms of timing, should a tax be imposed so as to bring a previously unregulated resource to the optimum path most efficiently? The second is: How should the tax be administered -- on harvest or on inputs? The method of the literature is to consider alternative specifications of technology and resource growth, and then to study the adjustment of prices and quantities until (if ever) a steady state emerges. While details vary slightly, the principal conclusions of this literature are that optimal taxes exist and can be levied on either inputs or outputs, that when harvesting requires more than one input and when at least one input is fixed, the optimal tax policy needs to differentiate between the inputs or must tax outputs (Gould 1972), and that tax policy depends on whether the stock of the resource and of harvesting capital is above or below optimal levels (McKelrey 1985; Clark, Clarke and Munro 1979). Price uncertainty is shown by Andersen (1982) to favor a tax on revenue (an income tax).

75. Theory is mute on the subject of the use of tax revenues from open access resources. Writers presumably have in mind the usual logical separation of government revenues from expenditure. Dasgupta (1982), however, cautions that while an optimal tax can induce efficiency, such a tax may not be strictly Pareto preferred. If tax revenues are not returned, in the form of some lump sum payment or via equivalent means, the taxing authority and its constituents win while the participants in the common collecting revenues in a communal kitty and redistributing them among co-owners on the basis of ownership shares in the common resource. In Hopcraft's (1981) case of grazing land such a system has the added attraction of redistributing wealth from owners of large herds to owners of small herds who, at least in theory, have equal rights to the range. However, the redistributional aspect of such fees implies strong resistance on the part of wealthy (read powerful) participants in the resource. Similarly, as Hopcraft points out, even less wealthy participants may view such schemes as standing in the way of their chance to accumulate wealth. Moreover, the mere imposition of a fee for what had been free can be expected to meet with resistance and evasion. Thus, problems with enforcement, assessment, collection, and responsible handling of revenues are likely to be difficult.

Quantity Controls:

76. Analogous to taxation is the sale of transferable permits or harvest quotas. The pricing of such permits would be designed to raise the same revenue (equal to the resource's rent) as the optimal tax. Resource users would be able to buy and sell permits and would thereby ensure efficiency in harvest. Comparisons of these sorts of quantity restrictions versus taxation indicate that in a world with perfect certainty, there is no theoretical preference for either type of instrument. In practice, quantity restriction may be more easily administered and enforced.

77. Uncertainty about harvest costs, output prices, or resource stocks and growth, has also been shown to have an effect on the choice between quantity and price measures to regulate resource use. Where there is such uncertainty, it can be shown that under plausible conditions relating to cost and growth, quantity restrictions are preferable (Koenig 1984).

78. Nontransferable permits have generally been criticized because they do not provide for a mechanism to promote efficiency by owners. There is the potential for quotas distributed by random or by means other than sale to dissipate rents via inefficient harvesting. Lotteries to distribute hunting permits and other quotas are in widespread use. Lotteries are one of the techniques that Bierkes (1986) describes for the allocation of fishing rights in community managed fisheries in Turkey. Total catch quotas may also lead to excess capacity in harvesting equipment by virtue of inducing a race among boats for the largest share of the quota. Rules restricting the number of sheep herded by bedouin shepherds, along with seasonal restrictions, is the basis of the Hema system of range management reported by Draz (1985).

79. As with taxation, the distributional effects of quotas need not be neutral (Dasgupta 1982). If the optimal number of quotas are sold (at the optimal per unit price), unless the revenue is returned to the co-owners via a lump sum subsidy, the co-owners will be made worse off and the regulatory authority better off. If the optimal number of quota is given away, rents will accrued.

Seasonal Restrictions

80. The use of seasonal restrictions to limit overuse of nonexclusive resources is primarily a measure to allow an opportunity for regeneration at specific, critical times in the resources' growth cycles. Thus, in the United States, hunting seasons for deer are timed for the fall to thin herds in advance of winter scarcities of forage. In African pastoral regions, block grazing schemes are intended to remove grazing pressure before damage is done to its regenerative capacity (Hopcraft 1981). Difficulties, however, have been encountered in enforcing seasonal constraints. Certain technological fixes, such as removing borehole pumps, are described by Hopcraft as "explosive." Seasonal restrictions, by themselves, do nothing to fundamentally alter the incentive structure facing participants in open access resources. Instead, if effective at all, they only lead to a concentration of effort during the "open" season.

Privatization

81. The theoretical criticism of open access exploitation is based on the gap between the hypothesized performance of the sole owner and unregulated use. Therefore, it is not surprising that a commonly heard prescription for nonexclusive resource problems is to convert the commons into private property (Hardin 1982; Stroup and Baden 1983). For such a conversion to be desirable requires that it be technically and politically

feasible and there must be some assurance that the sole owner will actually manage the resource optimally.

82. Privatization can be accomplished in different ways and may involve partitioning of the resource into units owned by individuals, larger subdivisions being transferred to groups of owners, or putting the entire resource under the control of one authority (the latter could be an individual, firm or even unit of government). In the case of small groups of owners, as in group ranching schemes, there may be problems stemming from lack of economies of scale in exploitation or with enforcing boundaries. An advantage of group ranching schemes in Kenya has been the desire on the part of pastoralists to gain some form of legal title to land (this apart from any potential for range management improvement) (Hopcraft 1981). However, simply dividing the commons among smaller groups, does not alter the underlying incentives that lead to overuse.19/ For such plans to work, there needs to be an accompanying system of enforcement or incentives to reduce overcrowding.

83. Even when technologically feasible, division of the commons among individual owners is not without problems. Again, economies of scale may not be possible with fragmented ownership and the protection of property rights by essentially powerless small owners is difficult. The actual process of dividing the common resource in any kind of an equitable fashion is difficult and subject to numerous subversions by powerful elites. Privatization of the resource poses many of these difficulties, especially those related to fairness. And all privatization schemes suffer from the possibility of divergences between private and social costs. These can include underpriced, or mispriced, values and differences between the private and social discount rates.

Nationalization

84. Nationalization is a special case of privatization in which resources ownership is vested entirely to the national government. The government then needs to develop and install on apparatus to provide for the utilization of the resource. This may involve the establishment of various kinds of administrative units to control and manage use by private individuals or some form of state enterprise which provides goods and services directly to consumers.

85. Nationalization of resources has been a policy pursued by numerous countries, including the nationalization of forest resources, first by the colonial regime and later by the independent governments of West Africa (Thomson 1977). While in principle nationalization could be an approach to nonexclusive resource management, the experience of these countries suggests that without adequate government investment in management,

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19/ Although it may make detection of free riders easier. Also, as discussed below, Olson's theory of collective action does imply that group size *per se* does affect the likelihood of group action.

supervision, and control, nationalization is not a sufficient management measure.

86. In Niger, the policy of nationalization of forest resources was first implemented under the French Colonial regime as it became apparent that demand for firewood was leading to an erosion of the forest stock. The policy amounted to a prohibition of wood harvest with the exception of controlled exploitation under a system of cutting licenses.

87. A system of fines was formally put into place, but was largely replaced by an informal system of bribes and corruption. The nationalization strategy had several overall effects. By supplanting traditional structures of resource ownership it eliminated private or community incentives for management and replanting, and it created a setting for rent seeking behavior by forest guards and police who could extract bribes from harvesters in lieu of collecting official fines (Thomson 1977).

Distributional Consequences

88. Any scheme to manage open access resources will, at a minimum, impose adjustment costs on users and will require public investments in enforcement. The imposition of management may also be resisted by those with vested interests in the current open access system and who will perceive that their rights are being abridged. These problems will be particularly severe with a skewed distribution of power and wealth. Schemes intended to privatize resources are especially subject to these distortions.

89. Measures to remedy open access are presented in the literature as microeconomic adjustments to isolated instances of market failure. To the extent that there are other distortions, such as other externalities, markup pricing, market power, or undesirable income distribution, simply introducing a control or new incentive on the open access resource will not insure overall economic efficiency. However, it should not in general be expected that resource policy alone can solve these more general allocational problems.

90. Distributional issues are given little attention in discussions of open access resource regulation. Expropriative taxes which may generate efficient resource use, but which are not linked to redistributive mechanisms, may actually impoverish traditional resource users. Mechanisms such as quotas may amount to giving away the larger societies' rights to a select group of resource users. In general, it is important to note that vis-a-vis private ownership, distribution of income under open access favors consumers at the expense of resource owners. The poor are disproportionately heavy consumers of nonexclusive resources and attempts to limit access will impose a heavier burden on an already disadvantaged group. Compensation schemes can be designed to overcome the adverse distributional effects of any potentially pareto improving regulatory

policy. However, this is of small solace unless such compensation is actually paid.

VI. THE FUTURE OF THE COMMONS

91. Strategies for the management of nonexclusive resources have to take into account several issues, including the development of an adequate technical package, the level of demand for the resource and the availability of other alternatives for the people involved. Another is that regardless of preferences for any one type of property rights regime there are likely to continue to be resources that are not subject to private control. For example, the technology of rangelands, irrigation and groundwater and other resources are such that a substantial degree of interdependence between users will continue into the foreseeable future. Given this, an institutional framework must be created through which specific management tools, such as those discussed in Section V, can be implemented. Certain aspects of the evolution of such a framework, specifically the emergence of cooperation in prisoner's dilemmas, has been discussed in Section IV. In this section another set of issues are examined relative to the ability of groups to come together to manage commonly owned resources.

92. While the Samuelsonian approach to public goods, outlined in Section IV, deals primarily with the consumption of these goods, in this section we review Mancur Olson's (1965) theory of their production via collective action. Olson's analysis focuses on the conditions under which group action can be expected and on the catalytic roles of privately appropriated by-products of goods. Because pressure on nonexclusive resources, and hence the need for management, is likely to change over time, it is also important to consider how changes in supply and demand may relate to institutional frameworks. Therefore, we conclude this section by considering the possible role of induced innovation processes in bringing about enhanced management of nonexclusive resources.

The Logic of Collective Action

93. Olson's analysis of collective action proceeds from two observations. The first is that due to the free rider problem, self-interested, rational individuals may not necessarily work collaboratively in a group to serve their common interest. The second is that, in spite of the first, we see voluntary groups producing goods and providing services of a public good nature in a wide variety of areas including education, labor unions, as well as natural resources. Group action can also be observed in such less desirable forms as collusion and oligopolies in which firms or agents collaborate to restrict quantity and maintain high prices.20/ One explanation of the provision of some public goods is simply that if the cost involved in satisfying the demands of one consumer are sufficiently low for that one consumer to undertake private provision, then, since the

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20/ In fact, Olson's analysis can also be used to generate the standard Cournot model of oligopoly.

consumption of a public good is not rival, all consumers will benefit. However, such a level of provision may not be optimal. More generally the level of private provision that individuals will find desirable can be determined through a simple maximization exercise. Let the level of the public good be given by T, and the size of the group by S_g. The value, V_g, to the group is

$$V_g = S_g T \tag{15}$$

The cost of the good is an increasing function of the level

$$C = C(T) \tag{16}$$

The value to any individual i is V_i21/

$$F_i = \frac{V_i}{V_g} \tag{17}$$

The net advantage A_i to any individual is simply benefits less cost, C.

$$A_i = F_i S_g T - C = V_i - C \tag{18}$$

Taking the usual derivative, we see that the consumer will purchase units of T until

$$\frac{dA_i}{dT} = F_i S_g - \frac{dC}{dT} = \frac{dV_i}{dT} - \frac{dC}{dT} = 0 \tag{19}$$

or, since $dV_i/dT = F_i(dV_g/dT)$: (20)

$$F_i(dV_g/dT) = dC/dT$$

In words, the individual, if he should obtain any of the public good, should procure an amount such that marginal value of the good to the group times the fraction accruing to herself (marginal private benefit) equals marginal cost. In contrast, the socially optimal level of provision would have marginal cost equated with marginal social benefit.

$$\frac{dV_g}{dT} = \frac{dC}{dT} \tag{21}$$

94. Olson's model thus identifies F_i , which can, in a general way, be related to the size of the group, as the critical parameter in determining how close to optimal will be the level of provision of the public good.22/ Specifically, Olson defines three sizes/types of groups and relates them to

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21/ Olson does not specifically define the units of V_g or V_i.

22/ See R. Hardin's discussion of Olson's use of the concept of group size (pp 38-49).

his model. The first, and Olson suggests the smallest, are those groups for which

$$V_i > C \qquad (22)$$

for at least one i. These are privileged groups, in the sense that free riders will be privileged by the self-interested provision of the public good by that individual. The burden of provision in such a group is not in proportion to private benefit, rather, "the individual with the largest F_i will bear a disproportionate share of the burden . . . there is a systematic tendency for 'exploitation' of the great by the small!" (p. 29, emphasis in the original).

At the other extreme, large groups for which

$$V_i < C \quad \text{for all } i \qquad (23)$$

are said to be latent groups. Large groups are likely to suffer without the public goods because no individual will take on private provision, because as group size expands, F_i is likely to fall, and because the cost of organizing members in a large group are likely to be high. A latent group may be coerced into providing public goods in which case it is termed a mobilized latent group. In between latent and privileged groups are what Olson calls intermediate groups. Intermediate groups are somewhat vaguely described as ones in which at least two individuals must act together to provide the public good, and which is not so large that others will not notice the contribution of individuals who do contribute. Intermediate groups may or may not have public goods provided but will always require some group coordination or organization before provision is forthcoming.

95. Latent groups and intermediate groups in Olson's typology differ principally by size, with latent groups presumed to be larger. Intermediate groups, however, are more likely to achieve collective action because of the interdependence of members. Intermediate groups are sufficiently small so that members can perceive each other's contributions and inclinations to contribute. Latent groups can only achieve collective action via selective incentives. Such incentives are selective in the sense that they are focussed on rewarding or punishing particular individuals in order to elicit contributions.

96. Intermediate groups may achieve the provision of public goods by other means as well. One technique is to provide privately appropriate by-products to encourage cooperation. For example, many professional associations which lobby (a public good) also publish professional journals (a private good).

97. Government initiative is another means by which collective action can be initiated. For example, in the United States, the Smith-Lever Act of 1914 provided Federal co-financing for agricultural extension. Many

state governments, however, specified that no funds would be provided unless county level farmer associations were established first. This requirement gave rise to a nationwide system of Farm Bureaus which not only assured the provision of technical extension advice, but has also become a potent political force (a public good) (Olson, 1965, pp. 148-153).

98. In his 1971 appendix to his 1965 book, Olson also discusses the possible role of the political entrepreneur. A political entrepreneur is a individual with a combination of traits: leadership, the trust of the community or its fear, the ability to discern the motivations of others, and the desire to organize the group for collective action. Olson suggests that the success of the political entrepreneur will be related to his ability to utilize selective incentives to motivate participation. Barker (1978) describes the difficulties faced by an individual promoting communal irrigation management:

> A major problem is that a leader who takes on both the formidable task of organizing his community for public works and convincing the government to contribute will benefit only marginally from the project if he is a small landholder. So only a rare individual dedicated to the community good will offer to organize a community project. On the other hand, if the leader is a large landholder, he will benefit substantially, but other members of the community will see the project as a means of promoting his interest rather than contributing to the common benefit. In this case, it would be extremely difficult to persuade the community members to contribute their labor (1978, p. 149).

99. Political entrepreneurship can also be provided by government agencies and nongovernmental organizations (NGOs). In Pakistan the Agha Khan Rural Support Program (AKRSP), an NGO, has been successful in improving management of common grazing lands. The AKRSP's approach has been to use credit and technical assistance for the construction of village infrastructure. These have served both as selective incentives and as lowering the costs of private contributions to common resource management (World Bank, 1987). Similarly in the Philippines, the Central Visayas Regional Project (CVRP) has created a special governmental structure which plays the entrepreneurial role. Project staff have access to inputs and are able to enlist the services of sector specific line agencies in support of community resource management. A specific example of the use of selective incentives is a program in which families and villages who agree to participate in common property management (for example observance of fish sanctuaries or deployment of artificial reefs) become eligible for employment in infrastructure development or for loans of pregnant livestock.

Induced Institutional Innovation

100. In sum, Olson's logic of collective action suggest that the supply of public goods is responsive to the costs of their production, individuals demand and the difficulty with which groups can be organized via selective incentives, entrepreneurship, and the supply and demand for the by-products of collective action. The problem of organizing and maintaining group action is essentially one of establishing institutional rules of the game. The ease with with such rules can be established need not be constant and may be related to a society's endowment of resources. The view that technical and institutional change is endogenously determined by relative scarcities has been developed in the induced development hypothesis.

101. The argument that relative factor prices play an important role in guiding technical change, induced technical innovation theory, is widely accepted (Ruttan 1982; Hayami and Ruttan 1971; Binswanger and Ruttan 1978). Although less well-developed, and certainly less rigorously tested empirically, the theory that relative scarcity drives institutional innovation is an appealing framework for the analysis of responses to nonexclusive property problems.

102. According to the induced innovation hypothesis of technical change, efforts by entrepreneurs to conserve scarce resources and to capitalize on abundant ones leads an economy to an efficient allocation of resources and also sets in motion demands for new technology that expands opportunities for conserving scarce ones. The classic comparison is the development and adoption of land-saving agricultural technology in labor-abundant Japan and labor-saving technology in the land-rich United States (Hayami and Ruttan). While induced technical change has generally been investigated in terms of privately owned resources, similar processes may be at work in terms of nonexclusive resources. Arnold and Campbell (1986), for example suggest that fodder scarcity in Nepal has led to the shift from open grazing of cattle to stall feeding.

103. Similarly, the theory of induced institutional innovation suggests that entrepreneurs allocate resources as efficiently as possible within a given institutional framework. When the constraints of that framework become binding, political "market forces" are brought into play, creating demand for new institutions. Demsetz's (1967) theory of property rights is an example of an induced institutional development hypothesis.

104. In recent empirical work, Hayami and Kikuchi (1982) argue that institutional change is responsive to supply and demand factors and can also result from changes in technology. For example, they relate the particular form of changes in the distribution between landowner and hired labor of rice harvest in the Philippines to the characteristics of high-yielding varieties and to the social costs of alternative adjustments. Work by Feeney (1976, 1977) on Thailand tenure systems shows a similar pattern. Changes in the value of riceland since the beginning of this

century led to establishment of more comprehensive and precisely defined land ownership rights.

105. The general thrust of research findings on property rights and scarcity has been that increasing scarcity tends to lead to more exclusive and well-defined property rights (Demstez 1967; Hayami and Kikuchi 1982). However, there is nothing to preclude the possibility of greater scarcity leading to tightened control over communal resources. Hayami and Kikuchi use this to explain the development of community management systems over Japanese forest reserves and irrigation systems. Hayami and Kikuchi also suggest that the supply of political entrepreneurship is a critical factor in the development of new institutional arrangements.

VII. CONDITIONS FOR SUCCESSFUL MANAGEMENT

106. There appears a tension in reconciling the insights of the open approaches. While there has been considerable attention given to the alleged emphasis of the open access approach on privatization, this is less one of theory than practice. As suggested in figure 2, common property and open access are related by an element of physical nonexclusivity and are distinguished by different levels of social coordination.

107. One real issue is the appropriate measure of success. The bioeconomic model of resource management described in Section II and which motivated many of the specific interventions discussed in Section V has a clearly articulated objective: maximization of present net value. While the arguments that make up the model's objective functional can be extended to include various sorts of values, the basic calculus remains unchanged by such extensions. The performance of policies to manage open access resources is, in principal, easy to assess. The analyst need only ask if the costs of altering management practices is warranted by any possible increases in the net present value of output. Common property management, however, does not necessarily imply any particular, single valued, goal. In fact common property management, whether by central government authority or through community based institutions is more properly seen as a process. The success of such a process needs to be considered in terms of its internal sustainability via generating participation and legitimacy, as well as by its contribution to various development objectives.23/

108. In this sense, there is less to reconcile between the open access and common property approaches. Both models depict situations in which uncontrolled private preferences acting through physically interrelated processes lead to socially undesirable outcomes, and both seek systems of control. While open access models lead to clear (and dire) predictions and to reasonably specific recommendations on alternative policy tools, common property theories focus on the process of selecting and applying tools, including precisely those discussed by open access theorists. Common

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23/ As Bromley (1983) notes, admitting different institutional arrangements may lead to different preference orderings over outcomes.

property theorists often go beyond taxes and other economic incentives to admit moral suasion, prestige, and ostracism, but the open access theorist could easily define these as special kinds of costs and incentives that are not at all inconsistant with the recommendations of his own model. Thus, the management of nonexclusive resources does not involve a choice between these two approaches, but an integration. Management of these resources involves not simply the imposition of new property rights or sets of financial incentives, but agreement on the process(es) of introducing these changes. At this more general level, the insights of common property theory are helpful in revealing the conditions surrounding collective choice, whether the collective is the individual village or a country acting through organs of national government. Models of open access resources have the potential for guiding management toward preferred ends within a framework of agreed upon institutions.

109. An additional consideration that needs to be factored into the analysis on nonexclusive resource regimes and the promotion of common property, is the identification of the relevant community. Most resource using activities seldom involve only one individual. When referring to individual or private strategies, families may be the appropriate unit. However, extended families, clans, friendship associations or other units may be validly said to pursue private strategies. Where this occurs, the precision of the distinction between collective and individual begins to blur. From an operational perspective the appropriate focus is on the relationship between groups of users (possibly as small as one) vis-a-vis other groups with respect to claims over resources.

Lessons From Resource Management

110. One can identify a number of conditions which the literature on the evolution of cooperation suggest are critical for effective nonexclusive resource management. An analysis of the resource-based literature suggest that there seems to be a key need for recognition of resource scarcity. The need for such a recognition is consistent with the induced innovation hypothesis, with the open access resource model, and with observations of the performance of specific attempts to deal with resource management problems (Abel 1977; Levine, Chin, and Miranda 1976). Scarcity presumably needs to be felt at all levels involved in the selection and enforcement of management efforts such as government authorities, village leaders and individuals (Hoben 1979). Kloppenburg (1983) emphasizes that initiative for group formation must start among the members themselves. A system of competitive prices is one mechanism for creating an awareness of scarcity.

111. The role of scarcity, however, probably cuts both ways. There seems to be an inverted "U" relationship between the degree of resource scarcity and the probability of successful resource managements. At low levels of scarcity, management in a formal sense, does not arise. When scarcity is severe the costs of introducing and maintaining management are high. In the intermediate zone the probability of success is higher. These observations are borne out by Molnar's (1980) and Arnold and Campbell's

(1986) observations in Nepal and by Skutsch's (1983) analysis of community woodlots in Tanzania.

112. Abel (1977) also maintains that management of nonexclusive resources requires a combination of centralized investment planning and decentralized management. This capacity is required to translate the awareness of scarcity into management projects and policies. It is particularly important in the case of infrastructure-intensive resources such as irrigation systems, or where external inputs are required for the management scheme. Coward (1977) also indicates the benefits of decentralized management.

113. A system for the exchange of information between users and managers is also necessary (Abel 1977; Levine, Chin, and Miranda 1976). Such a system may involve substantial monitoring costs, but will provide a means of detecting free riders (Wade 1986) and a means of allocating resources among users so as to promote efficiency. Valera et al. (1975), suggest that a main condition of implementing irrigation water control is to be able to measure water use; this probably applies to other nonexclusive resources as well.

114. Accountable leadership is mentioned by Coward (1977) as a key variable in the success of local irrigation systems. Three factors: size of the system (small); local selection; and method of compensation, contribute to the performance of leadership. Hayami and Kikuchi (1982) discuss the role of the political entrepreneur.

115. Coward (1977) also notes that successful indigenous irrigation systems tend to be based around the canal rather than around the village, and are thus not village systems but rather villager systems. Extended to other resources this implies that all prospective users of the resource must be encompassed by the management system. Disruption of grazing schemes by migrant groups is mentioned by Hopcraft (1981). In other words, community management resources must proceed from the existence of a community that encompasses the relevant co-owners, and excludes others.

116. There must be a solid technical basis for resource management (Kloppenburg 1983; Hoben 1979; Hopcraft 1981; Wade 1986; Yudelman, personal communication). Technical or extension services to assist local management is necessary (Kloppenburg 1983). Research and development investments may also be required to develop a satisfactory technical package.

117. Finally, in addition to all the factors that lead to the ability of communities or states to manage resources, there is a need for specific tools that have legitimacy and that can be enforced. Key examples of these are discussed in detail in Section V. The thrust of these is that tools must be employed that alter the incentives of individuals using nonexclusive resources so that there is not a divergence between public and private costs. In the absence of such incentives, well-intentioned institutions will not be sufficient for management.

Lesson from Cooperation Theory

118. The received theory on collective action and cooperation also suggests a number of important messages for those concerned with the management of nonexclusive resources. To start on a somewhat negative note, there is first of all the caveat that cooperation is costly and that where circumstances permit an appropriate course of action may be to avoid a collective choice situation when possible (Nicholson 1979). This should not at all be considered a blanket argument for the privatization of nonexclusive resources. As emphasized above, there are a large number of reasons for resources to be held in common, not the least of which are the technical and physical qualities of various resources. However, when adequate technical packages exist and objectives of income distribution can be met by exclusive resource development strategies, it may be unnecessary to bear the costs of generating sustainable collective action.

119. More generally though, community resource management will be at least a possible component and often an essential element of a resource development strategy. Recent developments also serve to soften the assumption that free riding behavior is somehow the natural behavior of rational decisionmakers. The evidence presented by Marwell and Ames (1981) and by Bromley and Chapagain (1984), while suggesting difficulties in sustaining cooperation, is consistent with the hypothesis that free riding is a response conditioned by social pressures and expectations that favour private maximization. If the structure of interaction over public goods can be modified, especially in early transactions, it may be feasible, possibly by appeal to ethical considerations, to motivate reciprocal behavior along the lines suggested by Sugden (1984).

120. In assessing the potential for community management of specific resources and groups, theory suggests consideration of a number of key parameters. Olson's logic of collective action focuses attention on the size of the group and on the potential distribution of costs and benefits. The smaller the group and the more concentrated the benefits, the greater the potential for collective action.

121. Axelrod's examination of cooperation in iterated prisoner's dilemmas, suggests that the time dimension of resource use is another important determinant of the chances for success. Sustained interaction with opportunities for punishment and forgiveness allow cooperation to emerge. Axelrod also concludes that the lower the rate of time preference the better the chance for collective action. This observation may have a number of implications that need to be explored. It is generally presumed that low income people have high rates of discount which suggests that in developing countries cooperation is less likely to emerge. At the same time the model described in Sections II and III indicates that net losses in social welfare from open access are inversely related to the discount rate.

122. Axelrod also argues that friendship, or warm social relations are not necessary for cooperation in prisoner's dilemmas. Thus it is not necessary to adopt a utopian view of rural society in order to propose community management of nonexclusive resources. More important, as shown by the Runge discussions, is the structure of the interaction and the ability of participants to understand the significance of their interdependence.

123. The literature on cooperation also provides some guidance for the design of broader policies to facilitate the management of nonexclusive resources. Government interventions have been shown to have both positive and negative effects on common property management. Olson's example of Farm Bureaus in the United States suggests that governments can promote collective action by providing or stimulating the provision of selective benefits of by products of collective action. Wade counters strongly that central governments can exert a strong destructive influence on local community management. Probably the most promising vehicles for outside interventions are measures to stimulate or directly provide political entrepreneurial activity. The emerging experiences of programs such as the Agha Khan Rural Support Program and the Central Visayas Regional Project suggest that externally sponsored agencies can provide the entrepreneurial input that seems to be required for community resources management and especially for its restoration. Based on approaches and tools such as those discussed above, there is reason to believe that development policy can directly improve management of nonexclusive resources and promote institutional innovations that will allow real scarcities to be reflected in individual and collective decision making.

REFERENCES

Abel, Martin (1977). "Irrigation Systems in Taiwan: Management of a Decentralized Public Enterprise," in Water Resources Problems in Developing Countries, K. William Easter and Lee R. Martin, eds. Bulletin No. 31, Economic Development Center, Department of Agricultural Economics/Department of Economics, University of Minnesota-Minneapolis.

Anderson, Peder (1982). "Commercial Fisheries Under Price Uncertainty," Journal of Environmental Economics and Management, Vol. 9, No. 1 (March), pp. 11-28.

Anderson, Terry L. and Hill, Peter J. (1975). "Evolution of Property Rights, A Study of the American West," Journal of law and Economics 18(1) pp 163-179.

Arnold, J.E.M. and J.G. Campbell (1986). "The Community Forestry and Development Project," in National Academy of Sciences, Proceedings of the Conference on Common Property Resource Management, April 21-26, 1985, Annapolis, Maryland.

Artz, Neal, Brian Norton, and J.G. Campbell (1986). "Management of Common Grazing Lands in the Case of Timahdite, Morocco," In National Academy of Sciences, Proceedings of the Conference on Common Property Resource Management, April 21-26, 1985, Annapolis, Maryland.

Axelrod (1984). The Evolution of Cooperation (New York: Basic Books, Inc.)

Barker, Randolph (1978). "Bars to Efficient Capital Investment in Agriculture," in Distortions of Agricultural Incentives, T. W. Schultz, ed. (Bloomington: University of Indiana Press).

Barker, Randolph (1984). "Renewable Resource Management in Developing Country Agriculture: Discussion." American Journal of Agricultural Economics, Vol. 66, No. 5 (December), pp.885-887.

Baumol, William (1976). "It Takes Two to Tango or Sind Separable Externalities Uberhaupt Moglich?" Journal of Political Economy, Vol. 84, No. 2 (April), pp. 381-388.

Belton Cobb, G. (1916). Stand to Arms (London: Wells Gardner, Darton & Co.).

Berck, Peter (1979) "Open Access and Extinction" Econometrica Vol 47, pp 877-82.

Bierkes, Fikret (1986). "Marine Inshore Fishery Management in Turkey: Some Examples, Problems and Prospects," in National Academy of Sciences, Proceedings of the Conference on Common Property Resource Management, April 21-26, 1985, Annapolis, Maryland.

Binswanger, Hans (1980). "Attitudes Towards Risk: Experimental Measurement in Rural India"; American Journal of Agricultural Economics.

Binswanger, Hans and V. Ruttan, eds. (1978). Induced Innovation (Baltimore: Johns Hopkins University Press).

Brokensha, David and B. Riley (1978). "Forest, Foraging, Fences and Fuel in a Marginal Area of Kenya," paper presented at the USAID Africa Bureau Firewood Workshop, June 12-14, 1978, Washington, D.C.

Bromley, Daniel W. (1982). "Land and Water Problems: An Institutional Prespective" American Agricultural Economics Association, Vol. 64, No. 5 (December), pp. 834-844.

Bromley, Daniel W. and Devendra Chapagain (1984). "The Village Against the Center: Resource Depletion in South Asia," American Journal of Agricultural Economics, Vol. 66, No. 5 (December), pp. 868-873.

Brown, Gardner, Jr. (1974). "An Optimal Program for Managing Common Property Resources with Congestion Externalities" Journal Political Economy, Vol. 82, No. 1 (January-February), pp. 163-173.

Chayanov, A.V. (1966). The Theory of Peasant Economy (Homewood, Illinois: Richard D. Irwin).

Ciriacy-Wantrup, Siegfried V. and Richard C. Bishop (1975). "'Common Property' a Concept in Natural Resources Policy" Natural Resources Journal, Vol. 15 (October).

Clark, Colin W. (1973). "Profit maximization and the Extinction of Animal Species," Journal of Political Economy, Vol. 81, pp. 950-961.

Clark, Colin W. (1976). Mathematical Bioeconomics: The Optimal Management of Renewable Resources (New York: John Wiley and Sons).

Clark Colin W., F.H. Clarke, and G.R. Munro (1979). "The Optimal Exploitation of Renewable Resource Stocks: Problems of Irreversible Investment," Econometrica, Vol. 47, No. 1 (January).

Coward, E. Walter (1977). "Irrigation Management Alternatives: Themes from Indigenous Irrigation Systems," Agricultural Administration, Vol. 4, pp. 223-237.

Cruz de Carvalho, Eduardo (1974). "'Traditional' and 'Modern' Patterns of Cattle Raising in Southwestern Angola: A Critical Evaluation of Change from Pastoralism to Ranching," Journal of Developing Areas, Vol. 8, No. 2 (January), pp. 199-226.

Cycon, Dean E. (1986). "Managing Fisheries in Developing Nations: A Plea for Appropriate Development," Natural Resources Journal, Vol. 26, No. 1 (Winter), pp. 1-14.

Dasgupta, Partha (1982). The Control of Resources (Cambridge: Harvard University Press.

Demsetz, Harold (1967). "Toward a Theory of Property Rights" American Economic Review, proceedings issue, pp. 347-377.

Draz, Omar (1985). "The Hema System of Range Reserves in the Arabia Peninsula: Its possibilities in Range Improvement Conservation: The Human Dimension in Environmental Planning, Jeffrey A. McNeely and David Pitt, eds. (London: Croom Helm).

Feeney, David Harold (1976). "Technical and INstitutional Change in Thai Agriculture, 1880-1940." Ph.D. dissertation, University of Wisconsin, Madison, Department of Economics.

Feeney, David Harold (1977). "From Property Rights in Man to Property Rights in Land: Institutional Change in Thai Agriculture 1850 to 1940." Working Paper 77-12 (Hamilton, Ontario, Department of Economics, McMaster University).

Glantz, Michael H., ed. (1977). Desertification: Environmental Degradation in and Around Arid Lands (Boulder, Colorado: Westview Press).

Goodwin, R.K. and Shepard, W.B. (1980). "The Use of the Commons Dilemma in Examining the Allocation of Common Resources." Reprint 179 Resources for the Future.

Gordon, H.S. (1954). "Economic Theory of a Common-Property Resource: the Fishery, Journal of Political Economy, Vol. 62 pp. 124-142.

Gould, J.R. (1972). "Extinction of a Fishery by Commercial Exploitation: a Note,' Journal of Political Economy, Vol. 80, pp. 1031-1038.

Guttman, Joel M. (1982). "Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context: Comment," American Journal of Agricultural Economics, Vol. 64, pp. 71-782.

Hardin, Garrett (1968). "The Tragedy of the Commons," Science, Vol. 162, pp. 1243-1248.

Hardin, Russell (1982). Collective Action. Published for Resources for the Future by Johns Hopkins University Press, Baltimore.

Hartman, R. (1976). "The Harvesting Decision When the Standing Forest has Value," Economic Inquiry (September).

Haveman, R.H. (1973). "Common Property, Congestion and Environmental Pollution," Quarterly Journal of Economics, Vol. 87, No. 3.

Hay, Ian (1916). The First Hundred Thousand. (London: William Blackwood).

Hayami, Yujiro and Kikuchi, Masao (1982). Asian Village Economy at the Crossroads.", University of Tokyo Press, Tokyo, Japan.

Hayami, Yujiro and Vernon W. Ruttan (1971). Agricultural Development: An International Perspective (Baltimore: Johns Hopkins University Press).

Hoben, Allan (1979). "Lessons from a Critical Examination of Livestock Project in Africa." U.S.A.I.D. Program Evaluation Working Paper No. 23, Washington, D.C. (June).

Hopcraft, Peter N. (1981). "Economic Institutions and Pastoral Resource Management: Considerations for a Development Strategy" in The Future of Pastoral Peoples, John G. Galaty, D. Aronson, P. Saltzman, and A. Chovinard, eds. Proceedings of a conference held in Nairobi, Kenya 4-8 August 1980. IDRC, Ottawa, Ontario., pp. 224-396.

Jodha, N.S. (1983). "Market Forces and Erosion of Common Property Resources," in Agricultural Markets in the Semi-Arid Tropics. Proceedings of the International Workshop, 24-28 October, International Crop Research Institute for Semi-Arid Tropics, Patancheru, India.

Jodha, N. S. (1985). "Population Growth and the Decline of Common Property Resources in Rajasthan, India," Population and Development Review, Vol. 11, No. 2 (June), pp. 247-264.

Kamien, Morton I. and Schwartz, Nancy L. (1980). Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management (New York: North Holland).

Kisangani, Emizet (1986). "A Social Dilemma in a Developing Country: The Massacre of Loxodonta africana in Zaire," in National Academy of Sciences, Proceedings of the Conference on Common Property Resource Management, April 21-26, 1985, Annapolis, Maryland.

Kloppenburg, Jack R. (1983). "Group Development in Botswana: The Principles of Collective Farmer Action," Research in Economic Anthropology, Vol. 5, pp. 311-333.

Koenig, Evan F. (1984). "Controlling Stock Externalities in a Common Property Fishery Subject to Uncertainty," Journal of Environmental Economics and Management, Vol. 11, No. 2 (June), pp. 1245-138.

Krutilla, John and A. Fisher (1985). The Economics of Natural Environments. Resources for the Future, Washington, D.C.

Levhari, David, Ron Michener, and Leonard J. Mirman (1981). "Dynamic Programming Models of Fishing: Competition," American Economic Review, Vol. 71, No. 4 (September), pp. 649-661.

Levine, G., L.T. Chin, and S.M. Miranda (1976). "Requirements for the Successful Introduction and Management of Rotational Irrigation" Agricultural Water Management, Vol. 1, No. 1, pp. 41-56.

Marwell, Gerald E. and R.E. Ames (1981). "Economists Free Ride--Does Anyone Else?" Journal of Public Economics.

McKelvey, Robert (1985). "Decentralized Regulation of a Common Property Renewable Resource Industry with Irreversible Investment," Journal of Environmental Economics and Management, Vol. 12, No. 4 (December), pp. 287-307.

Molnar, Augusta (1980) "The Dynamics of Traditional Systems of Forest Management in Nepal: Implications for the Community Forestry Development and Training Project", World Bank Office Memorandum, Feburary 12, 1981.

National Academy of Sciences (1986) Proceedings of the Conference on Common Resource Property Management (National Academy Press: Washington).

Noronha, Raymond (forthcoming) "The Sociocultural and Legal Dynamics of Natural Resource Management" Working Paper, Environment Department, The World Bank.

Olson, Mancur (1965). The Logic of Collective Action (Cambridge: Harvard University Press).

Palmquist, Raymond B. and E.C. Pasour, Jr. (1982). "Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context: Comment," American Journal of Agricultural Economics, Vol. 64, pp. 783-784.

Picardi, Anthony C. and Seifert, William W. (1976). "A Tragedy of the Commons in the Sahel" Technology Review (May), pp. 42-51.

Polanyi, Karl (1957). The Great Transformation: The Political and Economic Origins of Our Time, (Boston: Beacon Press).

Runge, Carlisle Ford (1986). "Common Property and Collective Action in Economic Development." National Academy of Sciences, Proceedings of the Conference on Common Property Resource Management, April 21-26, 1985, Annapolis, Maryland.

Runge, Carlisle Ford (1982). "Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context: Reply," American Journal of Agricultural Economics, Vol. 64, pp. 785-787.

Runge, Carlisle Ford (1981). "Common Property Externalities: Isolation, Assurance, and Resource Depletion in a Traditional Grazing Context, "American Journal of Agricultural Economics, Vol. 63, pp. 595-606.

Russell, Clifford S. and N.K. Nicholson, eds. (1981). Public Choice & Rural Development (Washington, D.C.: Resources for the Future).

Ruttan, Vernon (1982). Agricultural Research Policy (Minneapolis: University of Minnesota).

Sahlins, Marshall (1972). Stone Age Economics (Chicago: Aldine-Atherton).

Samuelson, Paul (1955). "Diagrammatic Exposition of a Theory of Public Expenditure, " The Review of Economics and Statistics Cambridge: Harvard University Press), Vol. 37, No. 4 (November), pp. 350-356.

Samuelson, Paul (1954). "The Pure Theory of Public Expenditure," The Review of Economics and Statistics, (Cambridge: Harvard University Press), Vol. 36, No. 4 (November), pp. 387-389.

Scott, A.D. (1955). "The Fishery: the Objectives of Sole Ownership," Journal of Political Economy, Vol. 63, pp. 116-124.

Sen, Amartya K. (1967). "Isolation, Assurance, and the Social Rate of Discount," Quarterly Journal of Economics, (February).

Skutsch, Margaret M. (1985). "Forestry by the People for the People -- Some Major Problems in Tanzania's Village Afforestation Programme" International Tree Crops Journal (3) 147-170.

Stroup, Richard L. and J.A. Baden (1983). Natural Resources: Bureaucratic Myths and Environmental Management, (San Francisco: Pacific Institute for Public Policy Research).

Sugden, Robert (1984). "Reciprocity: The Supply of Public Goods Through Voluntary Contributions," The Economic Journal, Vol. 94 (December), pp. 772-787.

Valera, A., E. Tabbal, R. Reyes, and R. Barker (1975). "The Effect of Improved Improved Water Control in Irrigation Canals on Crop Production." Agricultural Economics Department Paper 75-12, International Rice Research Institute, Los Banos, Philippines.

Varian, Hal R. (1984). Microeconomic Analysis (New York: W.W. Norton).

Wade, Robert (1985). "Common Property Resource Management in South Indian Villages, " World Bank Discussion Paper, Report No. ARU 36 (April).

World Bank (1987). "The Agha Khan Rural Support Program in Pakistan: An Interim Evaluation," Operations Evaluation Department, Washington, D.C.