NATURAL RESOURCES JOURNAL

Volume 9
Issue 4 *Fall 1969*

Fall 1969

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TOWARD A THEORY OF MULTIPLE USE: THE CASE OF RECREATION VERSUS AGRICULTURE

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I
INTRODUCTION

Multiple use is often extolled as a means of mitigating growing pressures on our natural resources. Any principle of management that has this potential deserves careful study, for it is certain that demands on our resource base will continue to increase, and that conflicts between uses will become ever more frequent and intense.

The idea of multiple use has great appeal. It is perhaps not surprising that it is accepted and expounded by so many harried resource managers and public spokesmen as a panacea for their problems. But any attempt to interpret or apply the concept where uses are more or less conflicting is met with great difficulty. Should two or more uses of a resource be served simply because it is *technically possible* to do so? Under what circumstances can we say it is *desirable* to accommodate one group of users when this necessitates a compromise in the resource's capacity to serve others? And when multiple use is desirable, *how much* of one use should be sacrificed for another?

William Howard Taft is reported to have said that there are a great many people in favor of conservation, no matter what it means. Perhaps the same can be said today of multiple use. A perusal of some of the basic literature in the natural resource sciences reveals that multiple use (like "conservation") while frequently alluded to, is a conspicuously vague idea. Standard texts on the management of forests, wildlife and ranges stress full use in terms of maximum physical yields. They also stress the necessity of accommodating all possible uses, given the imperative of preserving the resource base. But the critical issue of compromising conflicting demands is not rigorously dealt with. Economics, concerned as it is with social choices among products and alternative ways of producing them, probably comes closest to providing the required analytical concepts in the established theory of the multi-product firm. However, that problem is not strictly analogous because the resource inputs are all assumed to be variable and are dealt with entirely in

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terms of their total costs.[1] Economists have also demonstrated the mechanics of dealing with multiple demands in the context of benefit-cost analysis as it applies to the planning and evaluation of water resource projects.[2]

At another level, modern mathematical techniques and large-scale computers have greatly facilitated the development and use of systems analysis and the construction of complex models to investigate complicated interrelationships. Ecologists have employed these tools to study population dynamics, interrelationships among species in an ecosystem, predator-prey relationships and other phenomena.[3] Economists are using them in problems of resource planning.[4] These techniques can help to demonstrate the implications of various processes within fixed constraints, and hence offer promise for analyzing multiple simultaneous demands on a fixed resource base at a highly sophisticated level. Such developments intensify the need for a basic theoretical demonstration of the factors underlying the optimum combination of uses of a resource base.

In response to this growing need for reliable criteria for deciding among alternative patterns of resource use, a small number of articles have recently appeared in journals of quite different disciplines, all of which have employed the same basic concepts of production theory to analyze the multiple-use problem.[5] This article is an extension of that discussion. It begins by demonstrating the economic principles underlying the optimum combination of two (or more) competitive uses of a fixed resource. In order to provide some context for the discussion, we choose the example of competing demands of deer and cattle on a parcel of rangeland, although the principles are general enough to apply to a wide range of situations. This particular example permits a subsequent discussion of the nature of recreational values in contrast to commercially valued products.

1. *See, e.g.*, G. Stigler, The Theory of Price 162-65 (3d ed. 1966).

2. *See, e.g.*, J. Krutilla & O. Eckstein, Multiple Purpose River Development (1958).

3. These innovations are well illustrated by the contributors in Systems Analysis in Ecology (Kenneth E. F. Watt ed. 1966).

4. *See e.g.*, A. Maass, M. Hufschmidt, R. Dorfman, H. Thomas Jr., S. Marglin, & G. Fair, Design of Water Resource Systems (1966).

5. The nature of competition between domestic and wild animals on a range was investigated by Cook, *Common Use of Summer Range by Sheep and Cattle*, 7 J. Range Mgt. 10-13 (1954); and the economic interpretation of Cook's findings appeared in Hopkin, *Economic Criteria for Determining Optimum Use of Summer Range by Sheep and Cattle*, 7 J. Range Mgt. 170-175 (1954). Hopkin's *Use of Economics in Making Decisions Relating to Range Use*, 48 J. Farm Econ. 1594-603 (1956), prompted Hall, *Product Quality and Public Land Management*, Land Econ. 59-66 (February 1964). *See also* Gregory, *An Economic Approach to Multiple Use*, 1 Forest Sci. 6-13 (1955); and Pearse, *An Economic Approach to the Problem of Range Competition Between Cattle and Game*, 33 E. African Forestry & Agric. J. Special Issue: Proceedings of the Wildlife-Land Use Symposium, Nairobi, 1967, at 84-88 (1968).

II
OPTIMIZING THE INTENSITY OF COMPETITIVE USES

Let us consider a hypothetical parcel of rangeland capable of supporting domestic livestock (henceforth "cattle") or a species of big game animal (henceforth "deer") or various combinations of the two. The area is such that it encloses a range which provides the limiting constraint on the size of identifiable populations of deer and/or cattle.[6] The assumed objective is to maximize the value generated by the range under either or both of the two products.

Use of rangeland by deer and cattle conflict in various ways. The degree of conflict depends on the intensity of use of the range by each.[7] While the two typically have different preference patterns for forage, they will utilize the same vegetation at high intensities of use. They also have different requirements with respect to continuity of habitat, cover, topographical features, and the works of man.

Considering first the range in its natural state, it will have an average long-run capacity to support a population of deer of a particular size in the absence of any competition from cattle. In Figure 1, this population is depicted by the distance OB on the horizontal axis. Conversely, in the absence of any competition from deer, the maximum population of cattle that could be continuously supported is represented by the distance OA on the vertical axis.

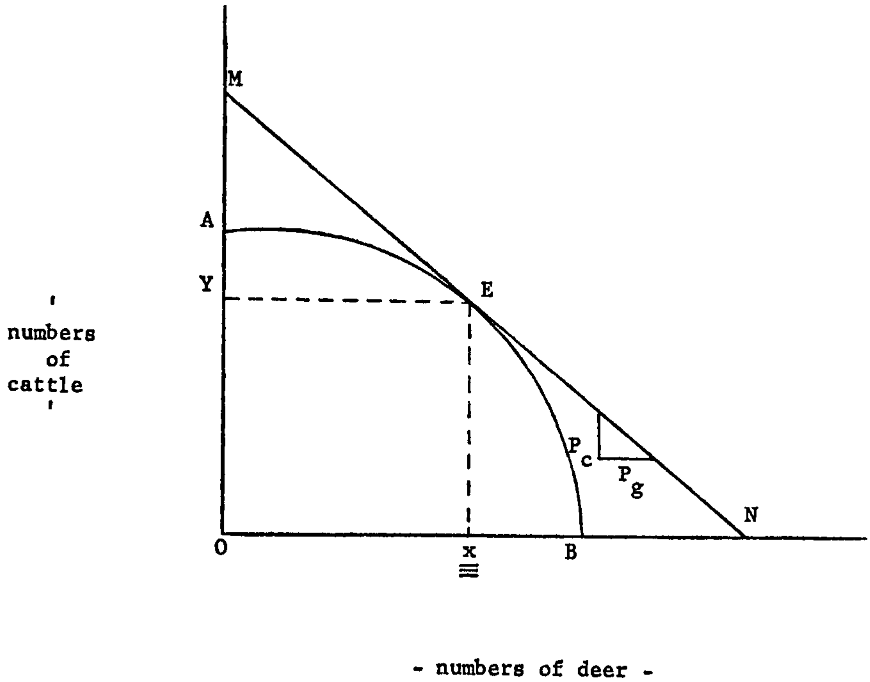
Between these two extremes, various combinations of cattle and deer can be supported. Each combination is depicted by a point in the quadrant. Joining all the points which represent combinations that will fully utilize the capacity of the range will yield a curve in the form AB.[8] This boundary of attainable combinations is the "pro-

6. But the range under consideration need not encompass the entire areas used by the two species. A common example is a winter range for game. While the game depends on the range only for a few critical winter months, its capacity is the major constraint on the wild populations, which often have surplus range for the rest of the year in adjoining (often high-elevation) areas. Similarly, cattle might use the range only for a few summer months, depending upon the regime of the farm enterprise.

7. There have been many scientific studies on the inter-relationships between wild and domestic animals. Particularly relevant examples include Julander, *Deer and Cattle Range Relations in Utah,* 1 Forest Sci. 130-139 (1955); Dasmann, *Deer-Livestock Forage Studies on the Interstate Winter Deer Range in California,* 2 J. Range Mgt. 206-212 (1949); Morris, *Elk and Livestock Competition,* 9 J. Range Mgt. 11-14 (1956); Pickford & Reid, *Competition of Elk and Domestic Livestock for Summer Range Forage,* 7 J. Wildlife Mgt. 328-38 (1954).

8. The author is aware of the considerable technical difficulties in identifying the points on this curve in any real situation. Cyclical fluctuations in wildlife populations change the relationship between population size and range capability over time. Weather conditions change the capacity of the range from year to year and affect different grazing species in different ways. Many ranges are in a state of long-run seral succession, and so on.

Figure 1



The optimum combination of cattle and deer on a parcel of rangeland.

duction possibilities" curve (or transformation curve) of economic theory. Several features of the curve should be noted:

1. Its curvature reflects the degree of competition between the two populations. If they were perfectly competitive, in the sense that they had precisely the same requirements, OA would take the form of a straight line. This would indicate that more of one could be carried at the cost of less of the other in constant proportion (such would be the case, for example, if the two populations were very similar species of cattle). At the other extreme, if they were in no way competitive, the curve would take the form of a right angle with projections to the axes.[9]
2. Any point inside the curve represents a possible combination, but one which will not fully utilize the range.
3. Any improvements to the range will shift the curve, but probably not symmetrically. A change that increases the carrying capacity

9. Near the intercepts, the curve is drawn almost at right angles to the axes, suggesting that at low levels of use by one species that species can be increased at small sacrifice in terms of the other. Several investigators suggest that a *little* cattle grazing will sometimes improve the range for deer, and the converse is also possible. This would cause the curve to curl inward toward the intercepts. Moreover beneficial interactions may occur at other intensities of use, causing irregularities in the curve.

for cattle will increase the distance OA, but this might increase or decrease its ability to support deer. On the other hand, any deterioration of the range will shift the curve inward toward the origin.

The technical relationships underlying the production-possibilities curve provide the necessary information relating to the potentialities of the resource base, but they do not offer a criterion for choosing the best combination. For this purpose we need additional information relating to the value of the two outputs. Assume that the value of both a head of cattle and of deer is known (we return to the problem of evaluation below), and that there are no costs involved in producing either, other than providing range capacity.[10] We can then depict the relative value of deer and cattle in Figure 1 by the slope of an exchange line. The base P_g, of the small triangle, represents the number of deer that is equal in value to a quantity of cattle measured by P_c. The slope of the hypotenuse and its projection—the line MN—indicates the rate of exchange (more precisely the social marginal rate of substitution) between cattle and deer.[11]

We now adjust the vertical position of the exchange line to discover the point at which the production-possibilities curve is parallel to it—the point of tangency E. This is the point on the production-possibilities curve that represents the optimum combination—OY cattle and OX deer—since no other point will yield so high a total value. To the left of E, the production-possibilities curve has a more gradual slope than the exchange line, which means that additional increments of deer are worth more than the associated sacrifice in cattle. To the right of E, total value can be increased by sacrificing game for cattle. Thus, on the logic that more of one product should be produced as long as it is worth more than the value sacrificed in terms of the other product, the best use of the resource is represented by the point at which the trade-off in physical possibilities is just equal to the trade-off in value between the two products. It is therefore impossible to increase the value of total output by any shift away from the point at which the two curves are parallel—at E.

III

SOME EXTENSIONS OF THE THEORETICAL SOLUTION

Because the slope of the exchange line reflects the relative value

10. If there are non-range costs involved, the term "value," where it is used below, should be changed to read "value net of non-range costs." This point seems to have been neglected by Hall, Hopkin and Gregory who refer simply to product prices, *supra* note 5.

11. The exchange line is straight providing only that the quantities of the two products that this range can produce are insufficient to affect their relative values.

of the two products, its intercepts indicate the value of the combined output in terms of the equivalent value of each product separately. Thus the optimum combination of OY cattle and OX deer is equal to the value of AM cattle (or of BN deer), because this is the excess over the maximum quantity (OA) of cattle that could be produced alone (or the maximum quantity, OB, of deer).

If the potentialities for multiple use involved three products, we would require another axis, at right angles to the other two in Figure 1. The production-possibilities curve would become a three-dimensional curved surface, and the exchange line a sloping plane. Again the point of tangency would depict the optimum combination of outputs. For four or more products the expositor must have recourse to simultaneous equations.[12]

This presentation also permits an illustration of situations in which multiple use is possible but not advantageous. The technical possibility of producing two products is indicated by any production-possibilities curve that extends outward from both axes. But the slope of this relationship might not be equal to that of the exchange line at any point within the quadrant. The curves will touch at one of the axes (at whichever end of the production-possibilities curve that has a slope nearest that of the exchange line), indicating that the highest use of the resource is the production of the product measured on that axis alone. To take an extreme example, if the value of deer above was zero, the exchange line would be horizontal, and the optimum output would be OA cattle.

IV

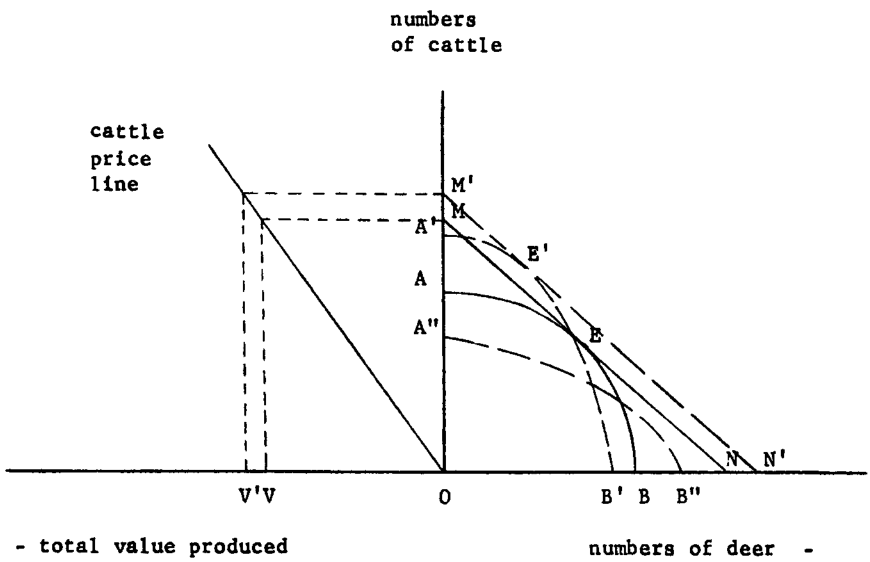
INVESTMENT IN RESOURCE IMPROVEMENT

We have hitherto discussed technical production possibilities assuming that the resource base is in a fixed state of development, namely in its unimproved natural condition. Various kinds of investment in the range (drift-fencing, vegetation control, fertilization, etc.) might be undertaken to improve its capabilities, and any such improvement will result in a new production-possibilities curve. An investment in resource improvement is justified whenever its cost is less than the increase in value of the combined products produced.

In the right hand quadrant of Figure 2 the earlier production-possibilities curve AB and exchange line MN are reproduced. The value of the optimum combination of products is converted to dol-

12. For an exposition of the mathematical counterpart of this geometric presentation, see Gregory, *supra* note 5.

Figure 2



Investment-induced change in production possibilities
and the effect on maximum revenue attainable.

lars in the left hand quadrant with the aid of a "cattle price line," the slope of which reflects the value of cattle. This line relates any quantity of cattle (or combinations of deer and cattle measured in cattle-equivalents) on the vertical axis with its dollar value on the horizontal axis. The optimum combination of cattle and game identified at point E is equivalent in value to OM cattle which is shown in the left hand quadrant to be equal to OV dollars (the conversion could alternatively be made, of course, from the deer-equivalents measured on the horizontal axis).

Now consider an investment that will improve the range for cattle but reduce its quality for deer. This would yield a new production-possibilities curve of the form A′B′. The curve is now tangent to the exchange line M′N′ at a point further away from the origin. This indicates that the total value of output is increased even though the quantity of deer produced at the new optimum combination is reduced (i.e. E′ is to the left of E). The increase in total value produced is equivalent to MM′ cattle, which is VV′ dollars. This gain, and information relating to the cost of the change, provide the data for a benefit-cost evaluation of the investment in range improvement. The investment is justified if its cost is less than VV'.[13]

Not all changes that increase the resource's capacity to produce one product will increase the value of the total output (let alone pass the test of economic feasibility). An improvement to increase the capacity for deer might produce a production-possibilities curve such as A''B''. Although more deer can be produced with this change, the maximum value of total output is below that which can be attained in the original situation. The reduction in maximum potential output is indicated by the tangency of the new curve with a lower exchange line (not drawn in the diagram), the projection of which would indicate a value for the combined product of less than OV. It should be noted that if deer were valued more highly, the exchange line would be steeper and this improvement would then yield greater values.

Various other results from improvements can be illustrated, such as an increase in carrying capacity for both products resulting in an outward shift in the frontier of attainable combinations over the whole range, and a reduction in competition between the two outputs which increases the curvature of the frontier. These results can be expressed in terms of their total economic effect in the left hand quadrant. This in turn permits an evaluation of the efficiency of alternative forms of investment in resource improvement.[14]

V

DATA REQUIREMENTS

Application of the above analysis to real situations of competitive demands on a resource raises formidable problems for data collection. Nevertheless, the theoretical solution serves the useful purpose of concentrating attention on the kinds of data that are necessary for dealing with these problems.

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13. The implications for evaluation of the time-pattern of costs and benefits will not be explored here. If the costs and resulting benefits are not incurred in the same immediate period, the appropriate comparison is between the discounted present worth of each.

14. Gregory, *supra* note 5, suggests that successive levels of management costs would produce concentric contours of production-possibilities. From this he develops an expansion path of optimum output combinations (similar to that in traditional production theory) which is then translated into total cost and revenue curves to determine the level of management for maximum profit. In view of the indivisibility of most resource management activities and their varying effects on the different products involved, it seems unlikely that production-possibilities curves will be symmetrical and hence the expansion path smooth. This approach is probably less appropriate for this problem than for the traditional production problem of the firm facing opportunities to adjust inputs or outputs in a continuous way.

The solution obviously involves marginal analysis. The determination of the optimum combination of outputs depends not on the total potential quantity or value of each product that can be produced, but on the implications of having a little more of one at the expense of another. It is a confrontation of the trade-off in physical quantities at the margin with their relative values on the other that enables the analyst to prescribe the appropriate direction of adjustment.

The data required consist of the purely technical relationships which lie behind the production-possibilities curve, and the economic information which lies behind the exchange line. Much biological research appears to have been done on the food requirements of different animal species. However, this research is of limited usefulness for the purposes of the present problem because it concentrates on forage preferences and protein intake rather than on the nature and degree of inter-species competition at different intensities of use of the range. Determination of the production-possibilities relationship described above for any particular type of range requires experimental control of the species mix on specific areas of land to determine the various combinations that will fully utilize its carrying capacity, allowing each species to adjust its forage intake and behaviour in the face of competition.

The economic data required consist of the value of each of the products. The two products in the example chosen above yield benefits in different forms. Competitive market prices are typically available to provide a guide to the value of cattle.[15] The evaluation of deer is a much more complex problem. It is not the game *per se* that is valued by consumers, but rather the recreation that it provides for hunters. The relationship between the available game and the quantity and quality of recreation it affords is largely an unexplored area of enquiry.

In attempting to develop a theoretical approach to the evaluation of a recreational resource such as deer, we should first recognize two quite separate issues. One issue is the evaluation of a unit of non-marketed recreation, and the other issue is the relationship between the physical availability of a recreational resource and the amount of recreation it generates. The evaluation of free outdoor recreation is discussed further below. In order to proceed with an examination of the relationship between recreation and the capacity of recrea-

15. But any non-range costs involved in rearing and marketing must be subtracted to yield the measure of value required for this analysis. *Supra* note 10. In some cases, subsidies and market imperfections may prevent the real value of the product from being reflected in its price, which must therefore be corrected for these influences.

tional resources, let us simply assume that we can ascribe reliable values to units of recreational experience, which in the present example are measured in hunter-days (hereinafter "hunts").[16]

VI
RECREATIONAL BENEFITS AND THE CAPACITY OF RECREATIONAL RESOURCES

An increment of deer population can increase the value of recreation produced in either or both of two ways. First, the game can accommodate more hunters and if the quality of hunting remains the same, the total value of hunting is raised in the same proportion as the increase in the number of hunts. Secondly, if the number of deer is increased but the number of hunters remains the same, the quality of hunting (and hence the value of a hunt) is raised. Both effects might be felt, in which case the increase in hunting activity would partly offset the rise in hunting quality.

Let us characterize hunting quality in terms of hunting success. There are many possible definitions of hunting success. Indeed, there are many factors that can contribute to a hunter's evaluation of the "success" of his hunt. But here, we are interested in the implications of different quantities of deer, and the most relevant measure of hunting success (S) is the number of animals killed (K) expressed as a ratio of the number of hunts (N). We can expect, other things remaining constant, that the index of hunting success will be directly related to the quantity of game available (G), and inversely related to the number of hunts. In summary,

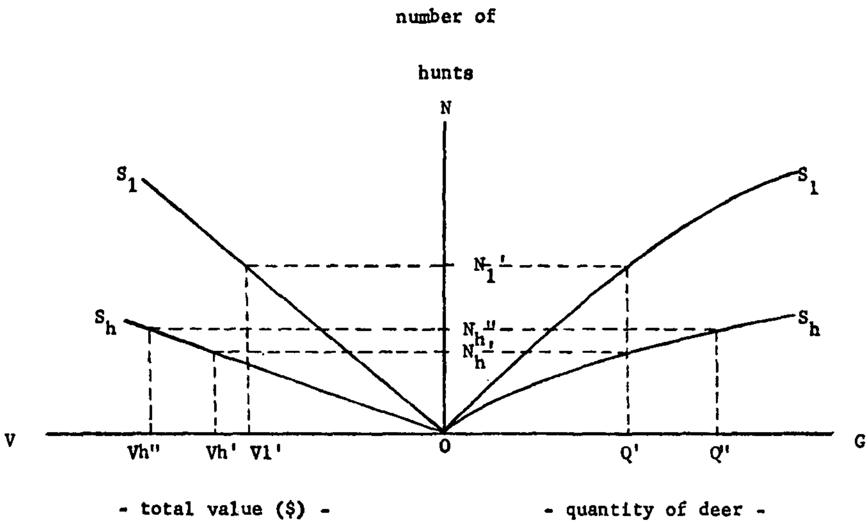
$$S = \frac{K}{N}$$

$$= f\left(G, \frac{1}{N}\right)$$

In the right quadrant of Figure 3 the curve S_h represents a "high" level of hunting success. It traces the relationship between the quantity of deer and the number of hunters that can be accommodated at that level of success. Curve S_l traces the same relationship for a "low" index of success. S_l is higher at all points than S_h, because for any quantity of deer, more hunters can be accommodated at a lower level of success. Of course, in reality, there are more than two symmetrical success curves, each relating to a higher level of success than

16. There may, of course, be benefits from the existence of game other than the recreation generated in the form of hunting; this sole benefit is assumed here for simplicity.

Figure 3



Relationship between quantity of deer, numbers of hunters and total value of game resources at alternative levels of hunting success.

the one above it. The shape of these curves in Figure 3 is based on a guess as to their real form.

In the left quadrant the number of hunts is related to the total value generated by the game resource. Consistent with the assumption that hunting quality is a function of hunting success, the value of a hunt is assumed to depend on hunting success. Thus hunts with a certain level of hunting success are worth a specific amount; and the more hunts, the greater the total value generated in constant proportion. The straight line S_h in this way shows the relationship between total value and number of hunts for our "high" level of success. Since "low" success means a lower value per hunt, S_l lies above S_h so that total value increases at a slower rate relative to the number of hunts.

According to Figure 3, a given number of deer (Q') could accommodate N_h' hunts at the "high" level of success, and these would be worth in total V_h'. If, on the other hand, a "low level of success" was maintained, the same amount of game would permit N_l' hunts. But these low-quality hunts are worth sufficiently less so that their lower individual value offsets their larger number, and their total value V_l' is less than V_h'. Maintenance of the higher level of success therefore, makes more valuable use of the game in this case. This result, of course, depends upon the shape of the curves.

We can now examine the effect on deer values of a change in the quantity of deer from Q′ to Q″. At the same "high" level of success the number of hunts can increase to N_h'' and the total value will rise from V_h' to V_h''. This is the value of an increment of deer which, with the value of cattle, provides the data for establishing the exchange line for the two products.[17]

It should be noted that if the relationships are similar to those drawn in Figure 3, we experience diminishing returns from game. As successive equal increments are added, the associated increases in both hunts and value gets smaller.[18]

Again, we are dealing with technical relationships on the one hand and economic relationships on the other. The relation between game and hunting success is a technical one, and can be determined by careful statistical observations and controlled experiments. The curve for a particular level of hunting success might be shifted upward by measures designed to make the game more accessible or obtain a better distribution of hunting activity.

The left quadrant in Figure 3 involves a simple economic relationship between the number of hunts (N) sold at a specified value per hunt (v) and total value (V), where

$$V = v(N).$$

The value of a hunt therefore becomes the critical economic variable, and deserves further analysis.

VII
EVALUATION OF RECREATION

Sometimes hunting opportunities are purchased on a normal market basis, and the prices paid for these opportunities indicate their value. This analytically simple case is unfortunately rare in North America; the usual situation being one of free access to any hunting area within a given public jurisdiction on payment of a nominal license fee. When hunting is not marketed, the nature of the benefits accruing to the people of the jurisdiction in whose interests the resource is managed depends upon whether the users are part of this same political group. Insofar as the users are not members of the population in whose interests the resources are managed,

17. Depending on the shape of the curves, an increase in the quantity of game might change the level of success which maximizes value. With a change in game, therefore, a new analysis would be necessary to determine the value-maximizing level of hunting success.

18. Hopkin, *supra* note 5, attempts to deal with quality differences by changing the relative value of the two products (and hence the slope of the exchange line) for each production combination. This enables a neat general mathematical solution, but is likely to prove operationally cumbersome.

the benefits take the form of any direct or indirect enhancement of incomes enjoyed by the resource-owning group as a result of the recreational activity of outsiders. Measurement of this benefit involves, in large part, estimating the purchases of outsiders from the resource-owning group, and subtracting the costs the latter incur in supplying the visitors with the goods and services they buy.[19] The net benefits typically take the form of private profits to entrepreneurs serving the visiting recreationists, government revenues from license sales and taxes, and economic rents.

When the recreationists are members of the community for whom the resources are managed, there is an additional benefit to be considered, namely the unpaid-for satisfaction which accrues to the consumer as "consumer surplus." This is the amount that consumers would be prepared to pay for something in excess of what they do pay, rather than go without it.[20]

The measurement of consumer surplus has attracted a good deal of attention from economists recently, especially in connection with outdoor recreation.[21] This is not the place to review or analyze the different methods of evaluation that are being developed. But it is probably not inaccurate to say that the increasing sophistication in techniques of evaluating non-priced resources already permits estimates of value that are as precise as those used regularly in other kinds of investment decisions.

We have hitherto ignored all benefits of game that accrue to nonhunters. First, there are the less consumptive users of the resource—photographers and tourists—whose benefits involve an evaluation problem similar to those of hunters, though the "product" they consume differs. Secondly, the wild resources may have scientific value which is not reflected in any form of observable human behaviour.[22] Finally, individuals may value wild resources even though they never seek them out, but merely derive satisfaction from the knowledge that they are there. This explains the real concern of nature

19. *See* Pearse, *An Economic Evaluation of Non-Resident Hunting and Guiding in the East Kootenay,* 16 Can. J. of Agric. Econ. 100-11 (1968).

20. At least, this is one definition of consumer surplus. *See* J. R. Hicks, A Revision of Demand Theory (1956).

21. *See, e.g.,* M. Clawson & J. Knetsch, Economics of Outdoor Recreation (1966); Crutchfield, *Valuation of Fishery Resources,* 38 Land Econ. 145-54 (1962); Davis, *The Value of Big Game Hunting in a Private Forest,* Transactions of the 29th North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Washington, D.C. 393-403 (1964); Pearse, *A New Approach to the Evaluation of Non-Priced Recreational Resources,* 44 Land Econ. 87-99 (1968); and Outdoor Recreation Resources Review Commission, Economics Studies of Outdoor Recreation, Report No. 24 (1962).

22. Krutilla, *Some Environmental Effects of Economic Development,* Daedalus 1058-70 (Fall, 1967).

groups about the despoliation of natural phenomena that they have never seen nor are likely to see. A related kind of value has been termed "option value." This term refers to the willingness of some people to pay something to retain the option of enjoying some activity even though they might not foresee actually doing so.[23] These latter values are exceedingly difficult to measure. They become important when the resources under consideration are unique, and where decisions affecting them may be irreversible.

VIII
CONCLUDING SUMMARY

This article has addressed the problem of simultaneous and conflicting uses of a natural resource. The assumed objective has been one of maximizing the contribution of the resource to the welfare of the social group in whose interest it is managed.

The highest value is found to be derived by a combination of uses specified by the confrontation of a set of purely technical relationships on the one hand with economic relationships on the other. The most valuable combination of cattle and deer is arrived at by sacrificing deer for cattle as long as the value lost in deer is exceeded by the corresponding marginal value gained in cattle and vice versa.

The particular geometric solution of the problem presented here also enables a demonstration of the relationships underlying an examination of the efficiency of investments in resource improvement by illustrating the relevance of changes in the value of combined output to benefit-cost criteria.

There are many difficult problems in determining both the technical and economic relationships required for the application of this theory. But while few studies have been made to establish the technically-possible combinations of different species on a range, the problems they raise do not appear more difficult than those encountered in more customary forage studies.

The most formidable economic problem lies in establishing the value of resources provided free to users. In these cases the market is prevented from supplying the usual indicators of consumer evaluations, and the unpaid-for benefits must be estimated from indirect evidence. Where unique phenomena of nature are being considered, additional and more difficult analytical problems are involved.

One of the purposes of this article has been to demonstrate the kind of information required to fix the socially-optimum combination

23. *See* Kahn, *The Tyranny of Small Decisions: Market Failures, Imperfections, and the Limits of Economics*, 19 Kyklos 23-46 (1966); and Krutilla, *Conservation Reconsidered*, 57 Am. Econ. Rev. 777-86 (1967).

of conflicting uses of a resource. As increasing demands are placed on rural resources, there will be more and more cases in which the most efficient management regime will involve providing for two or more uses at once. There appears, therefore, to be an urgent need to clarify the criteria for establishing optimum combinations of uses. This article has attempted to throw some light on the conceptual problems involved. These problems suggest a wide scope for interesting research bringing together the combined expertise of biologists and economists.