Staff Paper Series

Staff Paper P74-9a September 1974

Multiple Use of Wild Land: A Review of the Policy and the Concept

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PREFACE

Several term papers prepared by graduate students enrolled in Agricultural and Applied Economics 8-264 in the Fall of 1973 were of excellent quality. Because of their value to students of resource economics problems, several of these are being issued in the Staff Paper Series of the Department of Agricultural and Applied Economics.

This paper by Maurice Mandale provides an excellent review of the seminal literature on the multiple use of wild land. It also helps to synthesize the different analytical and policy concepts and provides a better basis for understanding and solving the problems related to the optimum use of any society's wild lands.

K. William Easter
Lee R. Martin

MULTIPLE USE OF WILD LAND. A REVIEW OF THE POLICY AND THE CONCEPT

Maurice Mandale*

INTRODUCTION: MULTIPLE USE AS A POLICY

Multiple use as a policy has a long history in public land management in the United States. Too often, however, it has been invoked as a panacea which it is hoped will automatically solve many of the problems of wild-land management. Too little seems to be understood about the economic and ecological relationships involved in wild-land management to justify use of the concept as a policy tool. This applies particularly to administration of the public domain if only because the relevant agencies should be concerned with a much longer run form of management connected with future welfare of society as a whole. Paradoxically it is public agencies who are frequently under the most severe political pressure to adopt this type of management system in an attempt to counter presently increasing strains on wild-land areas.

In fact the concept has been formally embodied in legislation, referring to forestry policy, in the Multiple Use and Sustained Yield Act of 1960. This Act contains the most frequently quoted definition of what multiple use as a policy should be:

> "Multiple use" means: The management of all the various renewable surface resources of the National

* The author is indebted to Dr. K. William Easter, Dr. Lee R. Martin, Dr. Philip Raup and Dr. Hans Gregersen for valuable comments and suggestions put forward during the writing of this paper.

> Forests so that they are utilized in the combination that will best meet the needs of the American people making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions: that some land will be used for less than all of the resources; and harmonious and coordinated management of the various resources, each with the other, without impairment of the productivity of the land, with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output (US Code 1960).

W. R. Bentley and S. S. Strand (1972) have identified several clearly expressed constraints in this definition. First, productivity is not to be impaired. Second, it builds in some flexibility to cater for changing management needs. Third, efficiency-effectiveness criteria are stressed but not necessarily in dollar or physical output terms. And finally not all possible uses need occur on any given land management unit. The definition adopted by Congress thus took in most of the attributes of what conceptually should be a good multiple-use system, and placed qualifications where appropriate.

In fact this legislation follows a series of largely qualitative appraisals of the multiple-use concept stretching back to 1905. The U.S. Forest Service had been created in 1897 and Gifford Pinchot had been appointed Chief Forester. The incumbent Secretary of Agriculture, James Wilson, sent Pinchot a letter in 1905 in which he outlined his aims for good management of the nation's forests, and this letter had contained a "greatest good for the greatest number" exhortation

(J. Wilson 1905). Thus very early in the game the management of forests from a social standpoint had been given emphasis, and the policy concept grew up largely within the context of forestry management (see R. W. Behan 1967).

S. V. Ciriacy-Wantrup (1938) is usually credited with bringing the policy into more sharp focus on a base of economics and wild-land management. He stressed the usefulness of the concept in a framework of constantly changing economic and social needs, a usefulness which has particular application to such a long-term investment as forestry. He also drew attention to the distinction which should be made between "the administration or management of several uses of wild land by a single agency" and "the use of a single unit (acre) of wild land for several purposes". It is in the latter case that difficulties arise in management, a matter touched on in the next section.

Following Ciriacy-Wantrup's contribution the forestry profession seemed to take its first good look at the multiple-use concept. This may have been a response to the changing pressures being put on areas of woodland in the context of an increasing population, or it may simply have been a realization that so little was understood about the economic and biological relationships inherent in managing a land-based enterprise from which several different products can be produced either jointly or separately. In particular the increasing importance of providing outdoor recreation for an increasingly affluent and mobile population put increasing strain on wild-land resources. S. T. Dana (1943) put some of the forestry profession's doubts into words as "What he (the forester) may not know is how to evaluate the various possible products of a given area fairly and intelligently from the point of view both of the owner and the community, and how to handle it under a coordinated plan of timber management, wildlife management, range management, and recreation management that will result in the optimum production of different values".

This approach of treating multiple use as a specific management objective was given further support by R. E. McArdle (1953), and is essentially an extension of the traditional Forest Service dictum of management outlined by Wilson in 1905. Counter to this policy was the approach of G. A. Pearson (1944) who believed that timber production and good silviculture should be the prime objective in forest management, and that other uses of woodland should be allowed only where expedient and appropriate, and where such uses would not interfere with a growing timber stock.

G. R. Hall (1963) was, however, one of the first to draw attention to the absence of any well-organized body of theory underpinning multiple-use management, although slightly earlier W. A. Starr (1961) had given an outline of what a multiple-use management system should comprise. He included consideration of administrative, inventory and management units, and then went on to outline hindrances to the operation of the concept because of such things as public concern, limited uses of some resources, competition for some products and not others, and evaluation of land parcels. Hall centers his arguments around the myth that multiple-use practices are capable of resolving all conflicting demands, and the reality that forestry decisions "are primarily judgments about the characteristics of goods and services produced .... This means that multiple use becomes a problem of evaluating the costs and benefits from alternative decisions".

It is around this "reality" that this account continues. Three broad sections follow this introduction. First, consideration is given in some detail to the theory underlying multiple use, plus an outline of some of the empirical studies which have been carried out in this field. Second there is a critique of the studies which also includes some suggestions for possible research emphasis in the future. And finally there is a concluding section which attempts to provide some indication of the policy implications of multiple-use management of wild land resources.

MULTIPLE USE AS A CONCEPT

In its simplest form multiple use is merely a variety of joint production. The production function of neo-classical analysis contains the standard variables of land, labor, and capital plus any further arguments the economist deems relevant. In the case of joint production from an enterprise where land is an important input, appropriately more weight must be placed on the fact that this can involve the management of an ecologically sensitive unit of production over time.

The biological and other physical, scientific and technical aspects of production economics have largely dictated that much of the work and progress in this field have been done by agricultural and resource economists. Standard works by E. O. Heady (1952) and E. O. Heady and J. L. Dillon (1961), particularly the latter, emphasize the natural base upon which output and profit maximization criteria are built. The work of agricultural production economists in estimating production functions, however, has increasingly been moving away from an emphasis on the natural resource base as fertilizers, herbicides, irrigation and other input variables have (at least until very recently) relegated land in its more Ricardian sense to a relatively secondary role in the production process.

There remain, however, land-based production systems where management cannot ignore the delicate nature of the resource being used. Agricultural production economists deal primarily with farmland more or less intensively managed and from which the bulk of the national production of food and fiber comes. Range and forest managers are dealing with systems where the emphasis on land as the major input is more prominent. As G. R. Gregory (1972) has observed in the context of forest management, "the forester is manipulating a land-based ecological system to produce a product or combination of products desired by man". It is therefore at the extensive end of the agricultural continuum and in forestry that land as an input takes on particular emphasis as being susceptible to bad management, and this is complicated by consideration of multiple uses.

In the theory of the firm some production processes yield more than one output. The usual examples given, such as wool and mutton from sheep, are the results of a single production process. In the case of forestry an example would be timber for sawlogs or pulpwood. The forestry case is somewhat different from the sheep example since the two outputs are competitors for the raw material, wood. On the other hand, with sheep you have a production process which can produce wool and meat in a fixed proportion and not be competitive. Joint production from an area of wild land can be extended to the production of goods and services which are not necessarily complements. An area of woodland could conceivably produce such different outputs as timber, forage, recreation, wildlife or watershed protection.

The concept of joint production uses the familiar production possibilities curve (product transformation curve) of supply theory (see J. M. Henderson and R. E. Quandt 1971). This curve is the locus of all output combinations of two or more products that can be secured from a given level of inputs, and is derived from the production function. The slope of the production possibilities curve measures the rate of product transformation (RPT), or the rate at which one output must be sacrificed to obtain more of a second output without varying the levels of inputs. Given two outputs, q_1 and q_2, which can be jointly produced from a given level of a single input X, the RPT is defined as the ratio of the marginal productivity of X in the production of q_2 to the marginal productivity of X in the production of q_1. The optimum combination of products is obtained by equating this ratio to the (inverted) ratio of the two product prices, or

$$RPT = p_1/p_2 = MP_{X_2}/MP_{X_1}.$$

This condition obtains where a given relative price line (exchange or isorevenue curve) is tangent to a specified production possibilities curve. Profit maximization in this model requires that the value of MP_{X_i} equals the price, r, of the input X, or

$$r = p_1 MP_{X_1} = p_2 MP_{X_2}$$

in the two-output case.

This model of output and revenue maximization can readily be applied to forestry or other wild-land management. In its least complex form it can be used to find optimum production combinations for timber products as mentioned above. This type of analysis was carried out by J. A. Sinden (1964) in an attempt to determine the rotation length of maximum profitability, the two outputs being pulpwood and sawnwood. This was a strict joint products model where the two products resulted from the same production process and were readily identifiable and measurable in terms of volume and value.

This "multiple products from a single use" helps to emphasize a point which needs to be made, and indeed which was made by Ciriacy-Wantrup in his 1938 article. It will be recalled that of his two definitions of multiple use, the second of these involved a multi-product case where the products could easily conflict with each other in the production process. He states "although several uses of wild land can be administered jointly with advantages in overhead costs, they are not joint products in the economic sense". Allowing for some degree of semanticism here, the point which Ciriacy-Wantrup goes on to make is that the economies realized by utilizing overhead costs more fully are not the decisive factors for joint use of the same unit of land for several products. In fact total social production from the same unit may be smaller from several uses than from a few uses or a single use. The objective in this case should be to develop an "optimum use" concept in which several uses would be permitted if they are socially desirable, but from which a single use as the socially optimal would be perfectly allowable. Thus in the framework of a given set of prevailing economic and social conditions timber production may be dictated as the socially optimum use of a given area of land, and within this "dominant use" philosophy joint production would still take place.

Whilst this kind of economic determinism seems to ignore larger social pressures to which the contemporary analyst would perhaps give more credence, it does serve to point out areas where the basic concept could be abused, or where at least some types of analysis would not be appropriate if a "dominant use" framework were adopted. Going back to the basics, however, Gregory (1955) was the first to formalize multiple use as joint production. In his hypothetical example timber and forage were the two outputs. After deriving a family of production possibility curves and isorevenue curves, a series of tangencies result which, when joined, given the optimal expansion path for the enterprise with a given level of inputs (see Figure 1)

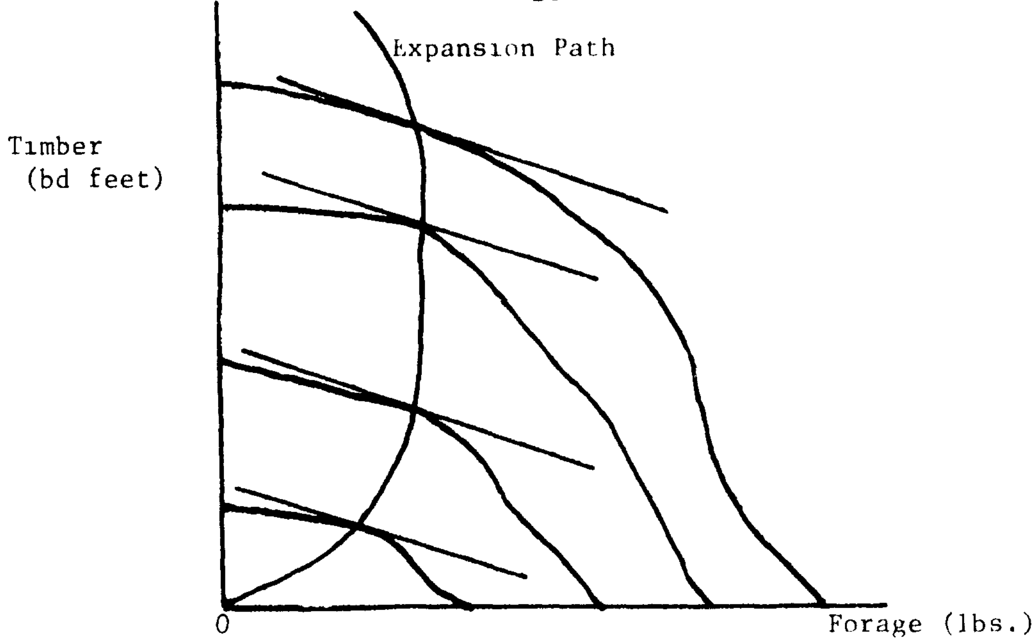

FIGURE 1

Given the nature of Gregory's production possibilities curves and the relative prices of timber and forage, this expansion path begins to curve back towards the timber axis, indicating that at higher levels of total output the optimum mix entails increasing production of timber.

To identify the precise combination of the expansion path the manager will choose, we need to consider the objective of maximizing net revenue to land and management. This assumes that values for timber and forage can readily be assigned, and that costs of inputs are known. In Figure 2 the expansion path in Figure 1 is reproduced in the lower portion, and in the upper portion the assumed function forms of total revenue (TR) and total cost (TC) are sketched. The optimizing combination of timber and forage (that which maximizes returns) is where the difference between TR and TC is greatest, or where MR = MC: and in this example

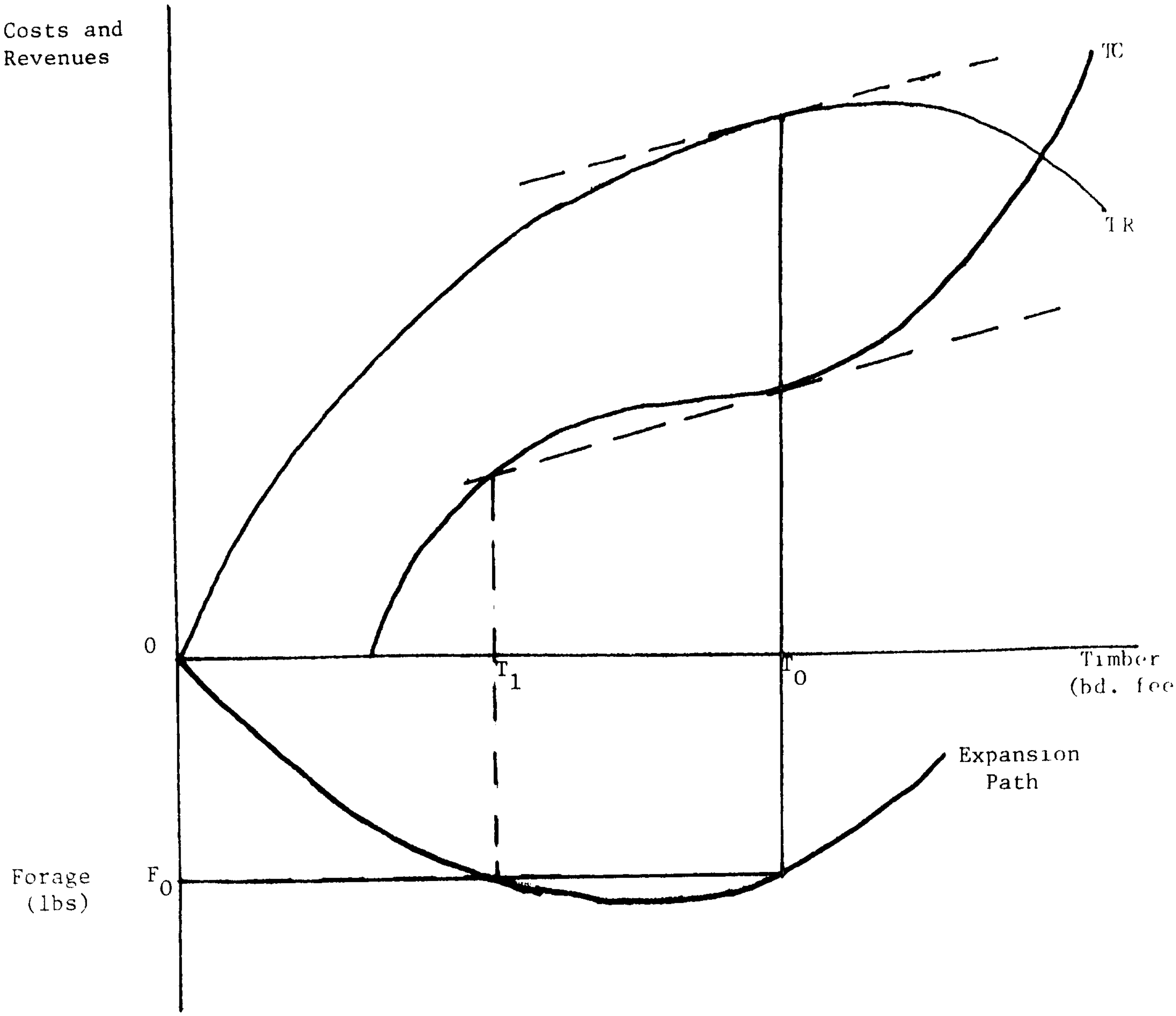

FIGURE 2

this would result in T_0 board feet of timer and F_0 pounds of forage. It should be noted that this output combination is deemed more acceptable than T_1 board feet of timber because of the constraint of maximizing net revenue, which only occurs with an output of T_0 board feet of timber in this model.

Expressed formally, the model can be reduced to a series of simultaneous equations. The production possibilities are shown by the appropriate curves, and can in the first place be expressed by a series of production functions in which the production of (n-1) joint products enters into the production function of the nth product on the assumption that at some stage there is interdependence between different outputs. Thus if Q_t and Q_f are the outputs of timber and forage respectively, and $(x_1, x_2, \ldots, x_n)$ are the variable inputs used in the production of the two outputs we could have

$$Q_t = f(x_1, x_2, \ldots, x_n, Q_f)$$

$$Q_f = g(x_1, x_2, \ldots, x_n, Q_t)$$

as the two production functions. There will be as many production functions as the products being considered, and no entry is made for land as this represents the fixed factor. Both TC and TR functions can be expressed generally as functions of the several products, and from these the MC and MR can be derived and equated to obtain solutions for output levels.

Within this framework it is evident that some joint-use solution is possible. The theory is not so easily observed in real world situations, however, but at this stage it is perhaps sufficient to recognize the applicability and value of production possibilities analysis in this context. As Gregory concludes, this approach requires "no methodology that might be considered new by a production economist."

Gregory went on to consider different shapes which may occur along a single production possibilities curve (Gregory 1972).

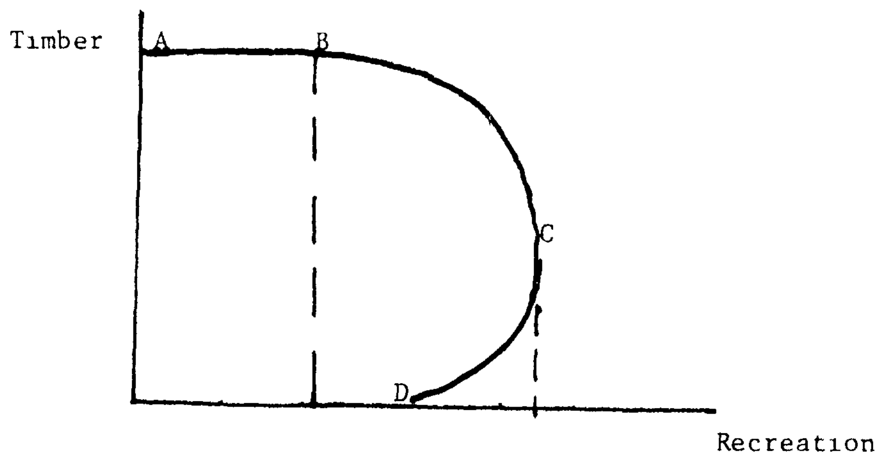

FIGURE 3

In Figure 3 the range A - B on the curve indicates a supplementary relationship between timber and recreation. Person-days of recreation can be supplied out to B without impairing the timber-producing capacity of the woodland. In the range C - D either product can be supplied in greater amounts without impairing the capacity of the land-area to produce the other product, a complementary relationship. In the range B - C the two products are competitive, in which range an increase in the output of one can only be achieved by sacrificing some output of the other.

Although Gregory was the first to formalize this application of joint-product theory, his work actually followed closely empirical work by J. A. Hopkin (1954) which represented the first significant attempt to use production possibilities curve analysis in grazing-resource allocation between sheep and cattle on an area of rangeland.

Hopkin recognized the usefulness of the joint products concept in range management, and used data first presented by C. W. Cook (1954) to demonstrate the derivation of the optimum number of sheep and cattle which could be allowed to graze a unit of rangeland. Cook had taken the first step in identifying the shape of the production possibilities curve, and furthermore provided valuable insight into the biological relationships intrinsic in the analysis. On the basis that the grazing habits of sheep are different from those of cattle, Cook was able to show that both types of livestock should be grazed in combination to maximize returns, rather than one or the other exclusively. Essentially those vegetation species largely ignored as fodder by cattle provide valuable feeding for sheep, and vice versa. Cook also demonstrated that the RPT between cattle and sheep grazing is unlikely to be a constant over its entire range on the premise that, at sub-optimal combinations and conditions of the range, some range units might be more suitable for sheep than cattle as the two animal groups shift around in space and time.

Hopkin goes on to extend Cook's findings using the data presented in Table 1. From these data it is evident that one animal unit of cattle can be added for each .177 animal units of sheep that are removed from the same area of range, without impairing the capacity of the range to support sheep and cattle, up to 422 animal units of cattle and 230 animal units of sheep. Beyond this point the RPT becomes 1.674 These data give a production possibilities curve with a discontinuity at (422, 230). The shortcomings of such a curve are demonstrated in Figure 4. If we assume two different relative prices for cattle and

Table 1
Combinations of sheep and cattle (in animal units) on the same range, and rate of product transformations of cattle for sheep

Cattle	Sheep	RPT
0	306	--
141	281	.177
281	255	.177
422	230	.177
468	153	1.674
514	77	1.674
560	0	1.674

Source: Hopkin (1954)

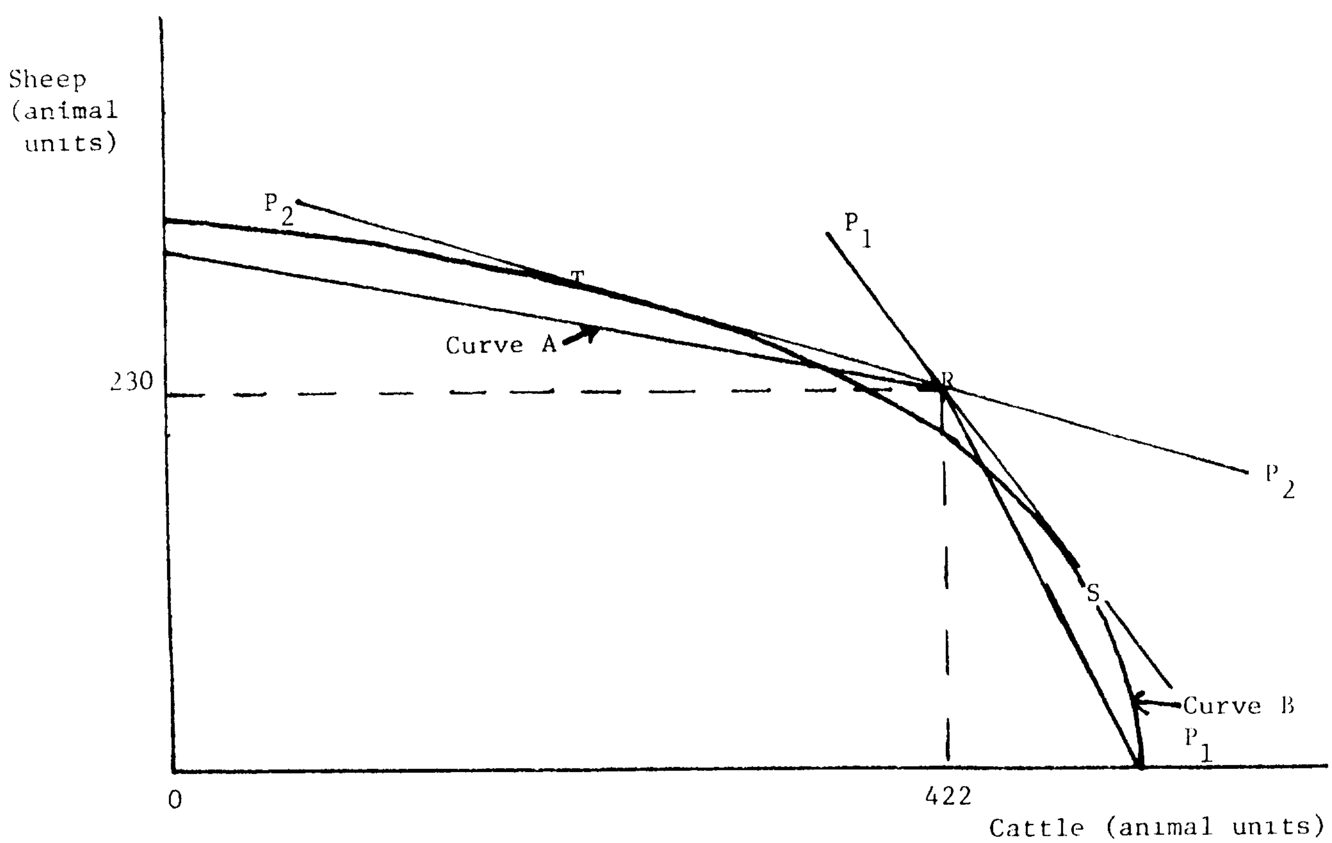

FIGURE 4

sheep, represented by lines P_1P_1 and P_2P_2, the maximizing combinations under each relative price set will be different using a strict curve derived from the data given above (Curve A) than from an "intuitive" curve which Hopkin fits to the data (Curve B). Under both price situations the optimum is at R, for Curve A, but if curve B is assumed to be the production possibilities curve the optimum is at S with P_1P_1 and at T with P_2P_2. The unique solution with a continuous curve is lost if a discontinuity is introduced. Hopkin concludes that "there is nothing in the logic of range management or economics that supports the hypothesis that the (RPT) remains constant at a low rate (.177) up to a certain point and then suddenly increases to 1.674, remaining constant at the new level beyond that point". Thus the rationale for Hopkin's intuitive curve B as a more realistic representation of the production possibilities curve.

Empirical and theoretical work on the application of the production possibilities curve to multiple-use problems has also been done by P. H. Pearse (1969) and G. R. Hall (1964). Pearse uses the approach to estimate the numbers of cattle and deer which could be allowed to graze the same area or rangeland, and the first part of his analysis is essentially the basic approach presented above, based on similar assumptions concerning measurement of costs and values, and concerning technical relationships. He then goes on to evaluate how various kinds of investment in the range (drift-fencing, vegetation control, fertilization etc.) could improve its capabilities.

In the right-hand quadrant of Figure 5 the optimal solution (combination) between cattle and deer is presented within a given prices framework

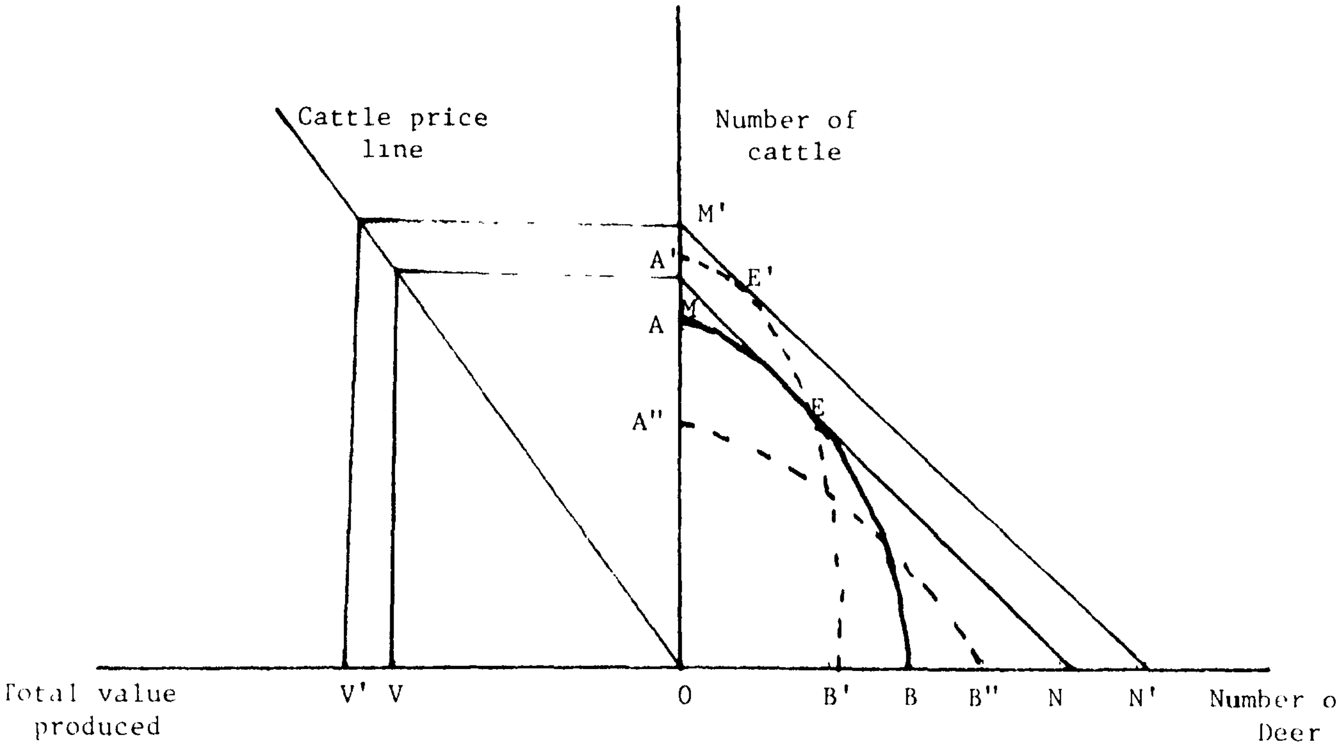

FIGURE 5

(MN) and an assumed production possibilities curve for a given unit of range land (AB). In this example the optimum is at point E. The value of this optimum combination of cattle and deer, measured in dollars per unit of cattle, is presented in the left-hand quadrant by means of a "cattle price line", the slope of which reflects the market value of cattle. Numbers of cattle and deer (measured in cattle-equivalents) are translated into a value V for the relative price line MN. If an investment is then made to improve the range for cattle a new production possibilities curve (A'B') might result, and this line is tangent to a higher isorevenue (price) line (M'N') indicating that the total value produced is greater even though the quantity of deer allowed to graze at the new optimum (E') is less. The total value increase is VV' and Pearse asserts that this gain, along with information relating to the cost of the change, provides the data for a cost-benefit evaluation of investment in range improvement. The investment is justified if the cost is less than VV'. Not all investments are justified on these grounds as it is conceivable to move to a lower isorevenue curve, such as A"B", given that the relative price line of deer and cattle has a different slope than MN or M'N'.

In Pearse's analysis it should be noted that there are some strictly non-quantifiable values, such as the pleasure of deer-hunting, which may not be fully reflected along the value axis. To this end Pearse also attempts to evaluate how some investment or other force which increases the number of deer on the range land influences the value of recreation produced. An increase in value can be by one of two ways. First, the game can accommodate more hunters and thus if the quality of hunting remains the same the total value of hunting is raised by the same proportion as the increase in number of hunts. Second, the number of deer can be increased but the number of hunters remains the same, and the quality, hence the value, of hunting is increased. Thus if hunting quality is measured in terms of the number of deer killed (K) expressed as a ratio of the number of hunts (N), we can expect, ceteris paribus, the index of hunting success (S) will be directly related to the quantity of game available (G) and inversely related to the number of hunts.

$$S = \frac{K}{N} = f(G, \frac{1}{N})$$

Pearse goes on to demonstrate that a "low" level of S gives a lower value of recreation by hunting than a "high" level of S for any quantity of deer (G). Conversely, and still consistent with the assumption that hunting quality (value) is a function of hunting success, certain preferred levels of value can be set for any level of success to give some indication of numbers of deer and hunts concomitant with that level of success. In Figure 6 curve S_{low} in the right-hand quadrant is higher

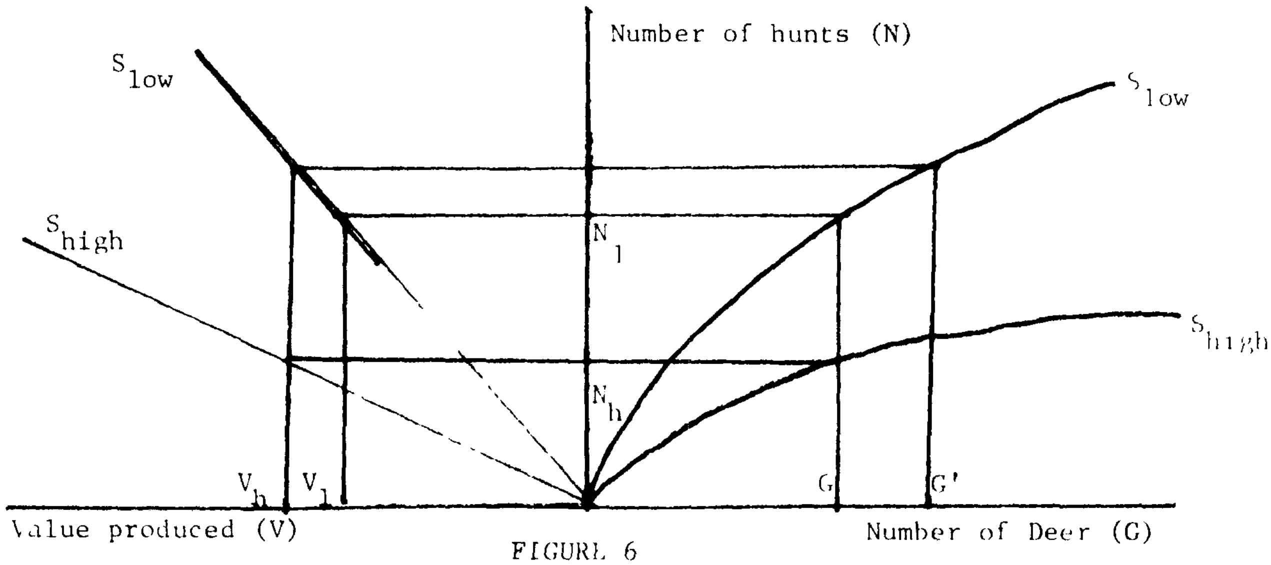

FIGURE 6

at all points than curve S_{high} signifying that for any quantity of deer more hunters can be accommodated at a lower level of success (hence lower level of value). With G deer, N_h hunts could be provided at a higher level of success and with a corresponding value of V_h, which is greater than the value V_l associated with a lower level of success and consequently a higher level of hunts at N_l To give a level of success of V_h corresponding to a low level of success the number of deer on the range would have to be increased to G', given this set of value lines and hunting success lines. The essential relationship, as Pearse concludes, is built around some value V as a function of the number of hunts N and "the value of the hunt therefore becomes the critical economic variable".

Pearse by no means specifies what is included in his V, and this is one of the fundamental weaknesses of all joint-products analyses which involve recreation as one of the outputs. G. R. Hall attempted to rationalize multiple use of public lands in which intangibles were included at an earlier data (Hall 1964). This was in terms of the social returns as opposed to purely economic returns. Hall was in part responding to a further article by Hopkin (1956) which extended his cattle-sheep model outlined above to a cattle-deer framework. The production possibilities curve in this example had supplementary and complementary, as well as competitive ranges, mainly as an expository device to demonstrate the versatility of the function rather than being based on any solid economic or biological relationships. Hall asserted that, whereas Hopkin's analysis of the cattle-sheep problem was unchallengeable, he was in error to apply a similar model to the cattle-deer problem. The same criticism could be levelled at Pearse's later analysis.

In a cattle-deer model numbers of deer and cattle in combination are the managerial optimum, but Hall asserts that the relevant product is not deer but is deer-hunting, and that the characteristics of this product are different at each point on the production possibilities curve. Hunting on a range heavily grazed by cattle, and consequently with a sparse deer population, is very different from hunting on range land lightly grazed by cattle and with a higher deer population. Thus "one may confidently assume that the price ... of the latter experience will be much higher than for the former," presumably because of a better chance of hunting success on range with a relatively higher deer population. Figure 7 as originally portrayed by Hopkin had numbers of deer measured on the vertical axis, and the implication was that the

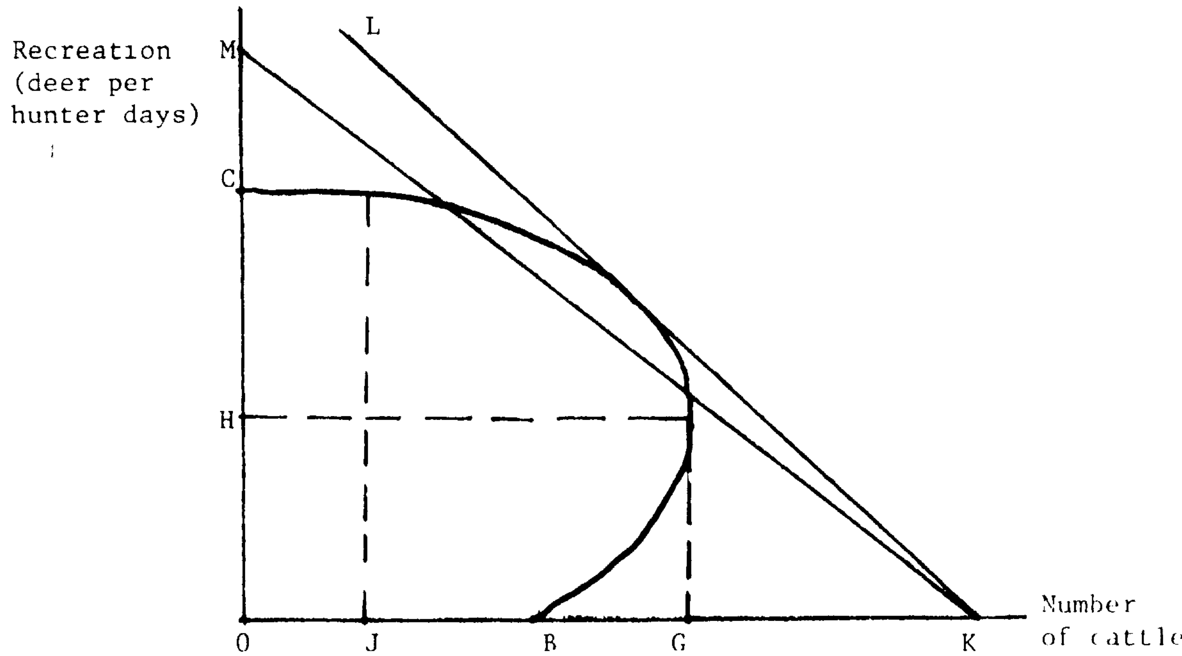

FIGURE 7

cattle population could be extended out to OJ before competition between cattle and deer for grazing produced a declining RPT. Hall argues (as demonstrated here) that if deer per hunter days are measured on the vertical axis, at point C the hunters are enjoying a "wildnerness experience" which any commercial grazing would detract from. So even with OJ cattle, although there are still OC deer, the characteristics of the product offered are different. With a combination of OH deer and OG cattle the type of hunting will be very different at the two positions J and C, and this means there will be a separate demand curve for each different product, and no unique price line can be defined This, Hall maintains, is where those who try to find a unique solution to such problems of range management by use of production possibilities curves will invariably fail, as not only the amounts of products to be jointly produced are in question but also the quality of products.

This assertion in effect requires a reformulation of the production possibilities analysis to treat the interdependence of quantity and quality, as when the product is a variable the equilibrium condition is no longer dictated by an isorevenue line and a transformation curve. In the situation represented in Figure 7, it is assumed that recreation (R) (measured in terms of deer per given number of hunters) is directly competitive with cattle (C) over some range of the transformation curve BC. The price of cattle P_c will presumably be invariant with the quantity of cattle grazed, but the imputed price of deer hunting P_r will vary directly with the number of deer and inversely with the number of cattle. Thus,

$$P_r = f(R/C),$$

and in equilibrium

$$dR/dC = \frac{f(R/C)}{P_c}$$

This states that the optimal position for the entrepreneur is where internal substitutional possibilities between the two products equal the ratio of the prices of the two products with some implicit adjustment for the impact of product mix on prices. A graphical exposition would involve an infinite number of relative price lines, each one dependent on the price relationship between cattle and different recreation products. KL and KM in Figure 7 are two such lines and are relevant only if the intersection or tangency of the relevant budget line represents the price ratios for cattle and the product represented by the point of intersection or tangency.

Hall uses his analysis to argue that public ownership of lands should be aimed at providing higher quality of the managed lands for respective uses, whether these are sole or multiple uses, for both present and future consumers. This argument has the connotation, unavoidable in all discussions of public land ownership, that nonmarket as well as market values are at stake in finding optimum uses or combinations of uses for any given area of wild land.

N. Muhlenberg (1964) has attempted to put more credibility in Gregory's model by subjecting it to a specific empirical test. His premise, and conclusion, is that "to operate Gregory's model successfully it would be necessary to obtain continuous expressions on a series of isocost curves. Unfortunately this becomes almost impossible in view of the complexities of the real world " The solution is to substitute a series of point data to approximate the model. By imputing values represented by these point data and developing costs corresponding to each value by use of appropriate discount or charge rates, Muhlenberg thus investigates cordwood versus deer production at various levels of sustainable growing stock. The study is worthy of note if only because of the explicit notion of error which Muhlenberg assigns to real-world studies which attempt to approximate a theoretical ideal. The dangers of extrapolation, he infers, cannot be ignored, but on the other hand this is a tool which forest and other wildland managers should be able to use to evaluate more fully the alternative products available.

P. F. O'Connell and H. E. Brown (1972) use an empirical study to approximate production functions for alternative uses of forested watersheds, and from here they move towards production possibilities functions. The effects of several different stages of forest clearance, varying from a 33 percent cut to a clearcut, are gauged upon timber production, water yield and forage yield. The production functions thus estimated indicated that clear-cutting was superior to one-third cutting for water yield, but because of detrimental effects of a clearcut on wildlife, environment and other nonmarket products this may not be a feasible solution. The relevant transformation curves show that clear-cutting and one-third cutting each would give optimum combinations of yields between water and timber depending on the relative prices of both products. A similar relationship holds between forage and timber, but if range and timber are considered in combination clearcutting would be the only economically feasible solution. Once again it would appear that nonmarket values, such as the environmental and wildlife variables mentioned above, might alter the solutions derived in this study, a consideration not taken into account by the authors.

A study by A. E. Lucas and J. A. Sinden (1970) tried to measure the institutional effect on a multiple use problem in Australia. Timber and livestock were considered on areas of Crown lands which were leased both for grazing and timber harvest, but where the lessee only received 5 percent royalty of any timber income, the remainder going to the Australian Forestry Commission. Under such conditions the question posed was whether joint production of timber and livestock is preferable to single use. The authors state: "It is obviously a major undertaking to identify and evaluate all combinations (of output) but this is essential to a comprehensive analysis". Consequently such an analysis should include investment in terms of inputs of labor, management and capital to the fixed resource. The study revealed that, under existing conditions of multiple-use management on the leased lands, and comparing the actual royalty payment of 5 percent with a potential 100 percent for timber, on seven out of eight leases multiple use was less profitable than single use for livestock grazing only, even when the lessee received a 100 percent royalty. This leaves open the question of whether the management input was being optimized, and extension of the study revealed that, with an improved level of management, multiple use appeared preferable to timber only, but that clearing after 20 years to grazing as sole use was superior to a mixed management system of timber and grazing. In this, as in most of the other studies, there is passing mention of the values which cannot be readily assigned, and which include intangibles such as amenity, wildlife and recreation. This is a point which is taken up at more length in the ensuing section.

CRITIQUE AND EVALUATION OF THE STUDIES

It is clear from the foregoing review that joint-product analysis is applicable to multiple-use land management. Equally, this type of analysis is not easy to apply in view of the real-world complexities surrounding allocation of wild-land resources. Several conceptual problems remain unresolved, some of which are explicitly admitted to in the literature, others which seem to have been ignored.

Basically, two general approaches could be used in a critical evaluation of the literature. First there is the evaluation of the more explicit shortcomings or weaknesses of the several models and empirical studies outlined in the preceding section, and second there is the body of possible strengthening devices and extensions which could be incorporated in any future models. Although the dividing line between these two approaches is frequently indistinct, the dichotomy is adopted here in an attempt to preserve some distinction between a criticism of the studies themselves and an evaluation of the theoretical and empirical extensions which could add to multiple-use analyses. Under the former heading are three main topics for discussion, namely the problem of data collection, the problem of nonmarket valuation, and the empirical nature of the production possibilities curve. Under the latter heading the determination of some nonmarket values is discussed in more detail, and the objective function for multiple-use management is examined.

DATA COLLECTION

The problems surrounding data collection are more physical than theoretical in nature, and, by implication, perhaps more imagined than real. Although there is little doubt that some of the nonmarket valuations do pose problems, several of the studies already discussed demonstrate that some proxy values can be obtained This is particularly exemplified in the Muhlenberg study, the O'Connell and Brown studies, and in the study by Lucas and Sinden. These three approaches are specific empirical approaches and tend to discount somewhat the claim by Pearse (1969) that "Application of the ... analysis to real situations of competitive demands on a resource raises formidable problems for data collection." He goes on to elaborate that "the data required consist of the purely technical relationships behind the production-possibilities curve, and the economic information which lies behind the exchange line." It must be admitted that Pearse, and several other researchers, is dealing with recreation as one of the outputs of multiple-use management. This is perhaps more strictly a problem of "how to quantify" and is thus more conceptual in nature than the physical problems of data collection.

This is not to discount or underestimate the physical problems involved in data collection. This is more a problem assignable to a policy-making framework, however, and the earlier, and rather bland, statements of the potential of multiple use as a management technique by Dana, McArdle and Pearson really do little to advance the analytical framework necessary for decision-making. Apart from the problem of valuing and pricing recreation, the data collection problem would appear to decline in importance as more resources are devoted to technical studies.

NONMARKET VALUATION

The nomarket valuation problem looms large in all of the studies which involve outputs usually thought of as provided free by some public agency or which are intangible and difficult to monitor. Indeed this problem is part of a whole new group of analyses and literature, and as such is accorded more detail below. Here it is perhaps apposite to review how the literature discussed so far is deficient in this respect. Evidently, wherever recreation, amenity, or "the wildnerness experience" crops up as one of the joint outputs, the analyst faces an apparently insuperable obstacle which is usually avoided by some assumption adopted as a theoretical nicety. Both Hopkin and Pearse, in their discussions of deer-hunting as an output, err in valuing recreation at some market value for deer meat. Hall quite rightly discounts this method of valuation on the grounds that the market value of deer meat would tend to underestimate the true value of deer-hunting as it ignores the nature of the true output of the area of wild land in question, which should be recreation, and further it ignores the value of recreation enjoyed by different hunters or the quality of the output. Hall's quite eloquent statement stumbles slightly, however, when he is faced with valuing his "quality" component and reverts to the theoretically acceptable, but by no means practically workable, technique of devising an infinite number of price lines to take account of an infinite number of recreationists in the market, over time, for units of recreation. Each recreationist (hunter) presumably places a different value on his hunting experience, and in this respect aggregation problems become important.

Implicit in this quandary of quality of product in deer hunting, is what hunter motivation is. Each different motivation, whether to provide meat, to provide sport, to provide the "thrill of the chase" or to provide some combination of these and other motivations, will generate a different demand curve. To complicate matters different types of deer-hunting may be supplied and once again aggregation problems become somewhat intractable. Some mixture of Pareto-relevance and non-Pareto-relevancy in the same aggregate demand curve is untenable. Pareto-relevancy in a strict sense lends itself to product valuation through a uniquely defined aggregate demand curve. Non-Pareto-relevancy would miss a true determination of price and output by underestimating, or wrongly estimating, the true marginal revenue due to the presence of such non-measurable arguments as quality of product.

These problems are intractable and are frequently recognized as such by the various writers. They do demonstrate the difficulty of underpinning what is a valuable management tool in a conceptual sense by more solid and practical criteria.

PRODUCTION POSSIBILITIES CURVE

The studies have revealed the conceptual attraction of the joint-products approach to multiple use analysis. There is some consideration of the nature of the production possibilities curve, but this is largely intuitive, and the verbal treatment is often no more than peremptory. Hopkin's original study of the cattle and sheep grazing did attempt to define an intuitively plausible shape for the function. Gregory also has posited intuitive competitive, complementary and supplementary ranges along the curve, and more recently the empirical work by Muhlenberg, and by O'Connell and Brown have attempted to derive estimates for the functions.

It is reasonable to argue that, under certain multiple-use potentialities, there will be some ranges of the curve which will be complementary or supplementary in nature. This is particularly relevant towards the axes. An area of wild land will be able to support some forage without undue deleterious effects on the timber harvest after a certain stage of timber growth, and it is generally conceded that well-supervised hunting is a valuable means of conservation in areas of woodland, particularly when young growth is involved. Little empirical work has been done to verify these suspicions, however, and this is perhaps indicative of a larger reason for the acute data shortage. Biological, ecological and economic relationships must all be identified and all require considerable research effort.

Muhlenberg's comment, referred to above, about the complexities of the real world prompts him to discount the pure concept, "whilst of great intellectual merit", as of little practical importance until the science of forestry is considerably more advanced. The transformation data he plots in deer per acre and cordwood per acre space is, by observation, convex to the origin (Muhlenberg 1964). Similar relationships of a decreasing, but still competitive, RPT are revealed in the O'Connell and Brown study (1972). It thus appears as though, in some cases, the assumption of an increasing RPT in the competitive range of the production possibilities curve is too strong for practical purposes, and that a production possibilities curve convex to the origin is perfectly admissible.

Still confining the discussion to the nature of the production possibilities curve, it seems that much work remains to be done in comparing RPT's between different products. This was mentioned in the previous paragraph, but, almost without exception, attempts at joint-products solutions involving recreation and some other product have tended to focus on the more "active" recreation pursuits such as hunting. Whereas this approach has particular relevance in the vexed cattle-deer allocation problem on range land, and much of the work to date seems to have been around this problem, such work does little to impart information on how more "passive" recreation pursuits, such as picnicking or walking, would enter into the production possibilities function. Hall (1964) is the only writer to dwell upon "quality" of product and even here the analysis is largely confined to posing the question as to how such quality can be measured.

The work to date also considers trade-offs along the production possibilities curve between such cases as cattle, sheep or deer grazing, or between different types of timber products. No attempts have been made to measure how different types of recreation may be in conflict. It is fairly self-evident that, within a given area, hunting may conflict with walking or picnicking, snowmobilers may annoy cross-country skiers. These comprise as much strict joint-products analyses as the cases mentioned above. The problems of valuation, both in monetary and output terms, are admittedly bigger in such work, but the intuition which has been widely employed in the timber or forage models could also be applied in recreation models.

There is a larger issue at stake in this respect, however, and this involves not so much a focus on the resource itself as on the users of the resource. This results from possibly a too restricted framework of analysis, particularly for policy making. Different groups of users are involved and there is no bargaining process, or no place in which tradeoffs including negotiations to reconcile uses, can be transacted. Without going into detail it should be mentioned that joint-product analysis is perhaps unlikely to yield a useful guide here since substantial policy problems, involving externalities such as those created by snowmobiles,are at stake.

In addition, however, there is a case to be made for sometimes setting aside the multiple-use concept in favor of a "linked" land-use managerial system. This presupposes the area being considered is sufficiently large to encompass an explicit separation of uses, and doubts could be raised as to whether this comprises a case of multiple use *per se*. The common factor of management for a greater social net gain is still implicit in this approach. The possibility of intra-areal transfers of land from one use to another over different time-periods may build more flexibility into the management process to cater for changes in tastes.

NON-MARKET VALUATION -- SOME EXTENSIONS

So far the discussion has been around the shortcomings of the various models, although unavoidably this spills over into the larger field of general evaluation. It also seems pertinent to discuss how research should direct itself in the future to strengthen the basic theoretical framework of multiple-use theory as joint-products analysis. As mentioned above, two main fields of discussion can be treated. The first of these deals with the larger field of nonmarket valuation of some of the outputs in joint-products analysis, the second with the objective function of multiple-use management.

Nonmarket valuation is a perennially intractable problem, especially in the case of recreation. At best only a proxy for the values of recreation services can be obtained. The literature to date has approached the problem from both "cost" and "toll" or "entrance fee" angles, although until fairly recently the predominant approach was from the cost angle. The first major statement of this approach was put forward by H. Hotelling (1947). He asserted that the costs a person was willing to incur in travelling to a place of recreation would give a fair approximation of the price that the individual places on the recreational experience at the final destination. This conception of the "willingness-to-incur-costs" in its original form left much to be desired, but it was put forward in an easily criticized form mainly as an expository convenience to derive some estimated demand curve for the faculty. Hotelling identified concentric population around a given recreational facility and thus was able to derive a willingness-to-pay index for the population in any particular zone.

The concept has been refined considerably by J. L. Knetsch (1963), and in its refined form determines both price and value of the recreational experience by means of consumer surplus estimates (see also M. Clawson 1959, M. Clawson and J. L. Knetsch 1966). Knetsch explicitly excludes the payment of fees to gain access to a particular facility. A cost function can be expressed generally as

$$V = f(c)$$

where V is the rate of visits per thousand people and c is the cost of a visit. He then moves to a demand function estimate "by postulating an imposed price for the enjoyment of the park in the form of an addition to the costs of the visit from each [population center]". He distinguishes this from fee-imposition on the grounds that it "imputes the cost reaction from general expenditure behavior". Knetsch then follows the Clawson criterion for imputing the value of the resource as "the capitalized net profit resulting from imposing the most profitable added cost". Further refinements include the extension of the general cost function to include arguments for income, the availability of close substitutes, and congestion of a particular resource. In addition the derivation of a demand curve for a facility gives a measure of the consumer surplus accruing to the user of that facility as another estimate of the value of the facility.

Knetsch also brings in a consideration all too frequently ignored or passed over in recreation pricing studies, that of the cost of time. As he states· "The method deals quite effectively with money costs as a constraint on visits to a recreation area. However, money cost is not the sole constraint to such visits. Time is certainly another." If analysts ignore the opportunity costs of time then the demand curve constructed from the cost function outlined above will be consistently biased to the left of the true demand curve. The difficulties of putting a cost on time are many, however, although recent work by F. J. Prochaska and R. A. Schrimper (1973) does clear up some of the haze around the topic.

Pearse (1968) has been particularly vocal in attacking the Hotelling/Knetsch/Clawson evaluation of recreation for the consumer, and concentrates mainly on the assumptions underlying the concept. Pearse contends that the concept cannot take account of benefits which accrue en route to the place of recreation, that all populations are assumed to face identical alternatives to the recreational opportunity being considered, that recreationists in all areas are assumed to have the same preferences for the recreational site, and that whole populations from which recreationists are assumed to have similar characteristics and preferences. This last, the homogeneity assumption, Pearse claims is particularly untenable. His alternative formulation "confines the analysis to the recreationists themselves, thus avoiding the necessity of assumptions about the characteristics and homogeneity of the base populations from which recreationists are drawn."

The formulation makes use once again of a consumer surplus argument on the grounds that "the benefits of a good or service available free of charge are entirely appropriated by consumers in the form of consumer surplus." But a distinction needs to be made between the different types of consumer surplus, as defined by J. R. Hicks (1956). Specifically Pearse uses the "compensating variation" concept to measure the maximum tolerable toll which could be levied, given a consumer's indifference map and budget constraint, before that consumer would forego the visit for recreational purposes to the facility. This toll is over and above the costs incurred in travelling to the facility. The value of the resource under free access consists of the sum of the maximum tolls that recreationists would be prepared to pay in addition to their existing fixed costs which include, among other things, costs of travel to and from the site.

Although quite a sophisticated concept _per se_, Pearse seems to avoid the population homogeneity assumption only by explicitly confining his analysis to defined income classes, and moreover makes several quite strong assumptions of his own as regards tastes, preferences and willingness to incur costs. It does have the advantage over the "direct" method of previous workers by using data which are restricted to observations about recreationists themselves and thus implicitly avoids assumptions about the homogeneity of base populations. It would seem, however, that the concept must run up against some problems of aggregation and some assumptions of homogeneity are apparently unavoidable.

Indeed valuation of recreation in the aggregate poses particularly intractable problems under any analytical or conceptual technique. It must be recalled that we are discussing a workable managerial technique in multiple use, and perhaps in the final analysis the only realistic value which can be placed on aggregate recreation might be some Lange-type socialist solution, where an ex post surplus of recreation capacity would indicate overpricing of the resource, and an indication of under-capacity would be reflected in overcrowding of the resource (see O. R. Lange and F. M. Taylor, 1938). This suggests some sequential kind of pricing each year or relevant time period which gives additional feasibility to management decisions.

OBJECTIVE FUNCTIONS

This more detailed discussion of the nonmarket valuation of resources used in multiple-use or joint-products analysis is meant to touch upon perhaps the most intractable problem on the conceptual side of the matter. On the policy side is the equally difficult problem of defining an objective function for multiple-use management.

How much of this problem is due to political and institutional factors seems at first immaterial, but on reflection such factors cannot be ignored to the extent that, at some stage, it is necessary to turn to political processes as substitutes for market processes that do not exist or cannot be effectively simulated. Almost all of the studies reviewed, whilst they recognize the value of, if not the necessity for, multiple use, seem to regard the problems as being forced upon management by the policy-makers. This is a demonstration of the blandness with which policy-makers dictate to the decision-takers. Lucas and Sinden urge the acceptance of multiple-use management as an objective function per se, to be optimized for the benefit of both private and societal groups. If this were recognized and accepted then the objective function in wildland management could be eased to the extent that it would no longer be an appeasing action but a well-established management practice.

The economic content of such an objective function would tend to center around valuation and investment decisions. Much of the preceding discussion indirectly points up the difficulties inherent in formulating such an objective function. Problems surrounding the investment decision are due to the same difficulties of valuation as problems surrounding the pricing decision in the demand and supply framework for the relevant joint products. Multiple use involves management of economic, social and biological relationships which are frequently difficult to identify and as frequently easy to disturb. There is little doubt that the concept as policy is an attractive one. This is evident by its widespread adoption over the past 70 years in the United States by public agencies despite a lack of an economic and analytic base. There is some need for more recognition of what the land is being managed for, the basis on which it is being managed, and a lot of research into the problems of such management.

L. K. Caldwell (1970) advocates a move away from the juridical economic or demographic concepts underlying public land policy both in the United States and abroad. His appeal is to modify the policy to take the ecosystem explicitly into account· "American public land policy is based upon a set of historically derived assumptions ... that provide no means for taking the fundamental ecological context of land use into account... There is a larger context for policy with which laws and governments must ultimately reckon: it is the condition of the land as the physical base for human welfare and survival".

The 1960 Multiple-Use and Sustained Yield Act recognizes this objective function of multiple-use management in a milder form (see above, page 1). For practical purposes as well, this will require some refinement of management techniques which in turn requires some firmer grasp of the principle of multiple use and, perhaps more fundamentally, it requires some redefinition of what such management sets out to maximize or achieve. Lucas and Sinden sum up the argument as "The basic economic model provides a viable tool so that the question now becomes, what is required for the application of the model to practical problems? Perhaps the first requirement is the acceptance of the model's objective function, which is the maximization of net benefits to society over time". This is perhaps an economic expression of Caldwell's more policy-oriented appeal, and in a general review such as this is perhaps as explicit a statement as can be put forward as an objective function in the economic sense.

J. V. Krutilla (1971) has demonstrated the potential of econometric analysis in evaluating the environmental impact of a proposed dam across Hell's Canyon in Idaho. Although his account deals with the value of an unique scenic resource, it could easily be adapted to the formulation of an objective function for multiple-use management. Krutilla assessed the potential benefits from a hydro-electric development, which would effectively flood the entire canyon, against three smaller dams which would preserve large parts of the canyon for future scenic and amenity value. In doing his analysis he invoked the concept of "option demand" (see B. A. Weisbrod 1964) and thus injected the essential element of demand for a resource over time as well as in space. When this type of analysis is allied with that of, for example, C. J. Cicchetti, J. J. Seneca and P. Davidson (1969) which further uses sophisticated econometric techniques to estimate the demand for and supply of outdoor recreation, perhaps the formulation of an objective function in a multiple-use framework involving recreation is not as nebulous or as far away as has been suggested. Indeed, as with the data collecting problem, the syndrome seems to revolve around physical rather than conceptual obstacles.

This lack of research work seems to have built up a further constraint in the multiple-use framework in the area of defining an objective function. Krutilla has shown a method which at least approximates the hard data of trade-offs between products previously considered non-measurable or non-estimable. Whereas this is by no means as precise as the objective functions used in linear programming techniques, it could fill in a gap previously thought beyond evaluation or estimation.

CONCLUDING REMARKS

It has been demonstrated that any discussion of the multiple-use principle in a joint-product analytical framework can very easily become a very disparate account as the various conceptually difficult elements are drawn into the argument. Essentially, the entire principle, whilst being theoretically attractive, will stand or fall on the intractability of the problems surrounding valuation of the several products, and/or identification of the production-possibilities curve. Perhaps the former of these is the more difficult.

Gregory and Hopkin laid the groundwork for further extension, but very little seems to have been done, particularly in the empirical sense, since these original conceptual statements. Hall did point out several pitfalls in putting some measure of recreation as one of the outputs, particularly as it is affected by quality (and consequently value) of the product And Pearse attempted to define some criteria for investment in rangeland under a multiple-use system of management.

All of the theoretical expositions run up against the problem of identifying the price line. This is particularly so when recreation and amenity are discussed. The studies by Muhlenberg, O'Connell and Brown, and Lucas and Sinden are valuable empirical beginnings to extending the theory, and do much at the same time to identify the intrinsic difficulties of valuation problems. If the discussion of the pricing of recreation in the preceding section seems somewhat lengthy and perhaps marginal to the main discussion, it should be recalled that this constitutes the major stumbling block to the use of the concept in a practical sense. It is at the heart of the valuation problem. If there were some easy value, determined through a normally functioning market process, which could be placed on such products as recreation the chances are that multiple-use management would be much better organized and better practiced on public lands than it is at present.

Another recurring theme throughout this review is that of data collection. It was mentioned above that this problem may be more imagined than real in the sense that collecting the data imposed a physical contraint rather than a conceptual one. The conceptual aspect enters when attempts to value or quantify certain products are considered, and in this case there is a very fine line to be drawn between data collection and product valuation. The fact remains, however, than any estimates of both the production possibilities curve and the price line required for joint-products analysis require acceptable and sound data foundations.

On the other hand it should be stressed once more that the concept, especially in its present insecure state, is not a policy panacea. It does provide a useful technique to evaluate possible alternatives in an age when increasing pressures are being placed on land resources by an increasingly mobile and affluent population in certain countries of the world. To make the best possible use of the approach, in the view of Caldwell, requires some changes in basic social and economic outlooks, especially because any ecological land management system precludes the laissez-faire land economics tenets basic to western or capitalist economies. Adherence to this approach, he argues, "is becoming increasingly inconsistent with the interests of the vast majority of citizens ... who live in great cities, own no land, and for whom the needs and amenities of life are becoming increasingly costly and difficult of access".

A return to a biologically sensitive approach to land management would be a good opportunity to realize the benefits of multiple-use administration of wild land. This must be accompanied by an effort to collect data on benefits and costs, and particularly on the non-tangible and nonmarket benefits. In addition, economics must work very closely with the biological and physical sciences to determine optimum ecosystems criteria in wild-land management. In some cases the balance is more delicate than in others, the pressures more acute, and the potential conflicts more intractable. Application of some of the well-established principles of production economics, as has been done to a refined stage in the management of cultivated land systems and in animal husbandry, can give a solid base on which to build a public land multiple-use management policy.

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