Principles of conservation economics and policy

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Principles of Conservation Economics and Policy

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Bureau of Agricultural Economics
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The economics of resource conservation is a complex problem. It not only involves relationships in production and consumption at a given point in time and within a single generation but also between generations over time. Many problems in the economics of conservation can be solved through empirical research. However, those decisions which must be made between generations and over long time periods must be based on the fundamentals of economic logic. Too, many of the less complex problems which may lend themselves to empirical solution cannot be treated effectively until a sound set of fundamental principles and hence an appropriate analytical framework has been developed. For these reasons, the authors were requested by the North Central Farm Management Research Committee to prepare a publication dealing with the fundamentals of conservation economics. This bulletin represents a development of fundamental economic principles as it applies to resource conservation generally and soil conservation specifically. It is not designed as a popular publication but as a technical manuscript for use and as an aid in research by agricultural economists, agronomists, conservation personnel, and any other advanced scientists who are concerned with problems in conservation to an extent that knowledge of the basic economics of conservation is fundamental. The study is an advanced analysis. Readers who are interested in acquiring basic knowledge in conservation economics but have little previous background may wish to review the references cited.

The study is not a complete statement of conservation economics. It does not treat conservation in a complete multiple-period fashion. Uncertainty and anticipations are touched upon only briefly. However, the important relationships in the economics of production and consumption have been adapted to conservation in a manner to indicate efficiency in choice between conservation and alternatives.

W. G. Murray
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SUMMARY

The first part of this study is concerned with the application of principles of production economics to practical problems of soil conservation. The second part is devoted to the further development of the basic theory of economics of resource conservation.

In the analysis of many applied problems, it is helpful to deal with soil conservation in terms of a single industry which can draw certain inputs from the outside.

In this isolated industry case, conservation has a special meaning separate from the concept of competition in production between time periods. In this applied aspect it may be defined as prevention of diminution in future production on a given area of soil and from a given input of labor and capital (apart from the conservation resource input, and with the technique of production otherwise constant). In other words the economic problem is one of retaining a given production function over time.

Society is confronted with two important problems with respect to the allocation of resources for soil conservation: (1) What total quantity of resources should be devoted to this end? (2) How can maximum efficiency be attained in the use of given funds? Attention in this study is devoted primarily to the second question.

The first essential in planning a public soil conservation program is the establishment of an economic definition of soil conservation which will permit a distinction to be drawn between true conservation outlays and mere production outlays. The definition presented above permits this distinction to be made. Without some such criterion there is no limit to the short-run production practices in which public funds might be invested.

It is a necessary condition for attainment of maximum conservation from limited funds that such funds be in fact used for conservation practices. Funds should also be allocated between soil types on the basis of equating the marginal productivities of such outlays in the relevant future time period.

In the same manner, marginal productivity should guide the application of funds between practices on a given soil type, if the greatest degree of conservation is to be attained per dollar invested.

If limited conservation funds are to be used in a way that will return the maximum amount of conservation, a distinction should be drawn between those practices which are not
profitable to the individual farmer and would not be carried out in the absence of subsidy, and those which are profitable and would be carried out even in the absence of subsidy. Economic criteria do not justify subsidization of private production where returns to the individual and to society do not diverge.

Socially desirable erosion control practices may be unprofitable to the individual for a variety of reasons. Some of the more important of these are (1) provisions in leasing arrangements; (2) capital limitations; (3) general economic instability; (4) situations in which benefits are realized in one locality from investments made in another; (5) length of time period between outlay for conservation and realization of returns. The desirability of using public subsidies to overcome these obstacles depends upon nature of the obstacle.

The manner in which public subsidy payments are made should be governed by the characteristics of each individual practice. When public subsidy is used for practices that are uneconomic to the individual, the form of payment should conform to the annual cost of the practice if the installation is to be maintained. Conservation practices that are profitable to the farmer but not as profitable as other nonconservation outlays, might be encouraged by the offering of loans that were definitely earmarked for expenditure on that practice. Other situations call for other variations in the public inducements that should be offered.

The present analysis is primarily focused upon the efficiency of using given funds for soil conservation. The question of the total quantity of resources that should be allocated to conservation is very briefly touched upon. Obviously, resources should be invested in conservation only as long as the marginal productivity of such outlays is not less than from competitive uses for these same resources.

*Conservation* and *development* can be used as substitutes in providing future food and fiber needs. The two should be so developed as to equate the marginal productivity of investment in each.

Because future food and fiber needs are to a considerable extent uncertain, society must provide for intertemporal flexibility in use of soil resources. The important economic problem is to carry a range of flexibility at least cost. This involves the consideration of alternative present uses that will provide given resource reserves for some future period.

Conservation economics, like other phases of production economics, deals with the problem of choice between alter-
native uses for scarce commodities. The distinguishing characteristic of conservation economics is that the pertinent alternatives exist between present and future use of resources.

Resources may be classified into two basic categories depending upon whether or not there is a joint relationship between the resource services that become available in different time periods. These classes may be called flow and stock resources.

Flow resources provide services which become available over time in fixed proportions. The productive services available from these resources in one time period cannot be substituted for services that become available in another. Examples include rainfall, sunshine, power from streams or wind, and scenery.

Flow resources can be subdivided into two classes: (1) Those which produce nonstorable services, and those yielding services which can be stored.

Nonstorable flow services are produced in fixed proportions over time and this is the only combination in which they can be used. Storable flow resource services may be used as they become available, or all, or part of the flow available in one period may be stored for use in a later one.

The second pure category includes those resource services that arise from exhaustible stock resources. With these, sacrificing the use of the resource in one period increases the quantity available in another, and vice versa. Examples include coal, petroleum and some soil mineral deposits.

The economic problem of allocating the use of consumption commodities between time periods may be analyzed in the same way as for resource services. For nonstorable commodities, the nature of the basic resource (nonstorable flow, storable flow, stock) determines the possibilities of allocating use of the commodity between time periods. For commodities that are storable, possible intertemporal use combinations are increased since they may be choice, both in allocation over time of the resource itself and of the commodity produced from it.

With respect to intertemporal consumption relationships, many expositions on conservation assume that the present value of goods available in a future period is determined by discounting the future value at some constant rate. It is more realistic to assume that future goods substitute for present ones at diminishing marginal rates. This hypothesis can be expressed by conventional indifference curves. The slope of the intertemporal indifference curve will depend
upon the relative values which present individuals attach to their own consumption in different periods and the values which present individuals attach to consumption by individuals of future generations.

The rate of resource use which maximizes intertemporal welfare can be ascertained if intertemporal production and consumption relationships are known. At the optimum rate of utilization of a resource over time the marginal rate of substitution (between time periods) in production of commodities will be equal to the marginal rate at which substitution between time periods in consumption of the commodities gives equal utility. The range of possibilities that will satisfy this condition depends upon the nature of the resource.

With stock-derived products, any combination of intertemporal uses would be possible, from utilization of the entire stock in the present to the saving of the entire stock for a future period or any combination between these two extremes.

With flow-derived products where neither the resource service nor the commodity can be stored, only one possibility exists for the maximization of intertemporal welfare. These products must be consumed in exactly the proportion in which they are forthcoming. With resources and commodities of this kind, the only economic question is one of equating marginal cost of producing the commodity (in terms of working capital and labor) with marginal returns from use of the service.

With respect to flow-derived products where either the resource or the commodity may be stored, the optimum intertemporal rate of use will depend upon whether or not future goods are discounted in relation to the present. If the future is discounted by any amount, products and resources should be used as they are forthcoming if welfare is to be maximized. In order for future consumption to be increased at the expense of the present, the individual or society must place a premium on future over present consumption.

Some commodities embody both flow and stock resource services, but this influences optimum intertemporal rate of use of the commodity only if both categories of resource service are limited in quantity.

The level of resource use which will maximize welfare over time varies with changes in the intertemporal rates of substitution of goods in consumption and of goods in production. Major forces that may alter consumption substi-
stitution rates include changes in population and changes in tastes of a given population.

Changes in the intertemporal rate at which goods in production substitute are brought about mainly by improved techniques. New techniques may increase, decrease or leave unchanged the rates at which resources should be conserved between time periods.

The extent to which flow resource services should be substituted for stock resource services in current periods in order to conserve the latter is an important economic problem in use of agricultural resources.

When the production of a commodity which is derived from flow resources is added to the production of the same commodity derived from stock resources, the intertemporal rate of utilization that will maximize welfare is the sum of the rates of consumption for flow-derived and stock-derived products considered separately unless consumers' intertemporal preferences change with increased quantity. But the problem of optimum rate of use of the total supply of a commodity that can be derived from stock and flow resources is of significance only if it is assumed that these resources, rather than labor and working capital, are the limiting factors in production. If, however, labor and working capital are limited, a problem arises as to the substitution of flow and stock resources. This is not a problem of the timing of production, but simply one of the allocation of a given supply of labor and working capital between production of stock-derived and flow-derived products in any single period. The solution lies in equating the marginal productivities of labor and working capital applied to the two classes of resources.

Existing economic tools are inadequate to permit conclusions to be drawn with respect to the rate of use of resources that will maximize welfare between generations. It is not possible to compare the utility received by one generation from consumption of a commodity with the utility values of some future generation. Existing economic reasoning can only state that the optimum level of conservation between generations is what each succeeding generation thinks it to be.

Interpersonal utility comparisons between individuals at a given point of time likewise cannot be made directly, but within a generation an optimum allocation of consumption over time can be formulated if objective means exist whereby each individual can express his relative values. These means might include the price mechanism and the ballot system.
Within a generation, at least two important conditions must be attained in order to maximize intertemporal welfare. (1) Marginal rates of intertemporal substitution of consumption goods must be equal for every pair of individuals. (2) The marginal rate of intertemporal substitution of production goods must be equal between every pair of resource services. In order for a society to determine and attain an optimum level of conservation it must inventory its resources and expected needs, convey this information to each member of the society and devise appropriate machinery whereby individuals are permitted and encouraged to act according to their own intertemporal values.
The central economic problem of conservation is the allocation of limited resources over a span of time in such a way as to maximize welfare over the same period. This is the core of the problem both for the individual producer and for a society. The pertinent time-period, and the extent to which the future is discounted over the present, varies between individuals, between societies, and between individuals and society. For society, this problem of welfare maximization over time involves a further question as to proper distribution of goods and services between individuals.

Previous investigations have made important contributions to economic analysis of the problem, although they have not been complete in terms of existing tools of analysis. L. C. Gray stated the central problem of conservation in terms of conflict between present and future wants, and discussed the general problem of arriving at a proper discount on the future with respect to utilization of various classes of resources. Ely et al. explored the distributive aspects of conservation as a social problem, particularly within the framework of property relationships. Hammar partially developed one aspect of the conservation problem dealing with the substitution of renewable for exhaustible resources. Schickele made a useful distinction between the reversible process of fertility depletion and irreversible soil deterioration. Bunce has explored many detailed aspects of the entrepreneurial problems of conservation, particularly with respect to the time, and the level, at which conservation becomes economic to the individual farmer.

1The authors are indebted to the seminar on economic efficiency sponsored by the University of Chicago and the Social Science Research Council. A large portion of the analysis was developed and evaluated during the seminar sessions.

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Other investigations also have made important contributions.  

The purpose of the present study is to analyze some fundamental economic and policy elements of resource conservation, and to refine and extend the general frame of analysis and point out some limitations in existing analytical tools. The investigation is in terms of basic economic logic. It is hoped that some of the questions and limitations posed will give rise to analyses more adequate than the current one.

This study comprises two quite distinct sections. The first is devoted to applied aspects of soil conservation economics. Conservation is viewed here in a restricted sense, as the problem of conserving one resource (soil) by the application of various other resources. It is assumed for this purpose, that, while the added costs of these conservation inputs must be taken into account, conservation aspects of the use of these other resource inputs need not be considered. However, the method of analysis used here could in turn be applied to each of these conserving inputs. The method of economic analysis applied to soil conservation would also yield, for example, an economics of phosphate conservation or of labor conservation.

The concept of the soil conservation problem here does not differ from that usually employed, with the exception of more rigorous definition. The analysis is in terms of usual production economics principles.

The second part of the study is an exploration of the general theory of conservation economics. The unique aspect of the economic problem of conservation is stated in terms of competing choices in production and consumption between time periods. This distinguishes it from other monoperson period resource allocation problems of production economics.

From the standpoint of logical order, these sections might well have been reversed. General principles discussed in

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6See especially:  
the second part should contribute to a better understanding of the problems dealt with in the first. However, there appeared to be greater advantages in beginning with the simpler discussion of everyday soil conservation problems and progressing to the more general, abstract and less well understood aspects of conservation economics.

SOME APPLIED ASPECTS OF CONSERVATION ECONOMICS

Current policies and semi-popular and scientific literature segregate soil conservation as a special case. In popular treatment, a single industry (which can draw certain inputs from the outside) is considered in isolation. In this section soil conservation will be treated in this setting in order to refine the concept of soil conservation and its economic and policy implications.

PUBLIC CONSERVATION PROGRAMS

Soil conservation has been an important element of the nation’s agricultural policy over the past two decades. Apparently society chooses to continue investing resources in this alternative. Two important economic problems relate to public conservation programs: (1) What over-all level of conservation is optimum and hence what total quantity of resources should society invest here? (2) How should given funds (once appropriated for soil conservation) be allocated if maximum efficiency is to be guaranteed? The two aspects are not entirely separate. The optimum total quantity of funds for conservation is partly a function of efficiency in use of given funds. However, the analysis which follows focuses on the second problem specified above. The purpose is mainly one of outlining principles which should serve as a basis for allocating funds once these have been earmarked for conservation. ¹⁰ The conformation of certain aspects of current conservation programs to these criteria is also examined. The optimum over-all level of conservation investment (relative to general resource use and specific soil development) is analyzed later.

Society uses two principal methods in dealing with the soil conservation problem, technical assistance and financial

¹⁰This study is confined to principles of economic efficiency. Of course, objectives other than economics alone also enter into the formulation of public programs, and properly so.
aid. Somewhat different philosophies might be visualized for the two approaches. Technical assistance, including education, more nearly supposes lack of know how as the major obstacle to a greater degree of conservation while monetary assistance more nearly supposes cost and return as the important obstacle. However, common principles should guide use of resources. Are the limited public funds set aside for conservation being allocated in the most efficient manner? Obviously there are many alternative ways in which the limited funds might be employed. These conservation resources might be allocated entirely to one soil type or to one erosion control practice. Or, they might be allocated equally to all soils and practices. The important decision, however, is the portion of limited funds which should be allocated to particular soils, particular practices and other alternatives within the framework of conservation.

**MEANINGFUL DEFINITION OF SOIL CONSERVATION**

The very first step in planning a soil conservation program at any level should be the establishment of a basic definition of conservation. Otherwise, there can be no systematic manner in which public funds and resources are used. It is doubtful that present action programs make sufficient differentiation between long-run conservation problems and short-run production problems. The distinction between soil conservation and other general production problems cannot be made on the basis of production from the soil per se; otherwise seed corn, tobacco plants and insect spray would qualify equally with terraces, lime and other resource inputs eligible for public assistance. Too, the distinction cannot be on the basis of time. Soil conservation is simply one element of the larger problem of the timing of production and investment; farm buildings, machinery and livestock in general would receive conservation subsidies were use of public funds based on the time variable alone. In the true sense, conservation does refer to the allocation of production and consumption over time. The economic decision is as much one of the quantity of resources to be used in the present as the quantity to be conserved for the future.\(^1\) However, for purposes of the

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\(^1\)This decision is indirectly implicit in public soil conservation programs. Society can tax itself in unlimited quantities and use the funds to subsidize and otherwise obtain higher and higher levels of soil conservation. In so doing it can bid manpower and capital materials away from current production of houses, automobiles and other consumption goods. In curtailing current production of the latter through diversion of resources to conservation practices society is making a choice between present and future production. The decision is, again, the optimum combination between present and future goods (even though these goods may differ between time periods). These questions are discussed in detail later on.
analysis in this section, soil conservation will be referred to in a somewhat different and restricted sense in which conservation is defined as prevention of diminution in future production on a given area of soil and from a given input of labor and capital (apart from the conservation resource input, and with the technique of production otherwise constant). \(^{12}\)

This definition and its implications are illustrated in fig. 1. Soil conservation is not involved in the traverse of production function OA in varying resource inputs. \(^{13}\) For example, if the original input of resources (labor and capital in the form of tractor fuel, seed, fertilizer and other inputs) is \(OX_1\) with a resulting output of \(OY_2\), conservation is not involved as the level of input is raised to \(OX_3\) and the product to \(OY_3\). This involves simply the traverse of a single production function (in respect to \(X\) resources). Neither need one be concerned as price relationships change over time and input falls back to \(OX_1\) and output to \(OY_2\) if the process can again be reversed and the same input always gives the same output. \(^{14}\) Concern with soil conservation should instead be one of preventing a fall from production function OA to production function OB. Lack of soil conservation in this sense refers to a discrete break between production functions and may occur as sheet erosion washes the top soil down to less responsive profiles or as gully erosion removes part of the total area (and a

\(^{12}\)Whether or not an equal output is forthcoming from the same level of input can be measured only in terms of a given technique. Obviously an improved technique might allow an equal product with a smaller resource input, thus hiding the decrease in productivity (which was potentially available had the technique been known earlier).

\(^{13}\)This is somewhat similar to the distinction between soil deterioration and soil depletion made by:


Also see Wilcox \textit{op. cit.} for a related discussion.

\(^{14}\)Certain of the inputs may have been stored originally in the soil. \(OX_3\) might represent such a "virgin state of fertility." These "inexpensive original inputs" may be transformed into product and the input level lowered and maintained at \(OX_3\). However, should price-cost ratios so warrant, inputs can again be raised to \(OX_3\) through purchased nitrogen supplies, etc., to replace the initial "less costly" supplies provided by nature. In this case we again realize a product of \(OY_3\).
given application of nonland resources on fewer acres gives a smaller product because of diminishing productivity. If this permanent break (from one productivity curve to another) does come about, the previous condition is no longer fulfilled. An equal application of resources in the future will not result in an output of the original magnitude. For example, if the input of labor and capital is increased to $OX_2$ (after the fall to $OB$) it results in an output not of $OY_3$ (production function $OA$) but only $OY_2$ (production function $OB$). This notion of soil conservation is entirely apart from the concepts which include the upward or downward traverse of a single production function as conservation. In this concept it is unimportant if one-thirtieth of an inch of soil is removed by sheet erosion from a top soil 100 feet deep (as long as the same input whether purchased or provided by nature gives the same output).

**INTERTEMPORAL COMPLEMENTARITY**

In the terms of production economics, conservation practices involve application of resource inputs (labor and capital) which are technical complements between time periods with resources which are transformed into product within single time periods. In other words, conservation inputs applied in one time period increase output in subsequent

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15 Rather than represent the problem in the simple terms of fig. 1, we might better indicate the implications of our definition in a slightly more complex production economics model. For example, we might use a production function of the nature $Y = f(X,Z)$ where $Y$ is the total production within a given production period (and from a given soil area), $X$ represents the nonconservation labor and capital (seed, fertilizer, tractor fuel, etc.) inputs of the same period and $Z$ represents the conservation labor and capital inputs of an earlier period. Thus as we start cultivation of a virgin soil we have production function $OA$. We are still on the same production function (in respect to $X$ resources) if in a later period equal inputs of $X$ result in an equal $Y$ output (as compared to the earlier period). Or, production function $OA$ represents the productivity of $X$ resources with some fixed magnitude of $Z$ resources over time. Curve $OB$ represents the productivity of $X$ with a smaller fixed input of $Z$. However, the discrete opportunities are not reversible since once curve $OB$ has been attained a given increase in $Z$ will not always result in the same output as if the latter ($Z$) inputs had been made before occurrence of erosion or other forms of soil deterioration. Or input of $Z$ necessary to retain production function $OA$ for $X$ resources is less than the input necessary to restore $OA$ once deterioration has come about. The relevant level of $Z$ input can thus be looked upon as the necessary fixed cost over time if the $OA$ productivity curve is to be retained for $X$ resources. The $OB$ curve represents a lower fixed cost in $Z$ resources over time in order that the indicated lower productivity of $X$ resources might be retained. If the $OA$ productivity curve for $X$ resources can be retained over time in the absence of $Z$ resource inputs then a true conservation problem does not exist.

We do not classify all complementary factors of production as conservation resources. Only those which are independent factors in early periods ($t_0$) but become complementary into future periods ($t_n$) are so classified. If one factor or production $S$ is complementary to the same extent with factor $R$ in all periods, it does not qualify as a conservation resource. Unless distinction is made in terms of the complementary characteristics which have been outlined here, soil conservation cannot be distinguished from any other aspect of production.
periods over what it would be if these inputs had not been applied. Nonconservation resources are characterized as competitive (technical substitutes) with other resources within a single time period. Also, they do not influence output in subsequent periods. (These conditions refer to attaining a given output on a particular tract of soil.)

The distinction can perhaps best be explained with an example: Suppose that an initial input of a resource combination $X_1$ (say 7 hours of labor, 50 pounds of fertilizer and a given physical quantity of other factors) results in an output of 50 bushels of corn per acre in the early period ($t_o$). If input of an additional resource $Z_1$ along with the original input of the combination ($X_1$) results in an output of 60 bushels in a later period ($t_n$), the additional resource (practice) is a substitute; some smaller input of fertilizer, labor or other resources in the original combination ($X_1$) can be used along with the $Z_1$ resource input to attain an output equal to the original 50 bushels. However, if in the later period ($t_n$) the original ($X_1$) combination of resources results in an output of (a) only 40 bushels without the $Z_1$ resource input but (b) 50 bushels with the $Z_1$ resource input, the latter is a conservation resource (practice); unless $Z_1$ resources are employed the original output cannot be attained over time from the original $X_1$ combinations.

Prevention of gullying is a conservation measure since future production will be diminished as the original inputs of capital and labor are applied to the remaining (non-gullied) land area in the absence of conservation practices or resources. Sheet erosion is not yet directly related to future production if its rate is at a fraction of an inch per year on a deep top soil (wherein the same application of nonconservation inputs results in an equally great output in successive production periods).\(^\text{15}\) Sheet erosion causes a break between production functions, however, if the remaining subsoil results in a smaller output (as compared to the original top soil) from equal applications of labor and capital. Application of nitrate fertilizer on level land which simply increases production when applied with previous

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\(^\text{15}\)We include the virgin supplies of nitrogen and other soil elements as part of the original input. If part of the natural supply of soil elements has been used, obviously it may be true that the original quantity of labor and capital (aside from fertilizer and related soil amendments) will not give as great a yield. However, our condition that the same inputs be applied would require also that soil elements be equal in quantity to those of the original soil condition. Thus our “early” inputs may have been partly furnished by nature whereas, to have equal labor inputs, fertilizer elements may have to be brought in from the “outside.” Thus a downward traverse of a given production function as the virgin supplies of nitrogen, phosphorus or potash are used is not a true problem of conservation by our definition. The original production level can always be regained by replacing the quantity of elements originally supplied by nature.
resource combinations does not meet this test as a conservation measure. A definition such as that employed here would largely eliminate so-called conservation subsidies on level land except to control wind erosion.

Without some such criterion there is no limit to the short-run production practices in which public funds might be invested. Funds might equally well be invested in improved livestock techniques as in agronomic and soil engineering practices which have a main effect of increasing production. In the discussion which follows conservation practices (resources) refer only to those which prevent diminution in output of the future from given resource inputs (retention of a given production function over time). In terms of this criterion, and assuming that society's willingness to finance a limited amount of soil conservation grows out of concern not for today's but for the future's production, efficiency in the use of limited annual appropriations is denoted by allocations which minimize the potential diminution of future production when given resources are applied to the land.

NECESSARY CONDITIONS FOR MAXIMUM CONSERVATION

A necessary condition for attainment of maximum conservation is that funds be used in fact for conservation practices. Some practices now receiving public assistance in the name of conservation do not meet this elementary test. Irrigation, drainage and weed control, for example, are not practices which are generally necessary to prevent a diminution in future production. (The practices are substitutes over time for other types of resources except as they prevent permanent deterioration of the soil.) If irrigation is not developed or improved on a tract of land now there is nothing to preclude its initiation at a future date with the same resulting increase in production as if it were done now. The same can be said for mechanical drainage practices and weed control under most conditions. Although the line cannot be drawn so clearly, certain other practices subsidized by public agencies can also be questioned. Green manure and cover crops often fall in this category. A legume or grass crop used to prevent erosion or permanent deterioration in soil structure is related to production of the future. However, where these crops are used simply to boost short-run production of subsequent grain crops on level soil types, they hardly qualify for public subsidy if emphasis is on maintenance of future productivity. Certainly a payment for plowing under second-year red clover or annual legumes on level land is remote from soil conser-
vation. In some cases payment for plowing under a green manure crop such as sweetclover may even induce diminution of future production. This is indeed a possibility on soil types such as the Monona and Ida of Western Iowa where the effect of sweetclover may be to loosen the soil and speed erosion. Payments for liming materials and inorganic fertilizers for grasses and legumes on level land with a main effect of increasing short-run grain yields fall in a similar category.

A similar analysis might be applied to technical education and assistance. Soil conservation districts were generally formed first in those areas with the greatest erosion hazard and hence where a true conservation problem existed. Too, a greater proportion of technical assistance is likely allocated to conservation (as defined here) practices than is true for monetary assistance. As the number of districts has expanded, however, these have generally been in the direction of soil associations with less critical erosion hazards, and a portion of technical assistance is devoted to developing irrigation systems, drainage and similar practices. Certainly the technical assistance used for irrigation, improved rotations on level land or drainage developments (where these are of a nonconservation nature) could better be employed where permanent deterioration of the soil is taking place. Given the objective of maximum conservation attainment, the efforts of a farm planner in York County, Nebraska, for example, should be allocated to erosion control on the rough land rather than to irrigation development on level lands. Similarly, one farm planner in level Champaign County, Illinois, and one in rolling Switzerland County, Indiana, would not represent the best use of resources (in terms of our criterion of conservation maximization) were effort directed to drainage in the former and to erosion control in the latter county.

SUFFICIENT CONDITIONS AND ALLOCATIONS BETWEEN SOILS

Allocation of public funds to practices or soils where potential diminution in future production is prevented is a necessary condition for maximum attainment of conserva-

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17 It may be argued that assistance to a farmer in draining a piece of bottomland increases either his feed supply or income so that he can afford to remove hill land from intensive production. Yet were this to be a real basis for aid in draining the bottomland, there is little point why technical assistance should stop here. Why not help the farmer improve livestock rations, breeding and sanitation? These may be as or more effective than drainage in offsetting any (a) lowered income, or (b) lessened feed production resulting from withdrawal of hill land.
tion (from given funds). It is not, however, a sufficient condition. On the basis of this criterion alone, public funds would be allocated to the various soil areas on the basis of the number of acres of soil subject to erosion or other permanent deterioration. An acre of one soil subject to erosion would have as much claim on public assistance as an acre of any other soil subject to erosion. Yet this would not guarantee the greatest degree of conservation (the smallest diminution in future production from given resource inputs).

Present funds should be given allocative priority between soil associations in terms of their marginal productivity in the relevant future time period. Each increment of investment in monetary or technical assistance should be spent in a manner which minimizes the diminution of future production (due to erosion or other processes which permanently lower productivity). For example, if a given current investment averts future loss of 100 bushels of corn (or equivalent units of other crops) on soil A but only 60 bushels on soil B, then public assistance, if limited, should be devoted to the former soil. Limited conservation resources should have priority in preventing loss of an acre of the more productive Tama-Muscatine soils of eastern Iowa over an acre of Shelby-Sharpsburg in southern Iowa or northern Missouri. Similarly, investment of limited public funds would call for preventing loss of an acre of Decatur-Dewey-Cumberland soils of Madison County, Alabama, over the Guin-Atwood-Savannah soils of Franklin County, Alabama.

The analysis outlined above is given greater refinement in figs. 2, 3 and 4. The goal should be one of equating the (future) marginal productivity from current investment

\[ \text{OUTPUT OF PRODUCT IN FUTURE PERIOD (t_{1})} \]

\[ \text{INPUT OF CONSERVATION RESOURCES IN PRESENT PERIOD (t_{0})} \]

Figs. 2, 3 and 4. Allocation of conservation resources between soil types to equate marginal productivities.
between soils. Figure 2 suggests the (future) productivity of various quantities of (current) conservation investment on Soil A. Figure 3 represents the situation for soil B. Figure 4 represents fig. 3 inverted counterclockwise and transposed over fig. 2. With a total possible current investment of \( OZ_1 \) in fig. 2 (which equals \( O'Z'_1 \) in fig. 3) the entire investment should be made on soil A. The marginal productivity of all investments up to this point on soil A (fig. 2) is greater than any investment, however small, on soil B (fig. 3). Given a total possible current conservation investment of \( OZ_2 \) (equals \( O'Z'_2 \)) for the two soil types, as indicated in fig. 4, \( OZ_1 \) should be invested in soil A and \( Z'_1Z''_1 \) (equals \( O'Z'_1 \)) should be invested in soil B. Under this combination the marginal productivity of investment is equated between the two soil types.\(^1\)

If allocation of conservation funds were to be based on the criteria of maximum attainment from given or limited conservation funds, annual investment in either direct subsidies or technical assistance on one soil area might well amount to several times that of another soil with an equal acreage subject to erosion. These possibilities are suggested in the experimental data of table 1. If annual conservation appropriations are so limited and if diminution of future production is to be minimized, it is more important to save 2 acres of Marshall silt loam while 2 acres of Shelby silt loam erode away than to save 1 acre each of Marshall and Shelby while 1 acre of each also erodes away. Certainly within the framework of annual appropriations short of those necessary for complete safeguarding of future production, some soil areas should go entirely without subsidies while payments are concentrated on productive soils which

\(^1\)The situation for the two soil types might be represented by two production functions such as \( Y_n = f(X_n, Z_n) \) and \( Y'_n = f(X'_n, Z'_n) \) where the first refers to the output from and resources applied to soil type \( A \) while the second refers to the same product and resources for soil type \( B \). \( Y_n \) and \( Y'_n \) represent the product of the future (\( t_n \)) time period, \( X_n \) and \( X'_n \) represent the input of nonconservation resources of the same period (\( t_n \)) and \( Z_n \) and \( Z'_n \) represent the input of conservation resources from an earlier period (\( t_s \)) for the \( A \) and \( B \) soils respectively. In figs. 2, 3 and 4 we are holding the input of \( X \) resources constant to examine the productivity of \( Z \) resources. This is consistent with our presentation in fig. 13 where we are, in effect, holding \( Z \) resources constant to examine the productivity of \( X \) resources. Figures 2 and 3 thus also represent the future product sacrificed from given applications of nonconservation resources (\( X \)) if the relevant quantities of conservation resources (\( Z \)) are not applied earlier. For example, if the input of the conservation resource is \( Z(Z) \) in \( t_s \) on soil \( A \), the given application (say \( OX_1 \) of fig. 1) of \( X \) will result in output of only \( OY_1 \) rather than \( OY_2 \) in \( t_n \).

\(^1\)This is obviously true since \( \frac{dY'}{dZ} = \frac{dY'}{dZ'} \) under these combinations where \( Y \) and \( Y' \) represent the same commodity measured in the same scale except for difference in soil type and \( Z \) and \( Z' \) represent the same resources (or dollar investment) measured in identical units except for differences in soil types.
TABLE 1. EXPERIMENTAL YIELDS FOR TWO DIFFERENT SOIL TYPES UNDER SIMILAR MANAGEMENT PRACTICES, 1932-42*

<table>
<thead>
<tr>
<th>Rotation</th>
<th>Shelby silt loam, Bethany, Mo. 8 percent and 72.8 ft. slope**</th>
<th>Marshall silt loam, Clarinda, Iowa 9 percent and 72.6 ft. slope†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous corn</td>
<td>19.7 bu.</td>
<td>28.5 bu.</td>
</tr>
<tr>
<td>Corn-small grain-meadow</td>
<td>26.1 bu.</td>
<td>42.9 bu.</td>
</tr>
</tbody>
</table>

*The small grain was oats for the Marshall experiment and wheat for the Shelby experiment. Meadow included red clover for the former and red clover and timothy for the latter soil.


TABLE 2. EFFECT OF CROP ROTATIONS, TERRACING AND DIRECTION OF SLOPE ON SOIL LOSS PER ACRE FROM SMALL WATERSHEDS, 1934-41.

<table>
<thead>
<tr>
<th>Practice</th>
<th>Computed reduction in soil loss per acre* (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terraced compared with unterraced:</td>
<td></td>
</tr>
<tr>
<td>(a) Continuous corn</td>
<td>4.80</td>
</tr>
<tr>
<td>(b) C-C-O-M Four-year rotation**</td>
<td>1.38</td>
</tr>
<tr>
<td>Four-year rotation** compared with continuous corn:</td>
<td></td>
</tr>
<tr>
<td>(a) Unterraced</td>
<td>4.03</td>
</tr>
<tr>
<td>(b) Terraced</td>
<td>.61</td>
</tr>
</tbody>
</table>

*Computed from U.S.D.A. Technical Bulletin 959, p. 69, table 24. The data on the unterraced results are for a southeast slope while those for terraces are for a northeast slope.

**Corn-corn-oats-meadow.

are most important over the long run. There is little evidence that major allocations of public assistance between soil areas have been based on the principles outlined here.

ALLOCATIONS BETWEEN PRACTICES ON GIVEN SOILS

Current allocation of public funds between conservation practices also suggests some lack of economic system. Evidently one criterion is the selection of qualifying practices which enable most farmers to collect some amount of payment. The system has no basis within the framework of our efficiency criteria. Another basis for allocation of funds between practices which has been used to some extent is the cost of the installation or practice. For example, with cost of terrace construction at 15 cents per cubic yard of earth moved and waterways at 12 cents, 70 percent of
the cost of each might be subsidized. Absolute cost is not, however, a sufficient basis for allocating funds between practices. Greater conservation might result from given annual appropriations if 80 percent or all of one practice were subsidized while 40 percent or less of some different practice were subsidized.\footnote{The economic logic underlying the optimum allocation of conservation funds between practices and within soil types can again be illustrated by figs. 2 and 3. Given the goal of maximum conservation from given funds, allocation of assistance should be in terms of maximizing (future) marginal productivity of each increment of investment. Suppose that fig. 2 represents practice \( A \), such as terracing, which can be applied in different degrees over the soil area through terrace spacing, number of acres terraced, etc. Figure 3 might represent practice \( B \) such as lime, inorganic fertilizer, forage or cover crops which can also be applied to the land in varying degrees. Diminishing productivity would be expected. Given a total quantity of funds \( OZ \) (equals \( O'Z' \)) to allocate between practices \( A \) and \( B \), the cost-of-installation criterion would result in investment of one-half (or \( OZ \)) on practice \( A \) and one-half (or \( O'Z' \)) on practice \( B \). However, on the basis of the productivity criterion, the entire funds \( OZ \) (equals \( O'Z' \)) would be invested on practice \( A \). Future production from current investment would thus be maximized since the total product (prevented from eroding away) would amount to \( OY \) (which is greater than \( OY \) plus \( O'Y' \)). Given a quantity of funds greater than \( OZ \) (equals \( O'Z' \)) the task is one of equating future productivities between practice investments. (One of many such combinations is illustrated by fig. 4 for a total present investment between practices equal to \( OZ \) plus \( O'Z' \).) }

In practical application of this principle public agencies should discriminate carefully between the rates of payments for different practices even within a given soil area or farm. Where conservation problems do exist, funds should be spent on these practices which result in the greatest degree of conservation per dollar invested. The economic incentive should be greater (on a given soil type) for establishing a rotation with at least 1 year of meadow on a farm which has previously had no meadow than for establishing a rotation with 3 years of meadow on a farm which previously had 2 years of meadow. Or, it is more important to encourage terracing on a farm with continuous corn than on a farm with a meadow rotation. Possibilities do exist for differentiating between practices as is suggested in table 2.

TECHNICAL ASSISTANCE

Technical assistance for conservation should also be allocated between practices on the basis of productivity principles. Widespread application of those practices which have greatest effect in erosion control and hence in preventing diminution of future production should be attained before resources are devoted to simple practices which have less relationship to potential future output. Yet farm planners have been occupied in devising complete plans for some farms while there exist waiting lists of other farms to be
planned even on the same soil association. Optimum allocation of limited technical assistance would require application of fewer but critical erosion control practices on greater numbers of farms rather than application of the greatest number of practices on fewer farms.

The logic of this statement is illustrated by fig. 2. Suppose that two farms of the same soil makeup exist. Both have identical intertemporal production functions of the nature suggested by the relationship between present erosion control input and future output in fig. 2. The available amount of present input (technical assistance in this case) is $OZ_2$. In the vein of complete farm planning, an input $OZ_2$ of technical assistance would be applied on one farm while none was being applied to the other. However, in terms of the optimum allocative principle, $OZ_1$ (equals $\frac{1}{2} OZ_2$) would be applied to each farm. Future production would be augmented since the combined product would then equal $2OY_1$ on the two farms as compared to only $OY_2$ under complete farm planning. The output gained ($OY_1$) on the second farm would be greater than the output sacrificed ($Y_1 - Y_2$) on the first farm. Application of the entire $OZ_2$ input of technical assistance on one farm with none on the second could be justified only in the case of a linear production function.

The advantage of applying a few critical practices to a large number of farms rather than application of a greater number of practices to fewer farms will depend in part upon the degree of complementarity between practices. Terraces and contour farming, for example, are highly complementary in some situations. Where this is the case, it would represent a more efficient use of limited funds to get half the farmers to terrace and contour than to get all farmers to terrace without contouring, or vice versa.

PUBLIC SUBSIDY IN RELATION TO RETURNS TO THE INDIVIDUAL

Returns to the individual should be a basic consideration in any public conservation program which involves subsidy payments. Given a goal of maximum conservation from limited appropriations, distinction should be drawn between those practices which (1) are not profitable to the individual farmer and would not be carried out in the absence of subsidy and (2) those which are profitable and would be adopted even in the absence of public subsidy. There is foundation for public subsidy of enterprises, resource combination or practices which are economic to society but
which are unprofitable to the individual. Economic criteria, however, do not justify subsidization of private production where returns to the individual and society do not diverge. This distinction has often been ignored in public programs. Not only have farm practices which are clearly profitable been subsidized, but also payments have been made widely for practices which farmers would have adopted even in the absence of public subsidy. Such allocations represent inefficient use of limited funds if maximum conservation is the goal and if important areas exist where erosion control practices are not profitable to the individual or would not be adopted in the absence of subsidization. Obviously, given funds will result in greater conservation if used to bring about practices on 100 acres of soil B where erosion control does not pay the individual than if used to divide the same fund one-half to soil B and one-half to soil A where the practice is profitable and farmers have already adopted it.

There are numerous reasons why certain erosion control practices are economic to society but are unprofitable to the individual. These divergencies arise mainly out of the following situations: (1) Leasing arrangements whereby either tenant or landlord does not realize the full marginal product from his investment because of (a) the way costs and returns are divided or (b) the length of tenure. (2) Capital situations whereby the operator with limited funds realizes either (a) greater returns from investment in other alternatives, or (b) greater family welfare by consuming now rather than in investing for future returns. (3) General economic instability wherein uncertainty of future returns discourages conservation development (along with other long-term investments). (4) Situations in which benefits are realized in one locality from investments made in another. (5) Situations in which a long period of time intervenes between conservation investments and returns.

Should public subsidy be used as a permanent offset to these forces which tend to prevent conservation? Public subsidy, while suitable for the last two situations, is clearly not the basic economic remedy for the first three. Unless emphasis is placed upon elimination of these obstacles society must stand ready to subsidize conservation for score upon score of years. Positive steps would include action along the following lines: (1) Tenure arrangements: (a) developing leasing arrangements which resolve economic conflicts between landlord and tenant, (b) extending education which facilitates adoption of improved leasing sys-

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tems and (c) developing legislation (where this is the only alternative) to guarantee compensation for conservation and related investment. (2) Lack of capital: designing credit systems to conform to the timing and returns of conservation farming. (3) Economic instability: designing fiscal policy and other means to eliminate the wide fluctuations in returns and the uncertainty which accompany inflation and depression.

Obviously, these forces cannot be treated adequately in a period of one or two years. Conservation subsidy may be necessary as an offset in the interim. A more effective long-run use of public resources might well be diversion of the portion of funds currently used for practices which either (a) have little relation to preventing long-run diminution in production or (b) are profitable to the farmer and would be adopted anyway, to research and education in the areas specified above.

**FORM OF PAYMENT**

The form of payment is also of economic interest when public subsidy is for practices which are unprofitable to the individual. Payments may take either one of two forms, (1) as a variable payment over time directly proportional to the part of the original conservation investment transformed into annual cost within a single production period, or (2) as a lump-sum payment covering the original investment with no relationship to its annual transformation or depreciation. Annual recurring practices such as contouring, seed for close-growing crops and lime or fertilizer for obtaining catches of the latter are examples where the initial investment (labor, fuel, materials, depreciation on equipment, etc.) is generally the same as the annual cost of the practice. However, in the case of dams and terraces the initial investment does not represent the annual cost of the practice; the annual cost is represented by the depreciation of the investment and other costs which occur from year to year throughout the life of the installation. Subsidy for installation investment does not lower the marginal cost of installation maintenance. However, if interest on investment must be considered as an annual cost (especially where funds are borrowed) then subsidization of the original capital investment will result in a lower annual total per unit cost of the installation over time.

The form of payment should conform to the nature of the annual transformation (or depreciation) of the practice or installation if public investment in conservation is to be
safeguarded over time. For mono-period or annual recurring practices such as contouring, payment per unit of practice in the year applied is the appropriate economic vehicle if adoption of the practice is to be expected. This is true because the costs of the practice are variable costs in the sense that all inputs are *transformed* within a relevant production period. The costs within any production year are thus directly proportional to the units of practice applied in the same period. However, in the case of installations with a life of several years the full transformation does not take place in the year of initial investment. An installation subsidy for these *long-lived* practices in terms of a single payment per unit of installation may not guarantee or induce subsequent maintenance because the entire amount is paid at one point in time with no relationship to later unit costs of maintenance. If installation investment (terraces, dams, drainage, etc.) were originally unprofitable in a static sense and if the subsidy were in lump-sum form, then subsequent maintenance might still be unprofitable to the farmer. Or, if some quantity of a practice were already in application and the goal were to extend its adoption, the lump-sum subsidy might not guarantee its maintenance.

With a lump-sum payment, the firm could be expected to maintain the practice only if the following condition were realized. The annual value to the firm of the increased product, resulting from the practice, must exceed the annual cost to the firm of maintenance. There might, of course, be individual years in which costs would exceed returns, but over a period of years the practice must at least pay for the cost of repairs if it is to be maintained.

There are some cases in which long-lived installations are unprofitable to the firm under any circumstances. In these cases, the firm has a greater profit after the lump-sum subsidy (if the productivity of resources invested is greater than zero) but it cannot increase its profits further by maintenance. Under these conditions, retention of the practice would involve installation subsidies plus maintenance subsidies.

There are at least two situations under which installation subsidy may make it feasible to apply practices even in the absence of maintenance subsidy. One of these has to do with uncertainty and the other with capital limitations. The first situation is especially applicable where costs of the present must be related to returns of the future and where uncertainty surrounds the latter. Even if the historic return is greater than the historic cost, the farm firm may
still discount future returns to such an extent that it is subjectively rational to view the venture as unprofitable. In this setting a present subsidy tied to installation may in effect increase the certainty and lower the discount on future income (thus encouraging installations which would otherwise appear subjectively unprofitable). In the second situation, the operator might find it profitable to invest in conservation installations if capital were not limited. However, with limited capital and a prospective return on livestock at (say) 10 percent and a return on conservation installations at 5 percent, he will still forego investment in the latter. Subsidy earmarked for installation would, however, equalize the profitability of application of the conservation practice.\textsuperscript{22} Direct subsidization of installation investment is not, however, a necessary means under the situation where the practice is profitable in an absolute sense and unprofitable only in a relative sense (e.g. where capital is limited and other investments return more than conservation installations). One alternative would be an interest-free loan of funds provided they were used for conservation installations. (Installation subsidies in some current public programs are not only interest-free but also repayment of the fund itself is unnecessary.) If tied to conservation installations, the fund could not be used for other enterprises even though the latter gave greater returns. Then, too, loans of this nature would allow greater conservation accomplishment from given appropriations since the fund could be used over and over as it was repaid. Resistance to the use of additional borrowed funds, which might further lessen the farm firm’s equity ratio and hence increase the probability of insolvency in case of an unfavorable turn of events could be circumvented under arrangements whereby the liability incurred from the conservation loan was not directly a part of the firm’s total liability structure.

\textbf{RELATION OF CONSERVATION TO DEVELOPMENT}

Up to this point the analysis has focused on the efficiency of using given funds once these have been appropriated. Attention is now turned to the total quantity of society’s resources which should be allocated to conservation. The quantity of resources to be invested in direct conservation activities cannot be separated from alternative employment

\textsuperscript{22}An unrestricted (not tied to conservation practices) lump-sum subsidy or capital loan would still not result in the application of installations where capital is the limiting factor and other investment opportunities give greater returns. The operator would use the added funds in the alternatives giving the greatest returns.
of the same resources. Potential conservation funds can be used in intensifying and increasing production on soils which are not subject to permanent deterioration. They can also be used in developing new techniques which increase the product from given resources. Too, society’s demand for food is not apart from its demand for nonfood products. As food production is expanded, it takes on lower and lower consumer values relative to other products. Obviously, conservation should be extended only as long as the marginal productivity of resources so invested is not less than for the many competitive uses of these same resources. The primary purpose of the analysis which follows is to relate soil conservation (as defined earlier) to soil development opportunities.\textsuperscript{23}

In the isolated industry case discussed in this section, soil conservation does not have all the connotations of resource conservation (competition in production between time periods whereby a greater product in one necessitates a lower product in another). The same level of output may be attained in various time periods even if conservation of the soil (erosion control by means of terraces, dams, contouring, etc.) does not take place. For example, the initial output on a soil area may be $OY_3$ from an input of $OX_2$ (fig. 1. Production function $OA$ and including the virgin fund of fertility plus purchased inputs). Input may then drop back to $OX_1$ with a corresponding fall in product to $OY_2$ (production function $OA$), and eventually to $OY_1$ (production function $OB$) as erosion takes place. However, in a later period, output may again be pushed to the original ($OY_3$) level by a greater application of input ($OX_3$ on $OB$). In fact, the output can be boosted even beyond the level of the earlier period by employing an input of even greater magnitude than $OX_3$. Even were it true that erosion took place to the extent of removing one-fourth the United States land areas, output of various levels (including that of the present, or greater) could be attained on the remaining area through application of sufficient labor, fertilizer, irrigation water and other resources. Production of one time period does not preclude production of the same or greater level in a later time period.

Actually, the economic problem here is one of capital and labor substitution. The given output ($OY_3$) can be attained in various time periods by either one of two methods: (1)

\textsuperscript{23}We define soil development as characterized by use of resources which serve as technical substitutes for those already employed in agricultural production.
by a smaller application of specific capital in the form of fertilizer, irrigation water, etc. \((OX_2 \text{ and } OB)\) and a larger capital investment in terraces, dams and other erosion control measures or (2) by larger outlays for specific capital, and smaller investments of erosion control capital. The relationship is that expressed in fig. 5. The curve \(EF\) is an isoproduct (equal or given product) curve showing the many combinations of labor and capital which can be employed in attaining the given output. The hypothesis here is that the one class of inputs substitutes at a diminishing marginal rate for the other; a small amount \((x)\) of fertilizer, labor and similar materials applied on better soils may offset (substitute for) a given amount \((y)\) of terrace and similar investment on the poorest soils. However, one more similar increment \((x)\) in fertilizer and labor applied on the best soils (or on the next best soils) will not substitute for as great a quantity \((y)\) of terrace investment on soils a degree about the poorest. Conversely, \(x\) quantity of fertilizer may substitute for the first \(y\) quantity of erosion control investment but \(2x\) may be required to offset the second \(y\) decrement of erosion control materials (if the same quantity of output is to be realized). Obviously the optimum combination (either for an individual or society) of the two types of production factors depends on their relative costs; the marginal productivity of capital in the form of fertilizer and related resources should be equal to the marginal productivity of capital in the form of terraces and related erosion control investments.\(^{24}\)

Conservation should especially be related to irrigation and other national soil development programs. Actually conservation and development can be used as substitutes in providing future food and fiber needs. And the two should be developed congruously in the sense of equating marginal productivity of investment in each. The important economic consideration is the extent to which limited public

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\(^{24}\)Given the cost of the various classes of resources, equal marginal productivity would be defined at the point of tangency of an outlay contour and the product contour, denoting a ratio of prices equal to the marginal rate of substitution. Obviously, the marginal rate of substitution between the two major classes of resources and the exact combination (erosion control versus fertilizer, labor, water and associated inputs) will depend on the total (given) output to be attained and the portion of the total lands of various classes already under cultivation. Rather than represent the case of "conservation" in terms of different production functions we might have presented it as a production surface or single production function as \(Y = f (L_d, L_b, C_e, C_n)\) where \(Y\) is the total product. \(L_d\) is the land input, \(L_b\) is the labor input, \(C_e\) is the capital invested in erosion control input and \(C_n\) is the nonerosion control capital input. Then \(OA\) curve (output \(OY_3\) in fig. 1) represents the given production function with some magnitude of \(C_e\) and smaller magnitudes of \(C_n\) and \(L_b\) than \(OB\) which represents a zero \(C_e\) input and a greater \(L_b\) and \(C_n\) input. However, there is some doubt about this concept since once \(OB\) has been attained, an increase in the \(L_e\) input (after erosion has taken place) will not always result in the same output as if the \(L_e\) input had been made before occurrence of erosion.
funds should be invested in (a) controlling erosion in order that agricultural product from some soils will not be sacrificed in the future or in the alternative of (b) extending future production on other soils through irrigation, etc. In an applied sense a given investment should be made in control of erosion if it safeguards output of the future by (say) 100 units of wheat or other product while a similar investment in irrigation extends future production by only 75 bushels. Conversely, if 100 units of product can be made available by conversion of dry-land farming to irrigation while a loss of only 50 units of future production can be prevented by an equal erosion control investment, the former should be given priority.

Allocations of this nature would require that a goal or objective be established relative to the future need for agricultural products. The goal should suggest (1) the quantity of agricultural products needed relative to the products of other industries and (2) the minimum cost of guaranteeing this level through (a) conservation of soil and (b) irrigation and other development. Obviously, establishment of goals of future production is not easy. The needed extent of future production and hence erosion control (or its substitute, irrigation or other development) depends on (a) growth of population and aggregative demand, (b) changes in general techniques and the efficiency with which soil resources are transformed into product, (c) tastes of consumers for agricultural relative to other particular products, (d) war needs and international trade and (e) other variables. Prediction of these variables and hence the need for future agricultural production (relative to nonagricultural products) is obviously subject to error. This complexity does not, however, justify unlimited and unregulated public investment in soil conservation or development. Even though they be subject to error of prediction, careful inventories should be made (1) of the expected trends in techniques and demand, and (2) of the quantities of the various soil types, both (a) subject to erosion and
(b) capable of development through irrigation and otherwise. The total level of required conservation-development might then be estimated. After estimation of the aggregative portion of future product which depends on either (1) increasing output through irrigation, or (2) preventing diminution of production through erosion control, the exact components of this development-conservation quantity should be derived. Here we are concerned with attaining the quantity of product in question with a minimum cost. This condition is given in the productivity principle wherein irrigation would be extended only as long as the increase in output from a given investment is greater than the diminution prevented by an equal investment in erosion control (and vice versa).

UNCERTAINTY AND FLEXIBILITY

Given certainty (or expectations otherwise single valued) in prediction of future events, the entire portion of soil for which conservation is uneconomic (e.g. where the product lost through erosion can be offset at a lower cost by irrigation and other development) might be allowed to erode away over time. However, error of prediction is a reality which must be faced. Expectations of the future can at best be viewed only partially in the vein of empirical probability (historical trends). Expectations also must be viewed as subjective probability distributions wherein the likelihood of each possible outcome can only be estimated (apart from the empirical sense). Unexpected events (those not inherent in empirical trends); wars, changes in population growth, lags in techniques, or other contingencies may actually come to exist. There can be no turning back if soil needs have been underestimated and an important quantity has been allowed to erode away. For this reason, provision for intertemporal flexibility in the use of soil resources is doubly important; society must place itself in a position whereby standby production capacity (1) is available if the low-probability and hence unfavorable expectation does come about but (2) need not be carried at an extreme cost sacrifice if the contingency fails to materialize. (Should the contingency never materialize then society has sacrificed in the sense that it has invested resources in an alternative of low productivity.)

Flexibility would not be achieved were only a minimum soil area (that consistent with the expectation to which the
greatest subjective probability is attached) retained for future production. The possibility for turning back does not exist if the single expectation fails to materialize. However, if some range of surplus soil is carried into the future then it (1) can be used if the need arises or (2) can be left out of production if the need never arises.

The important question is one of how the range of flexibility can be carried at the lowest possible cost. Should the land which is needed only to meet future contingencies (and not for current production) be maintained in annual use through annual subsidies paid for the contouring, terrace upkeep and the seeds and fertilizers necessary for erosion control? This is not a necessary procedure. The margin of land carried for flexibility purposes might be better retired from production and returned only if the need arises. The alternative to be selected (a) withdraw from production or (b) maintain in production with continuous annual subsidy of erosion control practices) should obviously depend on costs. In many cases the first alternative will require a smaller outlay over time (once the land has been seeded down or otherwise prepared to prevent deterioration). Too, there are possibilities that the soil area retained for purposes of flexibility might also be employed for grazing or other extensive operations. Maintenance of a soil margin for flexibility would require that public control be exercised in a manner to regulate use and guarantee prevention of deterioration.

FUNDAMENTAL ECONOMIC PRINCIPLES
OF CONSERVATION

INTERTEMPORAL PRODUCTION RELATIONSHIPS

Conservation is not entirely a unique problem in economics. As in other areas of production economics, the problem is one of allocating scarce resources between competing alternatives. Competition, however, with respect to the conservation problem is between products of different time periods. With this exception, the optimum level of conservation might be defined within the usual framework of production economic principles. The relationships are between those denoted as joint products in economic analysis. Competition for resource services is, of course, between many periods on into eternity. In the analysis which fol-
lows the problem has been restricted to competition between two time periods, $t_1$ (the present) and $t_2$ (the future).\textsuperscript{25}

**INTERTEMPORAL JOINT PRODUCTS**

Resources can be divided into two *pure* categories depending upon the nature of the joint relationship between the resource *services* that become available in one time period compared with another.

In the first category are those resource services that become available over time in fixed proportions and which can therefore be called intertemporal joint products. These are sometimes termed flow resources. Well known examples include rainfall, sunshine, power from streams and wind, scenery, etc. These resource services are *joint* in the strictest sense; the possibility does not exist for substitution of the flow from one time period for that of another period.\textsuperscript{26} The case is illustrated in fig. 6 by letting the axes measure the quantity of the *service* itself that becomes available in $t_1$ and $t_2$. The intertemporal combination can be only one of $OU$ in $t_1$ and $OV$ in $t_2$. The service itself cannot be withdrawn from $t_2$ to be used at an earlier date, $t_1$.

Flow resources can be divided into two classes: (1) those which produce nonstorable services, such as wind, sunlight or scenery; and (2) those which yield services which can be stored, such as water for power or irrigation. For the nonstorable services, the intertemporal relationship is again that of fig 6. The services are produced in fixed proportions ($OU$ in $t_1$ and $OV$ in $t_2$). This is the only possible combination in which they can be used since utilization cannot be postponed from one period until the next.

The situation for storable flow services is illustrated in fig. 7 by the intertemporal opportunity curve $MPN_2$. Since

\textsuperscript{25}Additional periods could be incorporated into the analysis by resorting to higher mathematics. However, this step has not been taken in order that simplicity be retained. The basic principles and conclusions are similar in any case. The length of the time period ($t_1$ or $t_2$) is also irrelevant. It may be a time span of any number of years. The simple geometries employed understate the complexity of the problem and its solution, but use of other mathematics would increase the complexity of analysis. It must be recognized that the mode of analysis employed here is inadequate when sufficient time periods are included. Obviously, consideration of more than two time periods can hardly be handled by means of production or utility surfaces. In this sense our presentation is overly elementary (the problem involves infinite numbers of periods and individuals), too, while it is possible to imagine the utility relationships present here for one individual for a total time span $T$ (made up, for example, of two time periods, $t_1$ and $t_2$ of one or a few days each), it is less easy to visualize these relationships as they relate to a time span ($T$) of several hundred years. However, within the framework of these limitations the analysis provides some elementary but basic logic which is helpful to the nonmathematician.

\textsuperscript{26}Aside from short-run fluctuations in climate, the quantities of the important flow services available in different time periods are equal.
the resource services are produced in fixed proportions between time periods, utilization of the services at the time they become available in periods \( t_1 \) and \( t_2 \) would allow utilization of \( OM \) in the former and \( ON_1 \) in the latter period. However, since all of the service produced in the earlier period (\( t_1 \)) can be stored until the later period (\( t_2 \)), the maximum quantity available in \( t_2 \) is equal to that produced in this period plus that stored from the earlier period (which is equal to \( OM \) if the resource service does not deteriorate in storage). Thus the possible intertemporal combinations of resource services include: (1) \( OM \) in \( t_1 \) and \( ON_1 \) in \( t_2 \); (2) none in \( t_1 \) and \( ON_2 \) in \( t_2 \); or (3) anything between these two extremes.

The second pure category includes those resources which yield services that permit a latitude of substitution between time periods. They arise from stock (exhaustible) resources such as coal, petroleum and certain soil mineral deposits. Here sacrificing the use of the service in one period increases the quantity available in another period. The case is illustrated in fig. 8 where the axes also indicate the quantities of resource service available in different time periods. The line \( R_2S_2 \) is the intertemporal opportunity or iso-resource curve. It indicates the various possible intertemporal combinations of services possible from given stock resources. In the illustration the opportunities are as follows: (1) The total services (\( OR_2 \)) from the given stock of resources can be used in period \( t_1 \). (2) The total services (\( OS_2 \)) can be used in period \( t_2 \). (3) The intertemporal combination can include \( OR_1 \) in \( t_1 \) and \( OS_1 \) in \( t_2 \), or any other combination shown on the intertemporal opportunity (iso-

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The \( PN_2 \) portion of the opportunity curve will be linear or indicative of a constant marginal rate of substitution between two specific points in time even though an increasing rate of deterioration may hold over time.
resources) curve. A greater use in one period always necessitates a sacrifice of service in another period.\textsuperscript{28}

The relationships along the line $R_2S_2$ in fig. 8 indicate the possible combinations of use of resource services in $t_1$ and $t_2$ that will completely use up the services from the resource. Additional periods can be brought into the analysis, but the relationship is still one of using up the stock of resource services over the specified time periods.

**COMMODITIES**

The analysis above has been in terms of the productive services derived from basic resources. It can also be applied to *consumption commodities* which, although derived directly from the resource services are derived indirectly from the basic resources. The analysis thus remains the same except that the relevant relationship is now directly between the basic resource and the commodity (product). In figs. 6, 7 and 8 the axes now indicate the quantities (combinations) of intertemporal products available for consumption from the categories of basic resources in the different time periods.

For commodities produced in fixed proportions and not storable (atmosphere, scenery, etc.), the intertemporal relationship is again that of fig. 6. This combination is the only possible one since direct consumption of the services cannot be postponed from one period until the next.

For commodities which can be stored from one period to another, and which are derived either from storable or non-storable flow resources, the situation is illustrated by the

\textsuperscript{28}In fig. 8, as is indicated by the convexity of the curve $R_2S_2$, the rate of intertemporal substitution is at an increasing marginal rate. Each successive increment of services in $t_1$ ($t_2$) necessitates increasingly greater sacrifices of services available in $t_2$ ($t_1$). Another possibility is substitution at a constant rate (as suggested by the linear intertemporal opportunity curve $PN_2$ in fig. 7). However, fig. 8 (increasing marginal rate of substitution between time periods), is the most likely case; expansion in current services by increasingly greater magnitudes is possible only as easily accessible deposits of basic resources are exploited. Accordingly, supplies of future services may suffer in absolute amounts for two reasons. The less productive deposits which might otherwise have been extracted, are lost as gas pressure diminishes, coal shafts collapse, etc. Too, even in the absence of this absolute loss, a diminishing rate of extraction is necessary over time relative to a given quantity of *working resources* (labor and capital for extraction of the basic resources): A greater output of services in one time period ($t_1$) from a given ($X$) quantity of working resources is possible only through extraction of the most productive (accessible) deposits. Thus $X$ working resources must produce less in a later period ($t_2$) since they are employed in extracting less productive (accessible) deposits. (The productivity of $X$ working resources in period $t_2$ ($t_1$) is an inverse function of the productivity of the same $X$ resources in $t_1$ ($t_2$) except for the complementary case noted later. We employ the notion of increasing marginal rates of substitution for stock resource services in the analysis which follows. However, the basic principles would be exactly the same were the concept of constant rate employed.)
intertemporal opportunity curve $MPN_2$ in fig. 7. With respect to a storable commodity the intertemporal choices are the same whether the commodity is derived from a storable or a nonstorable flow resource. There are the following alternatives: (a) The resource services can be transformed into commodities which in turn can be consumed within the same time period. (b) The resource services can be transformed into commodities in an early time period ($t_1$) which can be stored for consumption in a later period ($t_2$). (c) With storable flow resources, the resource service can be stored for transformation into product in the later time period. If the resource services are available in fixed (and equal) proportions between time periods, consumption of the products at the time they are derived in periods $t_1$ and $t_2$ would allow $OM$ consumption in the former and $ON_1$ consumption in the latter period. However, since all of the product produced in the earlier period ($t_1$) can be stored until the later period ($t_2$) the maximum quantity of commodity available in $t_2$ is equal to that produced in the later period ($ON_1$) plus that stored from the earlier period ($OM$). (The quantity available for consumption in $t_2$ would also be $ON_2$ if the resource service were stored until the latter period.) Thus the possible intertemporal combinations of the commodity include (1) $OM$ in $t_1$ and $ON_1$ in $t_2$, (2) none in $t_1$ and $ON_2$ in $t_2$ or (3) anything between these two extremes. These relationships may be illustrated by possible alternatives in use of irrigation water to produce crops: (a) A given quantity of water might be used in each of two time periods to produce crops of wheat which were consumed when produced; (b) all or part of the wheat from the crop produced in $t_1$ might be stored until $t_2$; (c) all or part of the irrigation water available in $t_1$ might be stored for use in $t_2$.

For commodities produced from a given stock of resources, the intertemporal relationship is similar to that for stock resource services as illustrated in fig. 8, with one exception. The marginal rate of substitution between time periods may not be the same for the commodity as for the resource service. This situation is illustrated by fig. 9, in which $AC$ represents a stock of a given resource available in two time periods, and $AB$ represents the quantity of a consumption commodity that can be made available in the two time periods if all the resource is used up in period $t_1$. The stock resource might be phosphate for example, and the commodity, wheat. If all the phosphate were used up in $t_1$ to produce wheat, some of the wheat stored until $t_2$.
could be expected to deteriorate. With other resources and products, the reverse might be true. The trees in New England blown down by the hurricane of 1938 represented a stock resource that deteriorated very rapidly unless converted into a consumption commodity—lumber.

**Fig. 9.** Effect of resource use on production opportunities in two time periods.

**INTERTEMPORAL CONSUMPTION RELATIONSHIPS**

Up to this point the discussion has considered intertemporal production alone. Attention is now turned to intertemporal consumption relationships. These are expressed by means of the conventional indifference curves and indicate the various intertemporal combinations of products which make possible a given (equal) total consumer utility. An acceptable hypothesis is that future and present goods substitute at diminishing marginal rates. This situation is expressed in the concavity and slope of indifference curve $GH$ in fig. 11, the smaller the quantity of $t_1$ goods the greater the quantity of $t_2$ goods necessary for their replacement and vice versa. A concave curve is more realistic than suppositions in many expositions on interest and conservation that the total of goods in a future period is discounted by a given amount such as 5 percent. At some level of consumption the consumer or society places an increasingly lower value on present ($t_1$) than future ($t_2$) goods and vice versa (apart from the length of the time periods). The slope of an intertemporal indifference curve will then depend on two major factors: (1) the relative values which present individuals attach to their own consumption in different periods, and (2) the values which present individuals

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20 Alternative hypotheses are offered in figs. 10 and 12. One unlikely possibility is that consumers do not discount future goods. In this case the intertemporal indifference curve is linear ($IF_1$ in fig. 10) indicating constant marginal and equal absolute rates of intertemporal substitution. A second unlikely possibility is that the consumer discounts the future but by a constant marginal rate ($IF_2$ in fig. 10). However, two units in $t_3$ are necessary to offset one unit in $t_1$. (Commodities stored or conserved from $t_1$ to $t_2$ are discounted by one-half since $OF_2 = 2OF_1$.) The usual procedure of discounting the future by some given interest rate also assumes an indifference curve. However, it assumes a constant marginal rate of substitution such as $IF_3$ in fig. 10. Too, it is obvious that an indifference curve of the nature of $GH$ in fig. 11 also represents a discount of the future.
attach to consumption by individuals of future generations. The latter is a question of the extent to which present generations value survival of future generations and the level at which they wish future generations to live relative to their own standard. In the analysis which follows an indifference curve is employed of the nature indicated in fig. 11.\textsuperscript{30} (The basic conditions of equilibrium would remain unchanged, however, if one were to employ the alternatives of fig. 10.) Also, a community or aggregative indifference curve is assumed.

**INTERTEMPORAL WELFARE**

Given the production and consumption relationships outlined previously, the rate of resource use which maximizes intertemporal welfare can be defined. First the three production opportunities are examined separately as pure cases: products derived from stock resources; products derived from flow resource services and which can be either consumed currently or stored; products derived from flow services which cannot be stored. Later these *unique* cases are related to each other.

\textsuperscript{30}It is obviously true that the intertemporal utility surfaces are not identical for all individuals. However, the notion of a community indifference curve is useful at this point and leads through the same logic whether it is supposed that it (a) can be derived from heterogeneous individual curves; (b) is for a community of individuals with identical utility surfaces; or (c) represents a community of one individual. It is also likely that the individual's *ex ante* notion of his intertemporal indifference curve differs from his *ex post* notion of this same relationship. Thus if economic action is based on the *ex ante* indifference curve, total intertemporal utility is never maximized. This is a problem in consumer dynamics for which current economic theory provides few solutions. Without "solutions" here it is impossible to formulate a simple optimum time-use of resources in the vein presented here. It has been suggested to the writers that the use of a "future discount" such as 5 percent does not lead into the complexities of assuming a community indifference curve. This is not true, however, since even the notion of a discount society of 5 percent does imply a community indifference curve (except that it is linear).
For a society in which stock resources alone are available the conditions which define a maximum intertemporal welfare are illustrated in fig. 12 where $Y_3X_3$ represents the intertemporal substitution rates of goods in production while $G_1H_1$ and $G_2H_2$ represent different intertemporal substitution rates of goods in consumption (disregard the ordinates $O'Y'$ and $O'X'$ at this point). $G_1H_1$ represents a high (low) value attached to present (future) relative to future (present) goods while $G_2H_2$ represents a relatively greater value attached to future goods. Intertemporal welfare can be maximized when the marginal rate of substitution of goods in consumption (indifference curve $G_1H_1$ or $G_2H_2$) equals the marginal substitution rates of goods in production (transformation curve $Y_3X_3$). Geometrically, this is denoted by the tangency of the separate curves indicating production and consumption relationships. In respect to the intertemporal indifference curve $G_1H_1$, welfare is maximized over time by production of $OY_2$ and $OX_1$ in the time periods $t_1$ and $t_2$ respectively. The quantity $Y_2Y_3$ (equals $OX_1$ if resources do not appreciate or depreciate over time) should be conserved. This is the economic level of conservation. It can be defined in no other sense if the criterion is one of intertemporal welfare. For indifference curve $G_2H_2$ (a higher value on future consumption) $OY_1$ should be consumed and $Y_1Y_3$ (equals $OX_2$) should be conserved in period $t_1$ if welfare is to be maximized over time.

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31 Total welfare over the two time periods would always be less for any other combination of intertemporal products. Tangency of the two curves denotes a maximum utility: (1) An indifference curve indicative of a greater total utility over time would not be consistent (could not be attained) with the quantity of products possible (over the same time period) from the given deposit of resources. (2) An indifferent curve which intersects (one lower relative to both the $X$ and $Y$ axes) the production curve would represent a total utility less than could be attained with the given deposit of resources. This is evident from the fact that the consumer would always prefer (total utility would always be greater from) more rather than less of all products from all time periods. Accordingly, greater attainment of all can be realized by higher and higher (in respect to both the $X$ and $Y$ axes) indifference curves until the one which is tangent to the production curve is attained. Tangency of the two curves denotes equal slope and hence equation of the ratios of substitution. The relevance of production and consumption ratios are obvious: If (a) one unit of consumption in $t_1$ ($t_2$) gives as much satisfaction as two units in $t_2$ ($t_1$) and (b) sacrifice of one unit of production in $t_1$ ($t_2$) allows one unit of added production in $t_2$ ($t_1$) then (c) greater intertemporal welfare will be forthcoming by consuming the product (resource) in $t_1$ ($t_2$). If (a) one unit of consumption in $t_1$ is equivalent in utility to two units in $t_2$ while (b) sacrifice of one unit of production in $t_1$ allows output of two units in $t_2$ then (c) total welfare will be as great by consumption of all in $t_1$, all in $t_2$ or any "in between" combination. For detailed presentation of similar relationships which can be transposed into those discussed here, see:


FLOW-DERIVED PRODUCTS IN DIRECT CONSUMPTION

Only one possibility exists in maximizing intertemporal welfare over time if flow resources alone are available. The flow-derived products must be consumed in exactly the proportion in which they are forthcoming. The slope of the intertemporal indifference curve has no relevance. An indifference curve with the slope of either $G_1H_1$ or $G_2H_2$ (fig. 12) would denote the same intertemporal rate of use ($OU$ in $t_1$ and $OV$ in $t_2$) (fig. 6). The only economic question here is one of equating marginal cost (in terms of working capital and labor) with marginal return of utilizing the service in one period.

FLOW-DERIVED PRODUCTS WITH STORAGE ALTERNATIVES

A society falling within this pure case and attempting to maximize intertemporal welfare should always consume products during the period in which they are produced if the future is discounted by any amount whatsoever, as illustrated by fig. 7. Any indifference curve (denoting maximum utility) with a slope of less than 45 degrees (denoting a greater value on present than future consumption) would be tangent to the intertemporal opportunity curve ($MPN_2$). Any additional point is of interest previous to our subsequent analysis. In terms of production relationships, the output of one period is not always competitive with that of another period even though the supply of resource services is of fund or stock nature. This possibility is illustrated by the production opportunity line ($CM$) of fig. 17. Here the greater the output in period $t_1$, the greater also is output of a later period $t_2$. This possibility exists especially when we relax our conditions of an equal supply of working capital and labor. Extraction of increasing quantities of the stock resource deposits (even though these be the most productive or accessible) in $t_1$ which are not only consumed but also transformed into working capital, may make possible the extraction of greater quantities of resource deposits (even though they be less productive or accessible) in period $t_2$. Speeding up the rate of extraction in a current period simply makes possible a greater capital stock and thus an accelerated rate of withdrawal from the given resource fund at a later time. History is, of course, replete with examples of this kind. In agriculture, an exploitation of the soils by the pioneer made possible an increase in numbers of draft animals and tillage implements such that an even greater acreage could be cultivated and exploited. The same is still true to a wide extent, especially on tenant-operated farms. We can now return to our “one generation” consumption relationship and investigate the equilibrium level at which resources will be conserved (or conversely, exploited) if intertemporal welfare is to be maximized. Obviously, there can be no level of conservation which will maximize welfare over (the two periods of) time if production (exploitation) in $t_1$ is entirely complementary with production (exploitation) in $t_2$. Total welfare over time will always be greater by withdrawing a greater stock of the resource deposits in $t_1$. This is evident in the family of indifference curve suggested by $I_1J_1$ and $I_2J_2$ representing increasing higher levels of total utility respectively. (The rate of substitution between goods consumed in the two periods is still at a diminishing rate. However, consumers can always attain a higher total level of utility by consuming more of all goods. Indifference curve $I_1J_1$ represents a greater total utility than $I_2J_2$. The sum of the utility in the two periods will always be increased by exploitation in $t_1$ since production in $t_2$ is also greater, and a higher indifference curve is always attained.) As long as intertemporal complementarity exists, there is no economic limit to exploitation. Intertemporal welfare will always be increased by extending withdrawal of resources in current periods. Obviously, if the time periods are long enough, their products cannot be complementary.
at the point $P$ (denoting consumption at the rate of $OM$ in $t_1$ and $ON_1$ in $t_2$). In order for future consumption to be increased at the expense of present consumption in this pure case, the indifference curve must have a slope of more than 45 degrees (in some range and of 45 degrees at the point of tangency) denoting a premium on future over present consumption. Here societies of the present would anticipate a greater future need (say, in case of war) or would prefer that (even without technological improvement) future generations live at a higher level than themselves. If the discrete periods are long enough it is possible that commodities (produced from flow services) cannot be stored into the next period. This is the case of agricultural commodities. Meat and other perishables can be withheld from consumption only for short periods and storage for grains and other staples is also limited. If the relevant time periods ($t_1$ or $t_2$) are long enough, the category of flow-derived products which are storable become synonymous with flow-derived products consumed as the resource service is available (pure case 2 above), and the problem is not entirely one of conservation (competition between time periods).

Some commodities embody both flow and stock resource services. Widespread examples are in agriculture where crops draw both from the stores of chemical elements and the annual flow of sunshine and rainfall. In terms of pure analysis this hybrid case is still illustrated by two of our discrete and pure cases depending upon the limiting elements in production. If the flow resource is available in unlimited, and stock services are available in limited, quantities, then solution is still in terms of 1 above. If flow resources are the limiting factor in production, the solution is given in Case 1 or 2 above. There are also other hybrid flow-stock situations more complex than those outlined here.

POPULATION LEVELS, CHANGE AND OPTIMUM CONSERVATION

Two categories of changes affect the level of resource use (conservation) which will maximize intertemporal welfare. These include changes in the intertemporal rates of substitution of (1) goods in production and (2) goods in consumption. Major forces altering the consumption substitution rates are changes in population and changes in tastes.

Reference here is to the situation where the product stored from period $t_1$ does not grow but either remains constant or deteriorates in quantity.
(of given populations). The effect of changes in tastes (the relative rate at which future goods are discounted by a given population) are obvious.\textsuperscript{34}

Differences in population taken alone (in the absence of (1) changes in tastes or relative values of goods in various time periods and (2) changes in techniques) need not alter the level of conservation which will maximize intertemporal welfare. Suppose that two populations (one of \(N\) individuals and another of \(2N\) persons) are possible. If the two populations place similar values on consumption in different time periods, the slopes of their respective indifference curves will be identical and both must consume (conserve) products at the same rate to maximize utility (the transformation curve given). The \(2N\) population will have only one-half as much product per person in any one time period but its rate of use between time periods will coincide with that for the \(N\) population.

Changes in the intertemporal rate at which goods in production substitute for each other are brought about mainly by improved techniques (including discoveries of new, or loss of existing, resource deposits). Changes in techniques may conceivably increase, leave unchanged, or decrease the rates at which resources are conserved (consumed) between time periods. These three possibilities are illustrated geometrically in figs. 13, 14 and 15 respectively where the axes represent the quantities of product possible from given stock resource deposits in periods \(t_1\) and \(t_2\). Fig. 13 is the commonly recognized case in which the new technique results in (changes in tastes or similar variables absent) a greater absolute level of consumption in both the present \(t_1\) and future \(t_2\) time periods. In our example, the relative rate of consumption is also exactly the same under the new \((A'B')\) as under the old \((AB)\) technique. The new technique indicates that, given a specific rate of use in one period, a greater product (quantity of resource services) is physically possible in another period. For example, consumption at the rate of \(OY_1\) in \(t_1\) would allow consumption only at the rate of \(OZ_1\) in period \(t_2\) under the old technique \((AB)\). Under the new technique \((A'B')\) consumption at the rate of \(OY_1\) in period \(t_1\) will allow consumption at the rate \(OZ_3\) in period \(t_2\). Assuming no change in values at-

\textsuperscript{34}In fig. 12, a change in tastes which increases the rate of substitution of future \((t_2)\) for present \((t_1)\) goods would have the effect of altering the intertemporal indifference curve from \(GH_1\) to \(GH_2\). Accordingly, the level of conservation will increase (from \(Y_2Y_3\) to \(Y_1Y_3\) in \(t_1\)). A decrease in the rate of substitution of future for present goods (a shift from \(GH_2\) to \(GH_1\)) has the opposite effect.
tached to consumption goods of different periods (as denoted by identical slopes or marginal rates of substitution for indifference curves $GH$ and $G'H'$) total utility will be maximized (at a higher level) under the new technique only if the consumption ratio between the two time periods is exactly the same as under the old technique ($OY_1/OZ_1 = OY_2/OZ_2$). This outcome holds true, however, only where the marginal rates of intertemporal substitution of goods in production are the same under the new as under the old technique ($AB$ and $A'B'$ have the same slopes).

Figure 14 illustrates the case in which the new technique results in (1) a greater utility over time but (2) a greater absolute consumption in an early ($t_1$) and a lower consumption in a later period ($t_2$) (with no change in the slope of indifference curves). Under the old technique ($AB$) the level of conservation in $t_1$ which will maximize intertemporal welfare is $OZ_2'$. The optimum level of conservation is only $OZ_1$ under the new technique ($A'B'$). Intertemporal welfare is increased and maximized by present ($t_1$) consumption at the sacrifice of future ($t_2$) consumption only because the marginal rates of substitution of goods in production have been altered in the favor of former time period.

Figure 15 illustrates a case in which intertemporal transformation ratios are altered in a fashion which increases and maximizes intertemporal welfare by expanding later ($t_2$) at the expense of earlier ($t_1$) consumption.

Other alternatives are that both future ($t_1$) and present ($t_2$) consumption expand absolutely and either (1) $t_1$ consumption increases relatively or (2) $t_2$ consumption increases relatively. In agriculture, such innovations as hybrid
corn change the transformation ratio toward the present and encourage increased yields and hence a greater soil exploitation relative to the future. Innovations such as improved terracing and forages tend to throw an advantage in the opposite direction. In *extractive* industries, innovations which have greater application to easily accessible deposits have the effect of speeding up early as compared to later consumption.

**COMPOSITE SUPPLY OF STOCK AND FLOW RESOURCES**

Two pure cases of intertemporal production (joint products (1) in fixed proportion and (2) with a latitude of substitution) have been examined previously. Both categories of resource services exist side by side. An important practical economic problem is the extent to which flow resource services (flow-derived products) should be substituted for stock resource services (stock-derived products) in current periods in order that the latter might be conserved. This is partly the problem in the irrigation and reclamation projects of agriculture where there are alternatives of (1) exploiting the soil in developed farming regions now and initiating irrigation in undeveloped regions at a time when depletion and perhaps erosion has diminished the product from the former region or (2) develop irrigation projects at the present and save the chemical elements of developed regions for the future. These possibilities also exist in substituting electricity derived from water power for that derived from coal.

The analysis which follows treats equilibrium of production and consumption under the conditions of a supply of flow and stock resources in combination. It is retained as a pure case and hence is simply a variant of the situations already discussed. Presentation is abbreviated by means of the simple geometrics of fig. 16.

First, refer to the oy and ox axes (independent of the OY and OX axes) which indicate the situation for stock resources alone. The transformation curve $y_2x_2$, indicates the intertemporal production opportunities. Production can be, for example, at the rate of (1) $oy_2$ in $t_1$ and zero in $t_2$, (2) $ox_2$ in $t_2$ and zero in $t_1$, or (3) any combination (consistent with the opportunity line $y_2x_2$) between these two extremes. Given the intertemporal indifference curve $GH$, the optimum rate (as denoted by tangency of $GH$ and $y_2x_2$) at which the product derived from stock resource should be consumed in $t_1$ is $oy_1$ if intertemporal welfare is to be maxi-
mized. The product conserved in $t_1$ and consumed in $t_2$ is $y_1y_2$.

Second, consider the situation of flow resources alone and refer to the $OY$ and $OX$ axes (disregard the $oy$ and $ox$ axes and any of the geometric figures which fall within these). The point $o$ represents the availability of the flow-derived joint products (fixed proportions) in the period $t_1$ and $t_2$. Only one intertemporal combination of products, $OY_1$ in $t_1$ and $OX_1$ in $t_2$, is possible. Irrespective of the slope of the indifference curve (the marginal rates at which consumption goods substitute for each other between the two time periods), consumption must be at these rates for the reasons previously outlined.

Finally, the products derived from stock resources can be added to those derived from flow resources. In reference to the $OY$ and $OX$ axes, the maximum supply of products available in period $t_1$ is then $OY_1$ flow-derived plus $Y_1Y_3$ (equals $oy_2$) stock-derived product for a combined total of $OY_3$. Similarly, the maximum supply possible in $t_2$ is $OX_1$ flow-derived plus $X_1X_3$ (equals $ox_2$) stock-derived for a total of $OX_3$. The composite intertemporal transformation curve is now $Y_3y_3x_3$ $X_3$. The extreme consumption opportunities are (1) $OY_3$ (equals $X_1y_2$) product in $t_1$ and $OX_1$ in $t_2$ or (2) $OX_3$ (equals $Y_1x_2$) in $t_2$ and $OY_1$ in $t_1$. Any intertemporal combination (indicated on the transfor-
mation curve) between these extremes is possible but it will always include a flow-derived component of \(OY_1\) in \(t_1\) and \(OX_1\) in \(t_2\) if welfare is to be maximized.

What rate of consumption (of (1) total product and (2) stock-derived product) in each time period will maximize intertemporal welfare when flow and stock resources are considered jointly? Let \(GH\) (relative to the \(OY\) and \(OX\) axes) indicate the intertemporal substitution rates for consumption goods. Thus we assume no change in the marginal intertemporal rates of substitution of consumption goods but \(GH\) now represents a greater total utility (than in previous employment of \(GH\) relative to the \(ox\) and \(oy\) axes for stock-derived products alone). Maximum intertemporal welfare is again indicated in fig. 16 by tangency of \(GH\) and \(Y_3y_2x_2X_3\) denoting a total consumption in \(t_1\) of \(OY_2\) composed of \(OY_1\) flow-derived and \(Y_2Y_3\) stock-derived products. The optimum level of conservation of stock-derived product in \(t_1\) is thus \(Y_2Y_3\) (\(= OY_1\)).

Given identical slopes of the indifference curves, the level of consumption of stock-derived products in any time period will be the same regardless of the supply of flow-derived products. (The level of conservation of stock resources will be the same in fig. 16 regardless of whether the annual stream of flow-derived products is zero or \(OY_2\) (\(= OX_1\)).

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35 Consumption of flow-derived products will never be less than \(OY_1\) in \(t_1\) and \(OX_2\) in \(t_2\) since any indifference curve regardless of its slope (or the discount of future goods) which intersects the \(Y_2Y_3\) or \(X_2Y_3\) portion of the intertemporal transformation curve \(Y_2x_2Y_3x_3\) indicates a smaller total utility than is possible. Any indifference curve which does not represent a complete discount of either \(t_1\) or \(t_2\) goods could only intersect (could not be tangent with) these portions of the transformation curve.

36 An added alternative is that the slope of the intertemporal indifference curve does change (changes in tastes or utility surfaces still absent) the greater is the total of goods available or utility possible (and hence the higher the indifference contour that can be attained on the total utility surface). If moving to an indifference curve higher on the total utility surface has the effect of increasing the rate at which future goods (\(t_2\)) substitute for present goods (\(t_1\)) (increases the slope of the indifference curve toward the \(t_2\) axis), a form of substitution will take place when the supply of flow-derived products are added to the fund of stock-derived products. The higher utility contour will be attained by increasing consumption of flow-derived products and decreasing consumption of stock-derived products in period \(t_1\) (since an indifference curve of greater slope than \(GH\) in fig. 11 would be tangent to the \(y_2x_2\) portion of the combined transformation curve at a consumption in \(t_1\) indicative of less than \(OY_1\) stock-derived products). It follows that an increase in the absolute quantity of stock-derived products would thus be conserved for consumption in \(t_2\). The same qualification applies to earlier analyses of stock-derived products. Although two populations of \(N\) and \(2N\) might place identical values on products of different time periods (be made up of equal proportions of individuals with identical utility surfaces), the \(2N\) population will be on a lower utility contour (since it has only half as many resources per person). The lower the contour is on the total utility surface the greater is its slope in the direction of \(t_1\) products; the optimum rate of conservation (consumption) in \(t_1\) will be lower (greater) for the \(2N\) than for the \(N\) population. The same variations apply in the case of changes in techniques where higher utility contours are attained. Conservation of stock-derived products, of course, will shift in the opposite direction if higher indifference contours (on the total utility surface) are associated with a greater slope toward the \(t_1\) axis.
Previous discussion has assumed that the basic stock of resources (which serve as raw materials from which products are derived) were the limiting factors in production. The quantity of capital and labor available for transforming (basic stock and flow) resource services was considered great enough to allow an output of flow-derived plus stock-derived products in \( t_1 \) or \( t_2 \) indicated by the transformation curve \( Y_3y_2x_2x_3 \) (the transformation curve represents the totality of opportunities including limitations of labor supply and the basic resources from which either working capital might be fashioned or consumption goods derived). Now suppose that the quantity of working capital and labor is limited to the extent that attainment of the combined (flow-derived plus stock-derived) output indicated by \( Y_3y_2x_2x_3 \) is impossible in the relevant total period. Suppose, for example, that if the output of flow-derived product is \( OY_1 \) (\(OX_1\)) in \( t_1 \) (\(t_2\)) the limited supply of working capital and labor restricts output of stock-derived products to less than \( Y_1y_2(x_1x_2) \). The supply of basic (flow and stock) resources of raw materials is not then the limiting factor in maximizing welfare over the total time span \( T (= t_1 + t_2) \). Instead the limiting factor is the supply of working labor and capital.

Timing of production is not then a central problem in maximizing welfare in the total time span \( T \). The crucial problem is the extent to which the given stock of labor and capital should be allocated to production of stock-derived as compared to flow-derived product in any single period (\( t_1 \) or \( t_2 \)). The solution lies, of course, in equating the marginal productivities of labor and capital when allocated between the two alternatives of flow-derived and stock-derived products.

An important substitution problem arises out of dynamics and anticipation.\(^{37}\) The possibility always exists that a society will be called upon to draw heavily and rapidly upon its resources in case of future emergency. Availability of resource services which can be converted to product in a short-time span is thus important. Conversion of the given stream of flow services cannot be speeded rapidly. Hence

\(^{37}\)Actually, the real problems of conservation lie in the field of dynamics and anticipations. This analysis like that of others (Reder, Melvin L. Studies in the Theory of Welfare Economics. Columbia University Press, New York. p. 33-34. 1947) oversimplifies the problem by reducing time to static treatment of variables. Anticipations, the important framework within which decisions must be made, are hardly considered. Until there is a more nearly adequate set of dynamic tools, the important problems of conservation will go unsolved.
a premium may be placed on retaining (building up) a storage of stock resources (services) which can be converted to product on short notice. This may be accomplished by substituting flow for stock resource services in production of current consumption goods. A sacrifice or a cost thus occurs in the present if the working capital and labor employed in converting the raw materials into product has a lower productivity if the source is flow rather than stock resources. The loss in welfare is also for all time should the eventuality fail to be realized. However, the cost is one of flexibility and is not only consistent with (1) an *ex post* maximization of welfare if the eventuality occurs but also with (2) an *ex ante* anticipation of welfare maximization even if the eventuality does not occur.

**INTERGENERATION WELFARE**

Existing economic tools cannot be used to formulate a use of resources which will maximize intertemporal welfare beyond one and over all generations in time. The analysis outlined above can apply only to a generation. This is true because of the impossibility of interpersonal utility comparisons. Obviously, the problem of interpersonal utility comparisons exists and is accentuated between generations; comparisons cannot be made in *consuming* a unit of resources between an individual of an existing generation and an individual of a discrete generation 200 years hence.

Although interpersonal utility comparisons are impossible at a given point in time (within a generation) an optimum allocation of production and consumption over time can be formulated if objective means exist whereby each individual can express his relative values. In a democracy the mode of expression is provided in voting through either the price mechanism or the ballot system. In this sense reflection of a community indifference curve of the nature suggested by GH in fig. 11 is possible for a single generation. Expression is in the structure of market prices and in the legislation of the society. This utility expression or comparison is impossible, however, between distinct generations. An individual of a generation 200 years hence has no method of expressing his intertemporal indifference curves; he can vote neither through the market mechanism nor the ballot system. The welfare of a future generation \( g_n \) stands to be greater had not the increment of stock resources been consumed by an earlier generation \( g_{n-100} \). The marginal utility derived from consuming the increment \( X \) might well be greater for generation \( g_n \) than for genera-
tion \( g_n \) and vice versa. The impossibility of interpersonal (intergeneration) utility comparisons excludes proof that either holds true.

OPTIMUM LEVELS AND INTERGENERATION COMPENSATION

Modern welfare economics handles the problem of (inability to make) interpersonal utility comparisons at a given point in time by the principle of compensation. Two general types of economic reorganization are recognized (1) those which increase the total utility of some individuals without decreasing the total satisfactions of other individuals and (2) those which increase the total utility of some individuals but at the same time decrease the satisfactions of the other individuals. Social welfare increases under the second type of reorganization only if the increment in utility to the recipient group is greater than the decrement in utility to the sacrificing group. Because of lack of interpersonal utility comparisons, however, increased welfare can be guaranteed only through the principle of compensation; those who originally sacrificed as a result of the reorganization must be provided with compensation to completely redress their loss while the welfare of recipient groups must increase. The problem of intergeneration conservation is identical with the elements outlined above: (1) Conservation relates to a reorganization which improves the utility position of some persons (generations) but lessens the utility position of other persons (generations). (2) Intergeneration (and hence interpersonal) utility comparisons are impossible.

Accordingly, cannot the principle of compensation be applied to guarantee that while some generations will be made better off, no generation will be worse off and, accordingly, an increase in intergeneration welfare is guaranteed? The answer is negative under specified conditions.\(^{38}\) Compensation to a present generation for a greater level of conservation can be made only through use of the very resources which otherwise are to be conserved. An increment in conservation by \( X \) quantity of resources (beyond that which defines the optimum for the current generation)

\(^{38}\) These conditions are (1) the intertemporal joint products are competitive (arise from stock resources in the sense that the greater the quantity used in one period, the smaller the quantity available in another period), (2) the most efficient techniques of transforming resources into services are employed, (3) the existing level of resource consumption is the one which expresses the current generation's optimal position (tangency of the intertemporal product substitution curve and the current generation's intertemporal indifference curve—including the value which the existing generation places on varying levels of consumption by future generations) and (4) the particular conditions of equilibrium mentioned later in the study are attained.
would require use of the same $X$ quantity of resources for compensation were the present generation to be left as well off as previously. In this vein conservation compensation is impossible for an intergeneration society.

What, then, is the optimum level of conservation for an intergeneration society? Existing scientific logic can only state this: The optimum level of conservation is what each succeeding generation thinks it to be (including the relative value placed by the current generation on consumption for future generations). The values of discrete generations cannot be linked together *ex ante* into a single index for all time to give one optimum level of conservation for eternity. In this vein, the level of conservation which is ideal or optimum changes with the values of each succeeding generation. If today's generation chooses to be spendthrift and squander resources at the expense of consumption by future generations, the level of conservation expressed is the optimum at the time and through eternity as far as can be determined by existing tools of science. If tomorrow's generation chooses to be misers, merely subsist and hoard resources which are then used for luxury consumption by a succeeding generation, existing economic tools cannot defy that the level of conservation is optimum and that welfare has been maximized between generations.

**INTRAGENERATION RELATIONSHIPS AND COMPENSATION**

Thus far we have referred to a community intertemporal indifference curve ($GH$ in fig. 11). Use of this aggregative relationship, even for a single generation, must recognize that this community indifference curve must be regarded, however, as a composite expression of the intertemporal substitution rates for many individuals. Accordingly, the particular conditions of equilibrium are outlined which must exist in order that a community indifference curve be *reflected* in some sense and in order that intertemporal equilibrium be attained. Reference is to a *single generation*.

At least two important conditions must be attained between particular units before aggregate intertemporal intrageneration welfare can be maximized. (1) **The marginal rates of intertemporal substitution of consumption goods must be equal for every pair of individuals.** Intertemporal welfare can be increased by conservation of a unit of product from an earlier ($t_1$) to a later ($t_2$) time period by transferring consumption from one individual ($A$) in the early ($t_1$) time period to another individual ($B$) in the later ($t_2$)
time period if the decrement in utility to the former \((A)\) is less than the increment in utility to the latter \((B)\). Here we assume that both \(A\) and \(B\) live in the generation marked by the total time span \(T\) (which is a sum of \(t_1\) and \(t_2\)). (2) the marginal rate of intertemporal substitution of goods in production must be equal between every pair of specific resources. The (product from) various classes of resources (within the over-all category of fund or exhaustible resources) must be related in establishing the optimum level at which each particular class should be conserved. It is not a sufficient condition that coal be used up in one period and petroleum be largely conserved until a later period or that one soil type be exploited in one period while a substitute soil type be reserved as a later replacement. The ratios at which (products from) each particular resource substitute over time must be equated.\(^{40}\)

Two possibilities again exist in attaining these conditions: (1) Certain reorganizations of production increase the product for all time periods and all individuals (especially in some parts of agriculture where readaptation of the management program increases both present and future

\(^{40}\)Similarly, intertemporal welfare will be increased by lowering the level of conservation if the utility gained by \(A\) for a unit of goods consumed in \(t_1\) is greater than the utility of a unit consumed in \(t_2\) by \(B\). The optimum level of conservation is attained only when no more such transfers which will increase intertemporal welfare are possible. Further, these same conditions for optimum levels of conservation must hold between individuals even if direct consumption does not take place within the time period in which either lives. Suppose here that \(t_2\) is a period which coincides exactly with the life of both \(A\) and \(B\). Neither can consume directly a unit of product conserved until \(t_2\). However, if the increment in utility \(B\) indirectly derives from knowledge that a unit of product will be available in \(t_2\) for an individual \((C)\) of a later generation is greater than the utility \(A\) derives from direct consumption of the quantity in \(t_1\), conservation of the unit should take place if welfare is to be maximized.

This optimum can be defined (with proper interpretation of the relationships and ordinates) in fig. 12 if \(G'H_1\) is taken as the indifference curve of individual \(A\) and \(Y'X_2\) represents the (observed) indifference curve of \(B\) (relative to the \(O'Y'\) and \(O'X'\) axes). Here tangency of the two expresses the optimum rate (equation of intertemporal rates of substitution between individuals) at which products should be consumed by both individuals in \(t_1\) and \(t_2\). Individual \(A\) should conserve \(O'Y'\) product in \(t_1\) and \(O'X'\) in \(t_2\). Individual \(B\) should consume \(O'Y'\) in \(t_1\) and \(O'X'\) in \(t_2\).

\(^{40}\)If (a) use of (the product from) one unit in \(t_1\) requires sacrifice of two units of resource \(K\) (growing timber in period \(t_2\)) while (b) use of (product from) one unit in \(t_1\) requires sacrifice of only one unit of resource \(L\) (building stone) in period \(t_2\), the nature of intertemporal substitution is clear. (The examples assume certain conditions in respect to quantity of both specific resources and working capital but which are not enumerated for lack of space.) Resource \(L\) should be used in \(t_2\) (in a magnitude to replace the quantity of \(K\) which might otherwise be used) while \(K\) is conserved until period \(t_2\). Conversely, if (a) conservation of one unit until \(t_2\) requires sacrifice of two units of resource \(K\) in period \(t_1\) and (b) conservation of one unit until \(t_2\) requires sacrifice of only one unit of resource \(L\) in period \(t_1\), then \(K\) should be used in \(t_1\) and \(L\) should be conserved until \(t_2\). \((K\) may be a soil for which erosion or leaching is extremely rapid while \(L\) is a stable soil, or \(K\) may be natural gas that might otherwise escape while \(L\) is coal.)

These equilibrium conditions can also be illustrated in fig. 12 by letting \(Y'X_2\) represent the intertemporal transformation curve for (the product from) \(K\) type resource and \(G'H_1\) suggest the (inverse) opportunity curve for (the product from) \(L\) type resource. Marginal rates of intertemporal substitution are equated and maximum welfare is possible with consumption of \(O'Y'\) of \(K\) and \(O'X'\) of \(L\) in period \(t_1\) with conservation of \(O'X'\) of \(K\) (derived product) and \(O'X'\) of \(L\) (derived product) until period \(t_2\).
output and income). Here an improved position (utility) of each individual within a generation (A and B) and between generations (C as well as A and B) can be guaranteed. Two types of social action are justified here (since an improved position of all individuals and hence a greater total welfare is given) such as education to stimulate, or direct legislation (police power) to effectuate, the readaptation. (2) Other reorganizations may lessen the welfare of some (A) while increasing that of others (B or C). Since interpersonal utility comparisons are impossible, a greater total welfare cannot be guaranteed by simply transferring resources to an intertemporal use which will conform with one individual's (B) as compared to another individual's (A) preferences. The transfer must guarantee that no one is left worse off. This can be accomplished, in the lack of interpersonal utility comparisons, only through compensation from individual (B) who prefers more to the individual (A) who prefers less conservation. Increased welfare cannot generally be guaranteed by police power alone which forces readaptation in intertemporal resource use (in the absence of compensation). Compensation, however, is consistent with a greater total welfare if it allows the individual (A) who prefers early consumption to maintain current levels of consumption at the expense of the other individual's (B who prefers conservation) consumption in the same period. Indirectly this means that B must transfer part of his current consumption to A in order that A can conserve his resources and hence increase B's utility through the latter action (knowing that they will be available for a later generation, etc.). Directly, it is simply B who must curtail current consumption if we are to accept the doctrines of modern welfare economics.

The analysis above focuses on the consumer relationship as it should. Discussion of conservation and policy has centered largely around the producer (as the relevant consumer). It is not uncommon to hear both scientific and layman discussions wherein the producer (farmer, petroleum extractor, coal miner) is criticized because he "exploits his resources now." Yet the critic as a consumer goes home and orders (places a relatively higher price on) corn-fattened beef instead of lower-grade, grass-fattened mutton; a petroleum-burning automobile instead of a bicycle, or coal for a fire rather than wool clothing for warmth. (The preferences expressed verbally are not consistent with those expressed price-wise.) Emphasis on the producer (always as the relevant consumer) instead of on the consumer apart from the producer, throws the problem entirely out of perspective.
The logical foundation which has been laid in preceding sections suggests that certain information and steps are necessary to determine and attain a level of conservation which will maximize intertemporal welfare. These include: (1) a detailed inventory of the stock and the flow of each particular resource and the aggregate of all resources. This inventory is necessary to indicate the nature of the intertemporal opportunity curve (to indicate, for example, whether it is of the nature of $AB$ or $A'B'$ in fig. 15. (2) The present rate at which resources are being used should be determined (to indicate, for example, whether it is $OY_2$ or $OY_1$ in fig. 15. (3) The relative rate at which each individual resource is being or can be used should be established and a pattern of conformity established for these rates of intertemporal use (to equate intertemporal transformation opportunities). (4) The nature and extent of future emergencies (including the possibility of a decline in technological advance) should be estimated, and plans established for building reserves of stock resources (and for substitution of flow for stock resources in current consumption). (5) Information should be carried to each individual of society indicating the size of resource stocks and their current rate of use, and the attendant implications for future generations. (The purpose here is not one of forcing values upon individuals but of providing information so that, given the "facts," individuals can more nearly conceive their own values.) (6) Direct machinery should be devised whereby individuals can express their relative values on the intertemporal rate of use. (7) Compensation and other measures should be activated on a scale which will insure the level of conservation which society deems optimum.