THE EVALUATION OF CRITERIA FOR PROTECTION FORESTRY

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SYNOPSIS

The term protection forest is defined. Benefits which accrue from forests are divided between those concerning the soil and those concerning water. Methods of evaluating benefits are discussed with emphasis on those thought to be of particular significance in New Zealand. These are the effect of forest on flooding, and the effect on soil erosion. Some examples are given. There is also some discussion on the concept of multiple-use forests.

INTRODUCTION

Because protection forestry means all things to all people, it would be as well at the outset to consider what is meant by the term. By definition, a protection forest is "an area wholly or partly covered with woody growth, managed primarily for its beneficial effects on water and soil movement rather than for wood or forage production" (Kitteridge, 1948). The emphasis here is on the word primarily, for although in the strict sense of the word a protection forest exists for purely protective purposes, it is rare in fact to find extensive areas where some other values do not come into consideration. These values vary widely throughout the world, and are influenced by such factors as population density and degree of technological development of the population. They range from the basic requirements for fuel, shelter and forage in undeveloped areas, to the more sophisticated needs (of which recreation and wildlife habitat are two) of the affluent society.

In the New Zealand context there would be little disagreement with a classification which described protection forests as "the indigenous forests of hill country and mountain lands where the management objectives are control of soil erosion and water quality, and water yield regulation". Over relatively large areas of these forests, the only management practised is animal control, so that the New Zealand forests probably come as close to the strictly defined protection forest as any.

PROTECTION FOREST BENEFITS

The next stage is to consider the benefits which are likely to accrue from the maintenance or creation of protection forests, to look briefly at these in total, and then to select

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those which appear to have the greatest significance in the New Zealand scene and attempt to evaluate them. These benefits fall naturally into two classes depending upon whether or not it is possible to ascribe a monetary value to the benefit in question. They can be called direct or tangible benefits, and indirect or intangible benefits. In discussing how these benefits come about and how they may be evaluated, emphasis will be centred on the former group.

(a) *Direct Benefits Concerned with Water*

(1) *Effect on Water Yield*

There is ample evidence to indicate that the afforestation of a grassed catchment will result in a decrease in water yield. By the same token, removal of forest results in an increase in run-off. It is held by some that water use by vegetation is independent of vegetation type as it is essentially an energy process. In other words, there is only a limited amount of energy available for evapotranspiration and this is independent of vegetation type. This is true only if a number of conditions are satisfied, and these are, first, that the vegetation is adequately supplied with water; secondly, that the vegetation covers the total soil surface; thirdly, that the roots permeate the total soil mass. These conditions are seldom if ever satisfied simultaneously in nature, and most of the available evidence indicates that differences in water use by different vegetation types can be attributed to differences in rooting depth.

Hibbert (1967) reviewed results from thirty-nine studies of the effect of altering forest cover on water yield. The most interesting of these was without doubt that for a watershed in Coweeta in eastern North America. Here the cutting of hardwood forest increased water yield by the equivalent of 370 mm of rainfall over the area treated in the year following cutting. This increase declined progressively as regrowth occurred, but when the cutting was repeated 23 years later the increase in streamflow was almost identical with that following the original cutting. Hibbert suggests that for most of the temperate regions of the world removal of forest results in an increase in stream-flow of up to 4.5 mm per year (rainfall equivalent), for each per cent. reduction in forest cover.

(2) *Effect on Flooding*

This is the field of forest influences in which the most extreme views have been held. There were in the past those who claimed that wholesale catchment afforestation would make flooding a thing of the past; at the other extreme were those who contended that forests would have no effect whatsoever on floods. The answer lies somewhere between the two. It seems that, for small catchments, forests practically eliminate small storm peaks, and change the timing and duration for larger discharges (Johnson, 1967). Small catchments are ill-defined and many range from a few acres to 100 square miles and they cease to be small when the land use effect is over-

shadowed by channel storage. In other words, in a small catchment, quick return stormflow over and through the soil has more effect on peak flow than has channel flow.

In large catchments, the effect of forests on flooding is most pronounced in those catchments where floods arise mainly from snow-melt. Work in the United States by Anderson and Hobba (1959) showed that cutting of forests, and forest destruction by fire, increased flood peaks owing to rain-snow-melt and to snow-melt alone. In these cases it is the redistribution of snow drifts and slowing of the melt process which is of importance There are a number of interesting possibilities for manipulating snow cover by forest management so as to regulate water yield and flooding.

(3) *Effect on Snow Avalanches*

In densely populated alpine countries, the action of forest in preventing snow avalanches is of paramount importance. Where protection forest has been removed to make way for grazing on high mountain slopes, the danger of snow avalanches is greatly increased. A considerable effort is currently being made in the alpine areas of Europe to re-forest abandoned alpine pastures, with the objective of preventing physical damage to buildings and loss of life. Recent work by O'Loughlin (1969) indicates that snow avalanches in the New Zealand high country are an important agent in soil erosion.

(4) *Effect of Water Quality*

In the first half of the century, those concerned with forest influences were interested primarily in flood control, but there is no doubt that pollution in one form or another has pride of place now. Boughton (1970) has recently reviewed the effect of forests on water quality and he quotes many references for North America where public agitation has reached its highest pitch. In particular, forest management operations in the steep Pacific coastal belt are currently under very close scrutiny, and considerable funds are being expended on research in the fields of logging and roading practice. There is no doubt that, so long as the current world-wide preoccupation with "conservation" and "ecology" continues, there will be demands made for the maintenance of high standards in all operations which could conceivably influence water quality.

(b) *Benefits Concerned with the Soil*

(1) *Effect on Soil Erosion*

There is much evidence which illustrates increased erosion rates following vegetation removal. The rate at which erosion increases varies from a factor 10 to a factor in excess of 1,000, and depends upon a very large number of parameters. There seems to be little doubt that a healthy, mature forest is the most effective form of vegetative cover in preventing soil

erosion. The normal tiered structure of a mature forest means that much more rainfall is intercepted before it reaches the ground than would be the case with a low pasture cover for example. Raindrop impact is then considerably lessened. Further, in a mature forest in good condition there is a continuous cover of litter on the floor which not only reduces raindrop impact even further, but also has a retarding effect on surface flow. Thus, by effectively reducing the energy of falling and flowing water, the forest does much to reduce soil loss. Kitteridge (1948) cites many examples from North American experience with quantitative data. Only one example will be given to illustrate the point. Annual erosion from undisturbed brush cover in North Fork, California, did not exceed 0.01 cu. yd per acre. After the plots were burned over four times in different years, the erosion increased to between 2 cu. yd and 4 cu. yd per acre, a factor of 200 to 400.

(2) Shelterbelts and Dune Stabilization

It is not proposed to deal with these in detail although they are both important types of protection forest. Dune stabilization forests are only a form of protection forest to prevent soil erosion in a rather specific environment. Shelterbelts also have an important role in preventing soil loss, but their greatest value in most situations stems from increases in production to leeward consequent upon an amelioration of a number of environmental factors. Both these types of protection forest assume considerable importance in a number of countries throughout the world. Owing to the rather peculiar interpretation placed on the term protection forestry in New Zealand, however, these are not subjects to which New Zealand foresters have yet given much attention.

(c) *Indirect Benefits*

Most of the indirect benefits attributable to protection forests would also result from forests planted solely for the production of timber. The following list then should be seen as one of the indirect beneficial effects of forests in general.

A list of those fields which are indirectly benefited by forests would include health, preservation of scenery, recreation and wildlife, creation of employment, and utilization of resources. At this stage it is only necessary to indicate in general terms how these benefits come about. Under the heading of health it is generally recognized that the presence of forests and parks has a beneficial effect on those living nearby. The reasons range from the strictly physiological (pure air) through the mental (tranquility), to the physical (prevention of loss of life through avalanche and flooding). Probably only in the last case is it possible to draw a line between production and protection forests.

Scenery preservation, recreation and wildlife need little explanation. Neither is it necessary to elaborate on the benefits accruing through the creation of employment, and utiliza-

tion of resources which might otherwise lie idle or be less productively used.

EVALUATION OF CRITERIA

Before discussing the evaluation of those benefits of protection forests which would seem to be of most significance in New Zealand, it would be as well to consider a statement made in 1957 in connection with the economic evaluation of the small watershed programme in the U.S.A. The authors of the paper in question concluded that "nowhere in this country have complete watershed programes been established for periods long enough to evaluate their influences fully" (Weinberger and Otte, 1957). The important point here is that this statement was made after research into the effect of land treatment measures on stream-flow and soil erosion had been under way for twenty years. The situation has improved considerably since then in North America but information to assess these effects in New Zealand is practically non-existent.

Effect on Flooding

This is the field in which most published information on economic evaluation is available. The majority of it, however, concerns land use measures generally and includes measures which although forming part of soil conservation schemes could not be regarded as protection forestry. Little information is available on the evaluation of the effect of forest alone as most programmes have associated engineering works, whether these be check dams in torrents, or flood-retarding structures on larger streams.

In the absence of published information, it is reasonable to assume that forests have the greatest effect on flooding in New Zealand through their action on snow-melt timing, and the prevention of debris movement and aggradation of streambeds. This applies particularly to the major catchments draining the mountain lands.

Cost-benefit analysis is used to evaluate any land and water management scheme. The method came into prominence in the United States early in the century when it was used by the Army Corps of Engineers in the water resource programme. Initially, only direct costs and benefits were considered but in recent years growing attention has been paid to indirect benefits. Prest and Turvey (1965) in their survey of cost-benefit analysis had this to say. "Cost-benefit analysis is a practical way of assessing the desirability of projects where it is important to take a long view (in the sense of looking at the repercussions in the further as well as the nearer future), and a wide view (in the sense of allowing for side effects of many kinds on many persons, industries, regions, etc.), *i.e.*, it implies the enumeration and evaluation of all the relevant costs and benefits".

In the case of flood mitigation, it is usual to estimate the likely annual damage on the basis of flood frequency and

probabilities for different flood levels. The losses averted through the action of forest are thus a direct benefit. Losses, of course, may cover many types of assets such as property, furnishings, crops. Damage likewise occurs to many forms of property—roads, bridges, railways, and to industrial or residential sites. In all these cases it is possible to place a money value on the particular damage. It is only when secondary damage is concerned that problems arise. For example, if a bridge on a main highway is destroyed by a flood and the replacement cost is $50,000, then the direct cost is $50,000. Owing to the destruction of the bridge, however, it now becomes necessary to have a detour involving ten miles of secondary road. What is the cost of this in terms of added mileage for transport operators and loss of service to residents along the disused major road?

On the local scale, the benefits are usually easier to determine. The case of the Fox's Creek catchment in Ashley Forest, Canterbury, is a case in point. Prior to the planting of Ashley Forest in 1939, Fox's Creek flooded frequently and caused considerable damage to a country road. Flooding continued in the early years following forest establishment and in 1946 the Soil Conservation and Rivers Control Council voted a sum of $3,000 (of a total of $10,000) to be used for corrective engineering works in the lower reaches of the stream. Because at this time the new forest began to make its presence felt, none of the money was spent. Peak flows are now drastically reduced and no longer cause damage. For larger catchments the situation is not so clear as it is difficult to isolate all the factors involved in flooding. Kitteridge (1948, 269-70) has attempted an evaluation of the effect of forest on stream-flows in a storm of 10 in. rainfall. The decreases in depth of water available for flood flow are listed as:

Interception (10%)	= 1 in.
Depression storage	= 0.1 in.
Litter on forest floor	= 0.6 in.
Organic matter in soil	= 1.5 in.
Total	= 3.2 in.

Some work has been done in North America on the relationship of decreased run-off to flood heights. It has been shown for the Ivy River in North Carolina, for example, that a reduction in run-off of 0.67 in. would reduce peak gauge height by 2.24 ft in a storm of 4.92 in. in one day. If the same situation prevailed in the Waimakariri River, and the 2.24 ft represented the difference between the protection works being overtopped or not, then the benefit attributable to a protection forest would be substantial when it is considered that the capital value of the area threatened by flooding from this river was $450,000,000 at 1960 values.

Other Water

New Zealand is fortunate in its water endowment. At present there are few areas where water of suitable quality is

not available in sufficient quantity. It should not be necessary to point out that this situation will not always obtain, but there is little public awareness as yet of the danger to water supplies occasioned by forest clearing and industrialization. The current controversy in regard to the larger North Island lakes is timely. Perhaps it is sufficient here to point out that we tend to take our water quality for granted, and that there are few areas in the country *as yet* where shortage of water is other than a short-term problem of a seasonal nature. The picture will doubtless change if the current interest in irrigation increases.

Effect on Soil Erosion

Of all the benefits of protection forests that have been considered, that which has greatest importance in New Zealand is the mitigation of soil erosion. While there might be argument as to what degree forests influence floods, there is little doubt that a healthy, mature forest is the best insurance against soil erosion. In the New Zealand situation this would be the major reason for embarking on a programme of protection forest establishment. The critical importance of soil erosion in this country is due to the rate of the erosion process. Through a combination of circumstances, erosion rates are as high as anywhere in the world, with the result that aggradation of major river valleys poses serious problems for flood control programmes. The problem is not a simple one of the loss of a non-renewable resource as it is in many countries. In the New Zealand case a double issue is involved.

Most of the literature concerning the economic evaluation of soil conservation works uses the increase in production from protected lands as the basis for assessing benefits. This is natural as most of the overseas work has concerned farm plans in the United States, and increases in crop production are easy to measure. Data on the New Zealand situation are more difficult to find. True, in the case of downstream flood protection works, it is possible to measure increased production from land from which the threat of flooding has been removed. In so far as on-site benefits are concerned, there is little information on which decisions can be based. In most cases in New Zealand, the comparison will be between production from extensive sheep grazing and that from forestry. It is debatable whether mountain forests will be managed only for soil and water control or, in addition, for production of wood. While some information is available on the economics of high country farming (Johnson, 1969a, b) practically nothing is known on the economics of forestry in mountain land situations.

There is, of course, more to soil erosion than the immediate loss of production from the land concerned. Of even greater importance to any nation is the permanent loss of what must be considered a non-renewable resource. One has but to consider the case of the countries of the Mediterranean basin to realize the significance of the soil resource in a national economy. Not everyone can aspire to an oil well where the

back garden used to be. Considering the importance of the soil to any country's economy, it is surprising that more quantitative data are not available on the economic significance of soil loss. In a qualitative sense the importance is recognized as is shown by this excerpt from Memo. 1396 of the U.S. Secretary of Agriculture. This memorandum concerns instructions for the national inventory of soil and water conservation needs and states: "Certain conservation measures that prevent serious permanent loss to soil and water resources may be so much in the public interest as to justify expenditures in an area in excess of returns to landowners and operators, and even to the nation in the forseeable future". This excerpt is quoted by Weinberger and Otte (1957) who conclude their examination of this aspect of conservation with the statement: "the problem of establishing additional criteria to guide investment in such measures under the viewpoint indicated is obvious".

Some attempt has been made in North America to put a money value on some aspects of soil erosion. In his extensive bibliography, Boughton (1970) quotes a report by Brown (1948) which gives an estimate for the total annual damage from sediment deposition in the United States. The figure arrived at was $174,000,000 as against total annual flood damages of $100,000,000. A breakdown of the estimate is interesting:

(1) Damage to agricultural land resources from overwash of infertile material, impairment of natural drainage, swamping due to channel aggradation, associated flood plain scour, and bank erosion — $50,000,000.

(2) Damage from sedimentation in storage reservoirs used for power, water supply, irrigation, flood control, navigation, recreation and multiple use — $50,000,000.

(3) Cost of maintenance or progressive impairment of the capital value of drainage works — $17,000,000.

(4) Cost of maintenance of irrigation enterprises — $10,000,000.

(5) Cost of maintenance of harbours and navigable channels as a result of sedimentation caused by erosion on the catchment and stream banks but excluding sedimentation caused by tidal currents in harbours — $12,000,000.

(6) Cost of water purification as a result of excess turbidity — $5,000,000.

(7) Sedimentation damages wholly or partly included in flood damage estimates including crop losses due to deposits of sediment on plants, costs of cleaning sediments from streets, etc., increased flood heights due to channel aggradation — $20,000,000.

(8) Other damages not yet evaluated separately including the increased maintenance costs of highways, railways, oil and gas pipe-lines, communication lines, damage to power

turbines, damage to the fish and oyster industry, damage to wildlife, damage to recreation and impairment of public health — $11,000,000.

While it would doubtless be easy to question the accuracy of some of the estimates (how does the author estimate the damage by sedimentation in reservoirs used for recreation, for example?), the report is useful in highlighting the many ways in which the erosion process affects the community. One would wish for similar estimates for New Zealand.

EVALUATION OF INDIRECT BENEFITS

It is not the purpose of this paper to attempt an evaluation of those indirect benefits mentioned earlier. Most if not all are attributable to forests in general and not only protection forests. That these issues are of increasing importance is illustrated by the following statement: "It is evident that the Federal Government is moving in the direction of justifying water projects on the basis of benefits that are particularly difficult to evaluate. Benefits attributed to recreation, water supply, and pollution abatement were 27% of the total benefits of flood control projects authorized in 1962 (gross investment $2.6 billion) as compared with 3% in 1950" (Fox and Herfindahl, 1964). The current outcry on the Manapouri issue in this country indicates a growing interest in the same sort of values. At this stage it would seem opportune to quote from the conclusions of Prest and Turvey (1965) who in discussing cost-benefit analysis had this to say: "The practical problem is that decisions do have to be taken by public agencies. It can of course be said that one can sidestep the issue by requiring public agencies to operate on a 'commercial' basis, leaving resource allocation to be resolved through the operation of the pricing system. Those who wish to support this kind of policy must believe that externalities, market imperfections, etc., have no importance whatsoever. It seems reasonable to ask them to demonstrate this".

PROTECTION-PRODUCTION FORESTS

Much has been heard in recent times of protection-production forests in which the primary object of management is conservation of the soil and water resource, but in which there is a significant production value which can be achieved without detriment to the primary objective. The report of Forestry Working Party No. 4 of the Forestry Development Conference sees this type of dual-purpose forest as the answer to soil conservation problems in much of New Zealand's eroded mountain lands. The conference in fact noted "the urgent necessity for establishment targets for protection-production forests of up to 20,000 acres per year (gross area)". How successfully can these two objectives be reached in a composite forest?

In so far as protection values are concerned, there is little likelihood of conflict of interest in dual-purpose forests.

The most likely areas for the establishment of such forests are the mountain catchments of South Island which are already largely deforested and often denuded. Any forest cover will have a beneficial effect whatever its type of management. It is probably only at the exploitation stage that conflict between production and protection techniques will arise. Clearfelling of large areas is likely to be unacceptable, so that systems of staggered settings or strips will need to be used. Provided normal attention is paid to roading layout and logging method, there is no reason why the forest in such locations should not be run as a normal production unit.

The reverse side of the coin does not at first sight appear so attractive. Many of the criteria used for the establishment of production forests cannot be satisfied in the type of localities in which these dual-purpose forests are envisaged. Difficult terrain, low production, remoteness from markets, and often low quality products, all combine to make the proposition unattractive from a commercial viewpoint. There is no argument with this. Such forests when measured by the yardstick of the pricing system would attract few investors. But is it justifiable to evaluate these forests in purely economic terms? Part of the answer is given by Bunce (1950). He states: "Soil conservation is a physical or technological problem as well as economic, and it is essential that the inter-relationships between these two aspects be clearly seen. The physical specialist needs to understand the economic implications of physical changes just as the economist needs to understand the physical facts which underlie the problem. Those who formulate policies should base decisions upon both physical and economic factors if social action is to become progressively more effective and more economic in nature". In the case of dual-purpose forests in New Zealand, this means that the added cost of growing a cubic foot of wood (when compared with a purely production forest) should be offset against the benefits which accrue through the establishment of the forest. The difficulty in evaluating the benefits in strictly monetary terms is no reason for not attempting the exercise.

CONCLUSIONS

Those benefits of protection forests which appear to be of greatest significance in New Zealand are the mitigation of soil erosion and the regulation of water yield and water quality. Because the country is generously endowed with water resources, and because population pressures are low, there is a tendency to downgrade the importance of the water and soil resources. That this fortunate state of affairs will not endure for ever is already obvious in the case of some North Island lakes and rivers. Few data are available either on the physical or the economic benefits of soil conservation works under New Zealand conditions. Research into the effects of various land management techniques on water quantity and water quality is urgently needed, but so too is work on the economic aspects of land management. To quote

finally from Prest and Turvey: "an important advantage of cost-benefit study is that it forces those responsible to quantify costs and benefits as far as possible rather than rest content with vague qualitative judgement or personal hunches. Furthermore, quantification and evaluation of benefits however rough does give some sort of clue to the charges which consumers are willing to pay". The sooner we in this country begin the collection of data with this end in view, the better.

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