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Forest Harvesting and Water Management

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Abstract

Forest harvesting affects water management. Total water yield, flow regime and water quality are affected. Usually, in Western Canada, these effects — whether for good or ill — are accidental and are not taken into consideration in management. This is at least partly due to resource management people being resource oriented (technocentric) rather than society oriented (democentric) in their attitudes. Forest harvesting-water management interactions represent a technical problem of ultimate social importance. To cope with this problem requires coordination of resource uses, improved communication and administrative organization, more democentricity, expanded research into socio-economic factors, more attention to long-term environmental goals, examination of land tenure systems, more land use planning, re-orientation of resource management education, a broadening of social conceptual awareness, and increased professional staffing.

Résumé

La récolte des bois a des effets sur l'aménagement hydrique, tant sur la production totale, le régime du débit que sur la qualité de l'eau. D'ordinaire, dans l'ouest canadien, ces effets, qu'ils soient bons ou mauvais, sont accidentels. Les aménagistes n'en tiennent pas compte tout probablement parce qu'ils sont en partie, plus centrés sur les ressources que sur la société en général. Les interactions à l'intérieur de ce couple de gestions représentent un problème technique d'une importance fondamentale pour la société.

Pour faire face à ce problème il faudra: coordonner l'utilisation de toutes les ressources, améliorer les échanges à l'intérieur d'une administration renovée, et plus orientée vers la société, pousser la recherche sur les facteurs socio-économiques, scruter davantage certains objectifs à long terme, examiner les systèmes de tenures des terres, plannifier davantage l'utilisation des terres, re-orienter l'éducation de la gestion des ressources, élargir le sens du concept social et enfin augmenter le personnel professionnel.

Hydrology may be divided into two separate phases, a "land phase" and a "channel phase" (Larson, 1965). Forest harvesting deals with the land phase, while water management is concerned with the channel phase. "Water management" is management of water in stream channels, its control, allocation, use, storage and distribution. Most water in stream channels arrives by passing through terrestrial ecosystems. Logging, a profound ecosystem disturbance, can be expected to influence the amount of water entering the channel phase, its characteristics upon entry, and the pattern (regime) in which it is delivered, after passage through the land phase. It is with these interactions, and their implications, that this paper is concerned.

AN OVERALL PERSPECTIVE

Before undertaking a summary of available technical knowledge dealing with forest harvesting effects on discharge, it is desirable to try to place these effects within their larger framework, lest we forget (as technical people often tend to do) why we are interested in them in the first place. Our primarily technical training we apply in practice of various technical specializations. As a result, by training — and probably by inclination — most people managing resources are strongly "technocentric" in their orientation. Yet management of resources is, by definition, concerned with human benefits; the development of relevant technologies only has meaning to society (regardless of personal satisfactions accruing to the individual worker) in terms of such actual or postulated human benefits. Management, in other words, is "democentric".

We recognise the complexity of the physical-biological systems with which we work. Less frequently, however, are we as acutely aware that, added to these already complex systems, are human and social factors which make the ultimate system of our concern infinitely more difficult and complicated. Our preoccupation with resources — our technocentricity — leads to lack of insight into ultimate objectives, to thinking too seldom of what ultimately we are trying to do, and why we try, in other words to lack of democentricity.

Of course, our whole social environment is technocentric, inasmuch as the search for high levels of technology and for economic efficiency has high status, resulting in situations where, for short-term economic advantage, long-term values of substantially greater social importance may be sacrificed. The objector is "standing in the way of progress". Some human benefits, furthermore, are economically quantifiable, whereas others are not. Due to such intangible benefits, **"maximum human benefit"** may not always coincide with **"maximum economic return"**. However, since the intangibles cannot be quantifiably assessed, their protagonist, questioning some wholly "economic" evaluation, is often said to be "merely indulging in value judgments". Somehow, so technologically brainwashed have we become, that most of the time it never occurs to ask what is wrong with value judgments, especially until such time as we succeed in measuring more of the benefits. Hopefully, we shall eventually be able to assess all resources economically or, at least, at an equitable assessment of the costs, dollar and otherwise, of resource decision alternatives.

Most such difficulties emerge from the realm of social science, and are receiving increasing attention. This increased research activity will lead to higher levels of social science technology, which will allow a more definable answer to questions such as "what is wise use?" or "what are our responsibilities to future generations?", to mention only two of the commonest; or, if answers are impossible, at least we can perhaps reach a better formulation of the questions themselves.

One may justifiably ask what does any of this have to do with "forest harvesting and water management?"; to which one may reply "a very great deal" or, perhaps, "everything".

Forestry, we say piously, is "the management of forests for goods and services". Yet we know that in Western Canada this principle is often observed in the breach. "Forestry" frequently means in practice the management of forests solely for wood products. Benefits to other resources arising from such timber management activity are, as often as not, as accidental and unforeseen as catastrophies from the same source. The majority of Western Canadian foresters, in effect, are managing **wood** exclusively. How they may be affecting the human environment is frequently not a pressing preoccupation. This is perhaps understandable of the large industrial concern; however, to assume that corporate and public interests are totally coincident might turn out to be naive (cf. Fisher, 1967).

Wood production has attained its pre-eminent position because, compared to other resources, its large, immediate dollar returns are highly visible. Other resources are either of lower direct dollar value, or cannot be quantifiably assessed. The wood manager is therefore in a highly advantageous position when he argues his case **vis-à-vis** other resource interests.

It was Adam Smith who stated that the needs of man are "food, clothing and shelter". Today, the by-products of technology make us define these needs as food, clothing and shelter, plus a decent (i.e. acceptable, desirable) environment. The problem here is that everyone has a different idea of what constitutes a desirable environment, the biologist, economist, industrialist, nature lover, aesthete and investor. All these ideas are presented to the politician, who may in turn have his own ideas. Out of this disorderly amalgam, through the political process, emerge the key decisions governing levels of present and future environments. While rigour is applied to lower levels of decision making, at this superordinate level there is little rigour and little developed technology. Yet it is here that goals for future society are set. The danger is that, for short-term economic advantage, we sacrifice long-term social benefits; that in rapidly developing an economically-desirable industrial base we jeopardize a socially-desirable environmental base.

I believe we have run, and do run, such risks in

[1]Paper presented to B.C. Chapter, Canadian Society of Wildlife and Fishery Biologists, University of Victoria, Victoria, B.C., February 10, 1968.

management of forest lands. However, it is clear that by inference they are present in all areas of society every day. What risks are involved in the decision to invest monies in water resources development, if this means diverting investment from hospitals?; what are the hazards in putting money into transportation networks, if education deteriorates as a result? Clearly, these are alternatives involving investments of short and long term; of direct and non-direct, return characteristics; human benefits as equated against dollar returns. Equally obviously, prevalent social attitudes play a very large role.

Because of the above factors, in present western Canadian land management, benefits other than wood are most accurately regarded as by-products of a land management strongly devoted to wood production. Whether the by-product is for good or ill, in most cases it is accidental.

Water in channels is one such by-product. There are very few areas in western Canada where land management devotes equal attention to wood and water, and even fewer where land is being consciously and deliberately managed to provide desired water characteristics. This particular by-product of wood management can have far-reaching social effects; the manipulation of a physical-biological system affects a larger and more complex system having physical-biological and sociological elements; it affects the quality of the human environment; it results from technocentric activity; long-term and short-term, direct and non-direct, returns are involved; at present levels of technology, value judgments must play a large part; a desirable industrial base may be in conflict with a desirable environmental base; prevalent attitudes, professional and lay, are among the determinant parameters; corporate and public interests may not be coincident; bases for decision making are inadequate, disorderly and possibly weighted.

In other words, the forest harvesting — water management interaction meets the criteria developed above to describe a technological problem of ultimate social importance. It is in this light that this interaction should be considered.

FORESTS HARVESTING AND WATER YIELD

Considerable work has been done on the effects of forest harvesting upon water yield (Hibbert, 1967). This research has often been oriented towards the purposive augmentation of water yield through forest manipulation in water-short areas. Impetus for research is usually a function of acuteness of present or potential water yield shortages. Some work is now underway in Canada (Jeffrey, 1967a) and extension of such research seems desirable in certain regions (Jeffrey, 1967b, 1968).

Though studies have been undertaken to obtain a desired increase in water yield, it follows that, in appropriate landscape conditions, increases will occur whether they are desirable or not, as a necessary adjunct of timber harvesting activity. This is sometimes insufficiently appreciated.

Considerable knowledge is available on effects of forest harvesting on total water yield. Results, however, are not readily extrapolated from research watersheds to management practice, even within the same region. When applied to a landscape, forest type, or climate different from those where research was undertaken, great caution is needed. Canada, with its glaciated landscape, cannot confidently apply results from unglaciated U.S. areas, even contiguous areas.

Forest removal affects the precipitation-runoff relation by changing the magnitude of evaporative "losses" within the ecosystem. Factors influencing evapotranspiration, in particular those creating differential evapotranspiration between forests and alternative-replacement covers, are those which determine effect of logging upon water yield.

Effects of forest removal on total water yield may be considered under two components:
(1) immediate (first year after cutting) increases, and (2) durability of increases.

First year increases in total water yield

Immediately following forest harvesting, total water yield is generally increased. The size of yield increase seems closely related to the proportion of the basin cut-over. If less than 20 per cent of a basin is cutover at one time, any yield increase is difficult to detect, this appearing to be a "threshold" value.

Magnitude of yield response is highly variable. Total removal of scrub aspen forest in Colorado resulted in 1.3 inches increase, compared to an additional 16 inches in North Carolina mixed hardwoods.

To compensate for the degree of removal factor, studies are considered as yield increase pro-rated over area cutover. Few areas have produced more than 12 inches water yield increase in the first year after cutting. Where increases were higher, climate was generally humid. Low increases are found in dry climates, though they have also been found in some humid climates, including the Oregon coastal forest (Rothacher, 1965; Martin & Tinney, 1962).

It has been concluded (Hibbert, 1967) that water yield increases are largely unpredictable. Obviously more research is needed in regions (such as British Columbia) where no regional results are available.

Durability of yield increases

Water yield increases are subject to decay. Rate of decline seems associated with rapidity of vegetative re-invasion. Where revegetation has been rapid, yield increase decline has also been rapid. In one North Carolina experiment, with 14.6 inches first year increase, it was estimated that yield increase would be negligible after 35 years (Kovner, 1956). Where revegetation is slower, the detectable yield increase might last longer. However, where yield increase is small initially, less decay is needed for it to become insignificant.

Regional applications

Some yield increase estimates have been made for U.S. forests contiguous to Western Canada:

Forest type	Present yield (inches)	Potential initial increase in yield (inches)
lodgepole pine	14.0	3.0
englemann spruce-alpine fir	18.0	3.0
white pine-true fir	20.0	4.5
ponderosa pine	4.0	0.5
interior douglas fir	7.0	1.0
coastal douglas fir-hemlock-cedar	45.0	No estimate, but opportunities to increase yield assessed as abundant.

Source: U.S. Senate (1960).

These suggest substantial yield increases may result from removal of Western Canadian forests.

It is evident that relative concentration of logging is a major parameter in what happens to the hydrology of a watershed. At present, whether or not logging is concentrated or dispersed depends primarily on considerations other than water factors, particularly road building investment, timber conditions, and other elements in short-term economic evaluation. Results may vary from desirable to very undesirable.

FOREST HARVESTING & WATER QUALITY

Forest harvesting effect on water quality is one component of the larger subject of land use effects on water resources (Bullard, 1966).

Water from undisturbed forested watersheds is typically of high quality, though natural landslides can result in high "geological" sediment loads. Forest harvesting may impair quality. Influential variables are soil erodibility, geomorphology, physiography, climate (particularly precipitation regime) and the degree, type and quality of the harvesting operation. Most sediment from forest harvesting originates in wood extraction, main sediment sources being roads, landings, and skid trails.

Studies comparing tractor and cable logging in the north-western U.S. show tractors to create much more soil disturbance than cable logging. Skid trails on tractor-logged areas may occupy more than 25% of the total logging area, with associated soil compaction. On steeper slopes deleterious effects of tractor logging are enhanced (Dyrness, 1967; Packer, 1967). Quality of skid trail constructed is strongly correlated with sediment produced, poor skid roads yielding eight times the sediment of more rationally located tractor trails, even in the absence of major gullying (Trimble and Weitzman, 1953).

Very large sediment volumes may be produced. One California study showed tractor logging produced 3700 tons/mile^2 of cutover area in the first year after logging, and 900 tons/miles^2 in the second year, in excess of pre-logging levels (Anderson, 1962; Rice and Wallis, 1962). Packer (1967) and Dyrness (1967) have reviewed much of the North American experience. The picture which emerges is clear. It shows:

(1) Logging creates sediment, to a greater or lesser extent.
(2) Sediment produced is closely correlated with quality of management practice.
(3) Tractor logging is more damaging than cable logging.
(4) Roads are the main sediment source, not only skidtrails, but also haul and access roads.
(5) Duration of sediment production appears strongly dependent upon rate of revegetation, other factors being equal.
(6) Terrain steepness increases the effect of roads, other factors being equal.
(7) Means of minimising sediment production from logging are available.

Regional applications

In interpreting the results summarized above, some caution is desirable, for the following reasons.

(1) Management standards on U.S. public lands are generally higher. A greater consciousness of water values exists. More intensive planning results from higher levels of professional staffing and leads to more logging and road design, more professional layout, maintenance and inspection. Some tradition of careful land use has become established. A larger population, having a more informed and aware approach to land management, keeps a watching brief.

(2) For these reasons U.S. findings may be conservative for Canadian conditions.

(3) U.S. cable logging studies deal with uphill yarding, whereas cable yarding is frequently downhill in B.C. Conclusions about cable systems may not always be applicable here.

(4) Canadian glacial soils differ in many important properties from the residual soils of the United States.

Even cursory study of Western Canadian conditions leads to the conclusion that much sediment production is unnecessary. Attitudes (cf. Dunford, 1960) play a large part in this, though putative economic factors form the usual basis of justification.

The knowledge presently available dealing with preventive measures is not being fully utilized. The present problem does not primarily require the completion of large research programs; major improvement could be made immediately by incorporating present knowledge into management practice.

Much logging sedimentation seems the expression of a gross undersupply of professionally trained people, with concomitant overdependence upon non-professional staff.

It is noteworthy that some desirable measures, notably adequate pre-logging planning, may actually save money and lower costs. One study (Silen and Gratowski, 1953) showed that pre-logging planning significantly reduced both total road length and the percentage of steep road grades. Again, prevalent attitudes rather than objective economics may be a dominant factor.

Figure 1. Large sediment deposits developed below a poor quality logging road. These deposits, the result of road construction, formed in the course of a few weeks. Deposition was continuing actively when the photo was taken.

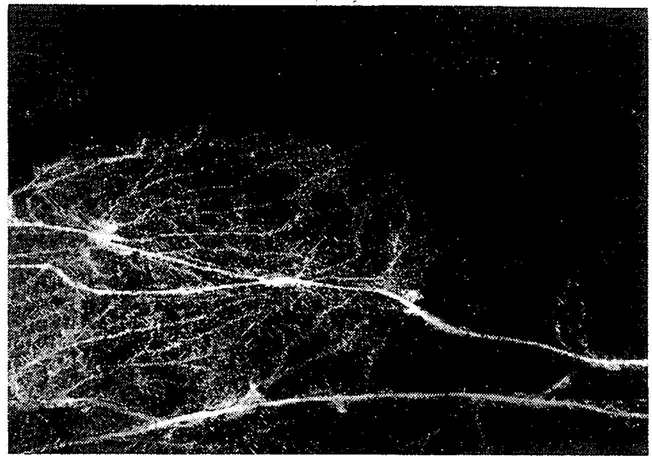

Figure 2. Tractor skidroads concentrate flowing water and are a major source of sediment production. This aerial view shows the road pattern in a typical tractor logging show in moderately sloping ground. As ground becomes steeper the road network becomes more dense.

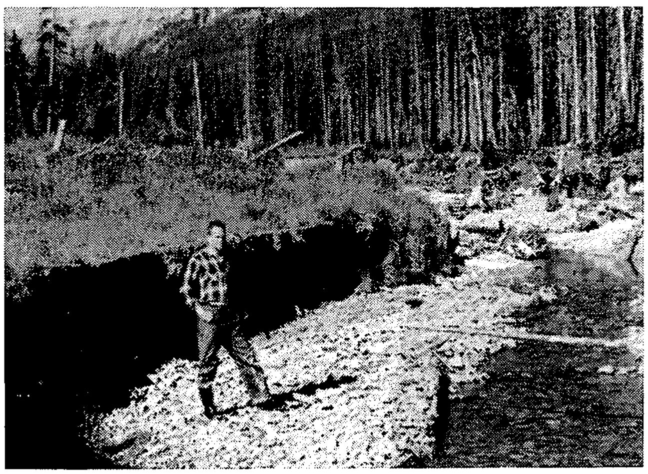

Figure 3. Stream damage results from channel obstruction. Where the man is standing it was possible in the previous year to drive a truck. Severe bank cutting has completely removed the logging road. The stream channel has been much widened and is now carrying large volumes of woody debris, witness the deposited stumps in the channel of upper right.

Figure 4. Poor road construction is evidenced by this actively eroding side ditch which will continue to be a source of both undesirable sediment and excessive maintenance for many years.

FOREST HARVESTING, FLOODS AND FLOW REGIME

The effect of cutting on floods and on peak and low flows is not completely clear.

It is helpful to categorize floods according to their genesis, as an aid to understanding. Zinke (1965) has provided such a classification, considering floods to fall into four types, as follows:

Type 1. Floods with all storage elements full, but without snow storage.

Type 2. Floods with all storage elements full, and with snowmelt.

Type 3. Floods with storage elements not full.

Type 4. Floods with no precipitation, but sudden release of storage elements.

Type 1 floods emerge from a completely saturated landscape, subjected to high precipitation for considerable periods. Land use has relatively little effect on such floods.

Type 2 floods result from snowmelt, or from warm rain falling upon a pre-existent snowpack. Land use may have important effects on snowmelt, since forest cover affects the amount of radiation and advected heat reaching snowpack. Clearcutting over large areas may result in accelerated runoff. Soil freezing differences may also affect the rate of runoff.

Type 3 floods result from high intensity rainfall whose rate of delivery exceeds soil infiltration capacity. Land use will have the largest influence upon this flood type, by adversely affecting infiltration capacity through soil compaction and litter removal.

Type 4 floods may result from extremely rapid snowmelt occuring without coincident precipitation. Presence or absence of forest cover may be influential in this flood type, in the same way as Type 2 floods are affected. This flood type may also result from sudden release of water impounded by temporary barriers.

Peak flows from forested watersheds may be considered affected in the same manner. Snowmelt peak flows may be increased by forest harvesting, the snowmelt-retarding effect of the continuous forest being sacrificed. With high road and skid trail densities, loss of infiltration capacity may lead to faster runoff and higher peak flows. Where surface conditions have been badly jeopardized by logging, faster runoff from increased overland flow may be expected. Results from Oregon (Anderson and Hobba, 1959) confirm some of these postulates. However, in areas of the Eastern U.S. no effect upon normal peak flows has been found after forest removal.

The percentage of basin cutover, the rate of vegetative reinvasion, and surface condition after logging, may be considered variables influential upon peak flow changes.

The possibility of hydrophobic soil conditions resulting from wild fire or slashburning (Krammes and DeBano, 1965) exists.

The effect of forest removal on low flows is contradictory and little generalization is possible. More studies have shown low flows to be increased by cutting, than the reverse case (Johnson, 1967).

Regional applications

The flood classification quoted helps assess forest harvesting effects. Forest influence on snowmelt, in conjunction with Western Canadian climate, suggests forest harvesting to be influential upon Type 2 and Type 4 floods, wherever they occur. Type 3 floods may occur in the B.C. Southern Interior. In the coastal forest, data[2] suggest that, while infiltration rates are reduced by logging plus slashburning, the reduction is not sufficient to generate a Type 3 flood, in relation to characteristically low rainfall intensities. It seems likely that widespread logging may result in higher peak flows in most areas. No guess can be hazarded concerning low flows.

Other aspects of water quality hazard e.g. biocide residues, stream driving, bark accumulations, also exist.

DISCUSSION

The foregoing technical material shows some forest harvesting effects on water resources. Some deleterious effects are avoidable, inasmuch as they stem from inadequate, indifferent or uncomprehending timber management. Others are inevitable and result, not from the level of management practice, but from the very fact of ecosystem disturbance. Management can only mitigate such effects, while enhancing the desirable. A given effect, such as increased annual flow, may be beneficial in some instances, undesirable in others. Watershed management seeks to recognise, understand, evaluate and manipulate these interactions in a purposive way, to meet specific needs in given situations. Waterhed management practice is increasing, but it is still much less common than the effects it seeks either to modify or encourage.

Though improvements can be seen, there is still a long way to go. The trend away from a narrow preoccupation with timber management values is well established, but is still suffers teething troubles, and still receives in some quarters more lip service than honest support. Ingrained assumptions are difficult to lose. Many people in forestry are there because of fascination with its industrial rather than its ecological facets. For them the transition to total resources orientation is a difficult one. For many others, the concept of integrated resource management schemes remains academic and somehow unreal.

Nevertheless, it appears that the search for integrated resource management has succeeded. The war has been won, though some — perhaps many — of the battles still remain to be fought. The relevant questions now are of the sort : how soon? how much? how complete? how difficult? It is these questions for which answers are now needed.

In searching for mechanisms by which these goals may be more readily met, the following compendium has been assembled. Together they may offer some food for thought.

1. Greater co-ordination of resources uses is needed.
2. This requires better communication, and better mechanisms of communication, between resource specialists, as individuals, in organised groups, and in public or private agencies.
3. Organization for resource integration in government is inadequate. Compartmentalization within government, according to individual resource interests, is divisive, inefficient and ineffective.
4. Resource managers should become less technocentric and more democentric in orientation.
5. Democentric resource managers merit a greater role in resource policy formulation, at a higher level of policy decision-making, than they have hitherto been granted.
6. A major research effort should be made to develop effective economic techniques to quantify and thereby evaluate those resources and benefits which do not yield direct dollar value returns (cf. Hildebrandt, 1967).
7. Social sciences research input into resources problems should be immediately and significantly increased (cf. Fahnestock, 1968). This would yield understanding of many aspects of human society which have direct bearing upon natural resources questions.
8. Allied with this, should be de-emphasis of short-term economic goals, with increasing attention to long-term environmental goals, along with the development of a composite technology leading to the identification, description and attainment of such long-term goals, through the development of more comprehensive models.
9. Within an increased social sciences research input, recognition is needed of land tenure as a highly pertinent parameter. It is illogical, unfair and dangerous to expect an industrial concern, whose economic survival is dependent upon one resource, to manage delegated public lands for a products — mix maximizing human benefits for society as a whole. Ways have to be found to ensure coincidence of corporate and public interests.
10. Resource use integration has to be based on integrated land use **planning,** presently virtually non-existent.

[2]Unpublished data, collected in U.B.C. forest hydrology research program.

11. Education of resource managers should necessarily require the creation of democentric attitudes and philosophies, through awareness of social inputs and social repercussions in resource management, along with a full understanding of the decision-making process within our political and economic system.

12. Education should strive for the graduation of **flexible** individuals, well equipped with problem-solving skills.

13. Education should provide people who have some awareness of all renewable resources and of their interdependence in complex systems.

14. Resources people should not discourage the formation of so-called special interest "pressure groups", having an interest in resources questions of one sort or another, but should recognise that such groups play a valid part in a free society, and that they create political influence which may counter-balance other pressures advocating strong devotion to short-term economic advantage. Resources people should, however, recognise their responsibility to ensure that special interest groups are exposed to technically reliable information sources.

15. The quality of the environment should be universally recognised as a basic human right, each individual having the right to live in an acceptable environment, in the same way, for instance, as society recognises the right of all persons to education (cf. Tarrant, 1966). It should also be accepted that it is the function of government to secure and safeguard that right.

16. Recognition of a broader governmental responsibility in environmental maintenance means that levels of professional staffing in government will have to be radically altered. There is little sense in universities producing optimally trained graduates, if each graduate is so overextended in his employment as to lose most of his effectiveness.

It has been said (Garrett, 1967) that Canadian forestry is "in the early stages of transition from exploitation to a pattern of limited management designed primarily to ensure future yields of timber for industrial use". It seems likely, however, that this transition will accelerate and embrace all land use. If so, what will the next problems be? To be ready with at least partial solutions, we need to begin trying to identify them, or at least parts of them now. It seems possible that the problems beyond technologically sound integrated resource management lie somewhere in the "hazy" area implied by democentricity.

Chittenden began his "History of the American Fur Trade of the Far West" by saying:

> "It is not an easy thing . . . to appreciate how great a place in the affairs of former times the fur trade occupied. The trade has not by any means become extinct . . . It is only in a relative sense that it has become less important. While it has remained stationary, other lines of trade have expanded many fold, until now it is almost lost sight of in the vast current of the world's affairs. Yet . . . it is not more than sixty years since it was almost the only business transacted . . . west of the Mississippi . . ."

How true is it that there is some parallelism between the fur trade of the early and mid 1800s and the wood trade of the mid 1900s, in the possession of a temporary historical pre-eminence which in time relatively diminished?

How true is it that resources problems go considerably beyond those inherent in formulating integrated resource management plans and operations?

These uneasy questions lead to the thought that we might — without neglecting the search for better integration of resource management — try to look further ahead to see the nature of the next set of problems, and to explore and re-define our roles within the wider physical-biological-sociological system.

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