ENVIRONMENTAL GUIDELINES FOR

Watershed development

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UNITED NATIONS ENVIRONMENT PROGRAMME

WATERSHED DEVELOPMENT

Environmental Operational Guidelines

1. Pesticide Use on Industrial Crops
2. Irrigation in Arid and Semi-Arid Areas
3. Watershed Development
4. Pulp and Paper Industry
5. Hides and Skins Industry
6. Coastal Tourism

WATERSHED DEVELOPMENT

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Contents

FOREWORD

It has been our concern, shared by other bodies and agencies within and outside the UN family, that development projects and programmes should take due account of basic environmental parameters and constraints. It is, indeed, clear that broad-based sustained development is not feasible, especially in the long-term perspective, without sound environmental assessment and management at the inception.

These guidelines have been prepared by UNEP in close consultation with the United Nations specialized agencies concerned and were jointly financed by UNEP and UNDP. These guidelines were adopted by UNDP and are included in its Policies and Procedures Manual.

As noted in the conclusion to the guidelines for watershed management, but equally applicable to the other guidelines, there are many pitfalls to be avoided in initiating activities in different sectors of development and many opportunities that can be missed. Experience during the last ten years has also shown that remedial measures identified must be incorporated, if they are to be effective, in the very conception and design stage of projects and of planning procedures. Later attempts may prove to be only cosmetic changes as the ecosystems under consideration are particularly fragile and complex and may not recover from the stresses to which they are exposed if they exceed certain limits.

The guidelines for remedial or preventive measures which have been presented in this study are meant to be illustrative rather than exhaustive in character: there are substitutes for local experience, foresight and prudence. We have only attempted to draw attention to the kinds of considerations which must be kept centrally in mind. The objectives for which we strive in this subject area are multidenominational and interrelated, requiring a formidable array of diverse technologies and disciplines. It should be noted that although the guidelines presented here are essentially national in nature and scope, international cooperation and co-ordination to bring into play the different inputs required may often be necessary.

I sincerely hope that the present set of guidelines will be acceptable and meet practical needs, particularly in developing countries. Additional sectors will be examined and further guidelines prepared in collaboration with the United Nations specialized agencies, UNDP and other multilateral and bilateral development financing institutions, taking fully into consideration comments and advice which we expect to receive regarding the present set of guidelines.

Mostafa K. Tolba
Executive Director

PREFACE

At an informal meeting held in Rome in September 1978 the Designated Officials for Environmental Matters (DOEM) of the United Nations Administrative Committee of Co-ordination recommended on the basis of a report prepared by a consultant, Mr. O.M. Ashford, that UNEP undertake, in close collaboration with the United Nations specialized agencies, the preparation of environmental operational guidelines to assess and minimize the possible adverse environmental impact of development activities. The report of the meeting states "that priority should be given to the preparation of guidelines aimed at improving the consideration of environmental aspects at all stages in the planning and execution of projects. It was recognized that the level of sophistication in such guidelines would depend on the audience for which they were intended. Much of the available material was of a general nature which would mainly be of interest to university circles or to senior international and national officials. At the other extreme, detailed guidelines based on in-depth studies of specific projects would be very useful for specialists but difficulties were foreseen in obtaining the necessary information for such analyses, which would take a long time to complete. The meeting agreed that at this stage the primary need was for guidelines which would be useful at the operational level. For this purpose each of the major categories used in the consultant's report (e.g. agriculture) would have to be broken down into a number of subareas (e.g. crop pest control and rangeland management). A first list of subareas on which guidelines should be prepared soonest was agreed on as follows:

1. pesticide use on industrial crops
2. irrigation in arid and semi-arid areas
3. watershed development
4. pulp and paper industry
5. hides and skins industry
6. coastal tourism

At a subsequent meeting the DOEM determined that the operational guidelines should "avoid undue technicalities. They should be clear-cut

statements of the environmental concerns, environmental parameters and environmental constraints arising in the area of interest. A distinction should be made between what would be useful for informed laymen, such as UNDP resident representatives or officials in the Ministry of Planning or Ministry of Economic Affairs of a developing country, to reach a decision on the need for and nature of environmental considerations in a given project at a very early stage of its formulation on the one hand, and the analytical tools required by engineers, economists and other scientific consultants in the form of coefficients, etc., to implement a project on the other. The latter should not be a part of the operational guidelines but on manuals of implementation." In the event, the six guidelines that have been prepared vary in the nature of the material assembled and the technical details analysed. This has been done deliberately.

In order to afford an opportunity to assess the practical utility of different approaches to the preparation of guidelines, it was considered necessary to establish models which could be compared and evaluated in terms of practical utility. UNEP would gratefully receive views on the analytical frameworks and approaches adopted in the different guidelines as well as suggestions for their improvement or amendment.

The environmental operational guidelines in this series are not intended to be prescriptions for corrective action or constraints on the methods, nature and scope of development activites. They are presented in the belief that dynamics and change induced by development aims are not without environmental hazards and risks; it is necessary to identify such hazards and risks where they arise and take early steps, in so far as prevailing circumstances permit, to contain or reduce them. It is necessary to take early steps, because later attempts at remedial action may be illusory, and always more costly than preventive action taken at the outset, and, as has been stated in the Conclusion to the Guidelines on Irrigation in Arid and Semi-arid Regions, "in some cases may be so costly as to bring into question the overall economic viability of the project".

We acknowledge with gratitude the contribution received from the United Nations specialized agencies, particularly the Food and Agriculture Organization, for the preparation of guidelines. Without financial assistance from UNDP, the operational guidelines could not have been completed effectively within the short time available. We are also dependent upon the assessment of the Resident Representatives and

the Headquarter staff of UNDP in regard to whether guidelines meet specific needs in the field.

Within UNEP, a number of colleagues have assisted in the preparation and editing of the operational guidelines. I wish to thank in particular Mr. Nat Htun (for the guidelines on the pulp and paper industry and on the hides, skins and leather industry) and Mr. Mohamed Tangi (for the guidelines on coastal tourism). Ms. Merran Van der Tak, Ms. Shahida Chaudhary and Mr. Mark Aeron-Thomas have assisted in the research and editing of the series.

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INTRODUCTION

Economic and development activities in watersheds can be manifold and the interactions between the physical, biologic and socio-economic factors very complex. Therefore watershed management and development needs an integrated approach to maximize the use of natural resources and to prevent undesirable environmental hazards. This guideline is limited to small and medium watersheds (that is up to approximately 1 million ha) in mountain areas, and deals essentially with those aspects which are related to the management and development of forest lands: timber harvesting, afforestation, range and pasture management, agro-forestry, mountain roads, dams and reservoirs, torrent and river control and resettlement of rural population. There are many other economic activities, such as mining, recreation, urbanization, which have not at this stage been considered, but should obviously be the subject of further publications.

The guidelines presented here are primarily for the guidance of the administrators and planners who are required to take a decision on the need and nature of the main environmental considerations in a given project at an early stage of its formulation. As such, they are mainly directed to the "informed non-expert". Undue technicalities have been avoided and the environmental parameters, concerns, and constraints have been dealt with in simple terms.

BASIC PROBLEMS OF MOUNTAIN WATERSHEDS

Forests usually occupy the upland areas on mountain watersheds because of high precipitation. Most of the flow in streams and rivers originates from these areas, and because of protective cover, the water is of prime quality. The beneficial effects of forests on regulation of perennial flow in streams and in maintenance of high water quality are well known. It is, therefore, essential that the environmental impact implications of development activities in forest and associated rangelands be clearly understood. Besides production of timber, forage, and water these lands

constitute important habitat for wildlife and fisheries and, because of aesthetic and scenic values, are preferred areas for recreational activities.

Under the undisturbed conditions hardly any overland flow occurs in the forested watersheds. Thus, soil movement due to erosion is kept at a minimum. The streams run clear of any sediment through most of the year and no damage occurs to the spawning areas, municipal water supplies, or to the hydropower and irrigation networks located in the headwater zone. It is only with the introduction of soil disturbance and reduction of protective forest cover that most of the problems related to environmental impact start in the upland areas.

Deforestation and land clearing activities associated with the construction of dams and mountain roads, and for human settlements and agricultural production, may involve extensive soil disturbance with resultant environmental impacts on the mountain watersheds. Overgrazing, forest fires, and the use of chemicals for pest control can similarly influence the quality of environment in many ways. Migration and resettlement of people evacuated from the mountain watersheds as a consequence of water resource development activities, such as inundations resulting from multipurpose dams and reservoirs, can introduce problems of different dimensions in the human aspects of certain important environmental considerations.

The list of development and management activities on mountain watersheds is long, but for the purposes of the present document only a few could be profitably considered within the time available for the preparation of operational guidelines.

MOUNTAIN ROADS

Road construction is an important activity on mountain watersheds for opening up new areas for forest operations and rural development. However, if it is undertaken without an awareness of the environmental hazards, or without taking the appropriate avertive action, the consequences can be most undesirable.

Environmental impact

Construction of new roads into areas for settlement and land use without prior land capability surveys and land-use planning control can cause land slides in vulnerable areas.

During construction water pollution by spillage and run off may be a

problem. Ill-considered project design, or absence of maintenance, can result in serious erosion, and sediment problems in nearby water systems either if reseeding does not take place, or if roads are of excessive grades or length of slope thus facilitating uninterrupted rapid movement of water along their surface. Gully formation may prove a problem if there are inadequate culverts or energy dissipation devices.

Guidelines

Many of the adverse environmental consequences of road building can be averted by the choice of correct location, design, and construction procedures. A tentative road alignment should first be selected in the office using aerial and topographic maps, wherever available, and all other geographical, edaphic and land classification information. This tentative route should then be checked in the field for any changes in alignment as dictated by soil conditions, grades and curves, water drainage, rock outcrops, etc. so that potential trouble spots can be avoided.

As the sediment from roads usually occurs during periods of seasonal rainfalls, the road-building activities are least damaging if confined to the dry weather seasons. Only that portion of the road which can be completed during the current construction season should be built.

It is important that grades be kept low but sufficient to allow for natural drainage. Energy of water for environmental impact is directly affected by steepness of grade. Avoid all up and down spur roads.

The provision of adequate road drainage, which is the most important design factor for controlling surface erosion, can be achieved by drains properly spaced to dissipate the energy of the flowing water, and the use of bridges, culverts or paved fords across live streams. Failure to provide such facilities may result in loss of road embarkment in vulnerable spots, and gully formation with exceeding soil wash.

Some erosion may inevitably occur and sufficient strips of vegetation should be kept to intercept sediment before it enters the stream. The road should be located as far from stream channels as possible.

Adequate provision should be made in the development project to assure subsequent maintenance of roads and drains after construction. Timely repairs should be done where needed in an attempt to minimize damage at a later date. Where culverts are used plan for cleaning before and during the rainy season.

Particular care should be taken in the planning of roads that traverse a

scenic area that aesthetic or touristic values are not adversely affected. Care should always be taken to avoid unnecessary despoilment of the landscape during construction.

Every effort should be made at the planning stage to avoid any potential disruption to wildlife migration routes as a result of the proposed alignment of the road.

TIMBER HARVESTING

Timber harvesting on mountain watersheds causes a number of changes in the environment. These changes result from both logging activity and the road construction that almost inevitably comes with it.

Environment impact of logging activity

The compaction of soil, due to felling, limbing, skidding and yarding of trees, in conjunction with the decreased transpiration losses after the removal of tree cover and the reduced interception of precipitation following the destruction of forest vegetation, will tend to increase overland flow, thus, accelerating erosion and increasing flood peaks.

The effect of rapid decomposition of the organic layer due to greater solar energy reaching the forest floor in the logged areas will accelerate the release of nutrients which may be flushed into nearby waterways. This may lead to eutrophication, which will add further to the shocks to the aquatic ecosystems resulting from increased sediment, raised water temperatures, and increased seasonal fluctuation due to accelerated melt rates. The net result for fishery resources is unlikely to be good. Furthermore extensive clear cutting over mountain landscapes will destroy or change the habitat of wildlife.

Guidelines for reducing environmental impact

Erosion from logging can be minimized by selecting a suitable logging system. Silviculture, economics and other factors of management should be considered for the overall choice of the system to be used. The logging system chosen should reflect the dual need of preventing soil erosion and increasing local employment (a factor of significant importance in developing countries). Air transporting systems such as cable yarding and balloon logging will cause minimum damage to the environment compared to ground skidding methods. Problems associated with erosion

on mountainous areas generally favour the use of cable yarding systems. Uphill logging is the preferable practice; with downhill logging water has greater opportunity to cause damage.

The practice of clear cutting, as opposed to selective cutting or shelterwood systems, leads not only to accelerated erosion, but also increases the height of flood peaks and the danger of landslides. Clear cutting should thus be avoided. In particularly unstable areas the selection system is advised, and where landslides are considered a major hazard, even-aged, single-species management is not recommended.

Trees should not be felled near stream banks nor should stream channels be blocked by logging debris. This will cause cutting of banks and bottom lands where the velocity of flow is accelerated, thus adding to the sediment load of streams and resulting in a deposition of coarse fractions and finer materials along gentle gradients. In addition, the existence of buffer strips of vegetation along streams will protect the stream channels by filtering out the sediment being carried by overland flow. Such protective strips also provide protection against a rise in water temperature.

By minimizing the environmental impact of logging activities in headquarters the disturbance and spawning areas will be reduced.

Time of operations can be an important factor in reducing erosion damage. Although snow occurs in only a few developing countries, in areas where snow cover lasts through a substantial portion of the year, most of the logging could be completed during that period. Work during dry weather is another possibility.

Environmental impact of road construction for timber harvesting

Naturally enough road construction for timber harvesting can have all the adverse environmental impacts outlined previously. However because of the number of roads required, the result can be particularly damaging.

Guidelines

All those precedures mentioned above should be observed where possible. However in addition two further points can be made:

In developing forest roads for harvesting systems, careful review of the management and harvesting plan to determine the areas to be served first is necessary. This will determine the site and direction of the proposed road for such purposes. Planning the road system in advance

will reduce the area of soil disturbance and lower costs of construction and maintenance.

Temporary roads used for logging should be "put to bed" after the completion of operations. This includes spur roads that were used for timber harvesting but are not needed for subsequent forest management activities. Raw cuts and fills should be seeded with grass. Compacted surfaces may need to be scarified before seeding. Provision for such after-care should be made in the project.

AFFORESTATION

Regeneration of timber harvested areas through natural or artificial means is an essential forest management activity. Reforestation projects are sometimes undertaken to conserve soil on tropical mountain watersheds or to rehabilitate lands which have been damaged through past misuse and excessive erosion. Tree planting also plays an important role in agro-forestry and urban forestry. Extensive areas of man-made forests are being established in the developing countries for wood production and industrial use. In spite of the diverse purposes for which such projects may be undertaken there are general impacts which are common to afforestation activities.

Environmental impacts

Beneficial effects of afforestation are improved capacity of the soil, reduced overland flows and flood peaks, increased opportunities for recharging sub-surface flow and ground water, perennial flows in streams and springs, reduced sediment movement and delivery, and enhancement of aesthetic and recreational potentials.

The harmful effects of afforestation activities on the environment are numerous. There will be a reduction in supplies of water to the downstream users and reservoirs due to increased transpiration rates, although the problem of excessive erosion from mountain slopes may be effectively controlled.

The land clearing needed to eliminate or reduce the brush cover will cause increased erosion and sedimentation rates. Such clearing is often needed to provide protection against undue competition from undesired plant species and to facilitate adequate establishment of those which are desired.

Chemicals, used in conjunction with other land clearing techniques.

and pesticides used to protect young plants, when carried by draining water, will affect fish and other aquatic life.

The burning of slash and use of fertilizers (to help establish seedlings on hard sites) have a harmful impact on nearby streams because of the nutrient enrichment, likely to be caused by drainage into such water bodies. In addition the burning of slash may have adverse effects on soil micro and macro fauna.

The Taungya, or Shamba, shifting cultivation methods are used for raising a forest crop in combination with a temporary agricultural crop in the hilly forest areas of many developing countries.

Guidelines

Compared to mechanical methods of erosion control, afforestation of eroded sites usually has the additional advantages of lower cost, less maintenance, and availability of saleable products resulting from the species. Once established, the vegetative control gradually becomes more effective with each succeeding year of plant growth. The vegetative control through afforestation may be used either singly or in combination with engineering structures. Often a combination provides the most effective technique for dealing with erosion problems in depleted watersheds. These roles can be complementary.

The use of single species in planting extensive areas should be avoided. Mixed crops provide greater safety against damage from pests and diseases. A wide choice of species is usually available to suit the local site and climate environment. Species should be selected according to the desired objectives of afforestation.

Trees use more water than grasses. This could be a critical factor in situations where water supplies in sufficient quantities are the prime consideration. The use of grass cover, instead of forest trees, may provide better vegetative control for erosion of such sites. Generally, the permanent grass cover has intermediate effects on the elements of hydrological cycle, between those of trees and the bare soil or cultivated land.

Eroded soils have fertility deficiencies and fertilizer applications are helpful in restoring their productivity. The early establishment of a dense tree or vegetation cover with the help of fertilizers will be an effective erosion control strategy. But precautions should be taken in using chemical fertilizers to help seedlings on depleted sites. The key advice in preserving the integrity of the environment in so far as fertilizer use is

concerned is moderation and monitoring. Fertilizer use recommendations should be carefully considered to avoid an irrationally high use. The use of the right amounts combined with continuous monitoring of the environmental effects will facilitate remedial and preventive action.

The use of chemicals for pest and disease control should be avoided as far as possible. However, tested chemicals can have minimum impact on water quality, if used in a responsible manner. Marshy areas and those in the immediate vicinity of lakes and streams are to be avoided. Built-in water quality monitoring and surveillance checks in the project, when using chemical insecticides or fungicides, are unnecessary.

Slash disposal of unwanted combustible materials by burning in heaps is an important routine operation in some forestry areas. The sites of burnt slash are good places for sowing and planting because of increased fertility and lack of competition from existing vegetation. Such sites should be far away from the streams and water bodies to avoid excessive leaching of nutrients and the attendant risks of eutrophication in lakes and reservoirs. Slash burning should be done in such a way as to cause no damage to the standing crops. It should be carefully timed so that the burning is most effective and also well under control for the prevailing weather conditions.

Post planting control burning is a necessity in some young forest plantations. It should only be done in fire-resistant species with thick bark and only after the tree crowns are well above the reach of the ground fire. The leaching of released nutrients into streams should be prevented.

AGRO-FORESTRY

The pursuit of agriculture is an important activity for the people settled in mountain watersheds. This often involves growing crops in forest lands. In many developing countries, systems such as shifting cultivation are age-old customary ways of raising agricultural crops temporarily by clearing and burning of forest cover. The environmental hazards of shifting cultivation on steep mountain slopes are many and varied. As a result, a number of modified methods have been devised which reduce the environmental impact of such practices. These include the systems of agriculture with tree fallow; agricultural afforestation methods such as Taungya and Shamba; and growing of perennial crops under forestry.

Environmental impact of shifting cultivation

The removal of forest cover will lead to an increased overland flow that will accentuate flood peaks in local streams. This increased flow in combination with reduced interception of rainfall, and, thus, increased exposure of the soil to rain drop splash action will accelerate both erosion and downstream sedimentation problems. The sediment will harm fisheries, disrupt the balance of the aquatic ecosystem and reduce the useful lifespan of reservoirs. The clearing and burning of existing tree and vegetation cover may lead to a change in soil temperature regime, local micro-climate, rate of organic matter accumulation, etc. Furthermore, damage may be caused by the flushing of the released nutrients into nearby streams. This will affect aquatic life.

Guidelines

Shifting cultivation systems or their modifications succeed best only when partial clearing is made in the forest cover, and when soils are not unduly exposed to the leaching and erosion processes, such as those on steep slopes. The system breaks down when the soils are laid bare too frequently. In agriculture with tree fallow modification, a drastic reduction of the forest fallow period due to increased pressure for agricultural productivity will similarly aggravate the detrimental effects.

Planting of perennial crops, which provide soil cover through most of the year, contributes to the successes of the modified systems. The agricultural tree species which are sometimes grown with forest species in many countries include tea, coffee, cocoa, oil palm, rubber, papaya and citrus. This practice does not create any environmental hazards which is the case when growing annual or semi-permanent agricultural crops.

Adequate precautions should be taken to prevent overland flow so that erosion hazard may be kept as low as possible. The soil washed down the slope by the indifference shown by the cultivator is not easily replaced. Soil stability can be improved by stubble-mulching, working-in of crop residues or other organic matter.

Loss of fertility due to nutrient losses and changes in the physical factors is responsible for diminishing agricultural returns in the succeeding years after initial forest clearance. This has often been the cause for the cultivator to abandon the existing cleared area in search of another where a similar cycle of changes is often ultimately repeated. A gentler use of land is likely to have a more enduring effect. Such practices

when not carefully carried out can result in invitation of undesirable species, such as imperator grass which in addition poses a fire hazard.

Protective strips of forest vegetation can be retained to serve as shelterbelts when clearing such lands for agricultural use.

Taungya method, used for planting forest trees in combination with agricultural crops in the initial years, helps in replacing the old organic regime with a new one. This approach has been successfully used in establishing forest plantations of improved economic value in place of the existing inferior vegetation cover in many developing countries. Choice of agricultural species can be suitably made to favour forest species: their nutrient requirement should not be such that they rapidly exhaust the soil. Agricultural crops should not cast too much shade and, if possible, they should help improve the soils through the fixation of nitrogen, and conserve water. The tree species should be fast growing so that they can quickly overtop the food crops, and should have the overall ability to withstand competition for light, water, and nutrients over short periods. The intention is to establish a tree crop as soon as possible.

RANGE AND PASTURE DEVELOPMENT

Rangelands occupy extensive areas of the world. Grazing is an important activity for rural support in many developing countries and the rapid increases in population have resulted in greater demands on the grassland resources in mountain watersheds. A good grass cover serves several useful purposes of watershed. It helps to provide protection to the soil against erosion, promotes infiltration of rain water with resultant decrease in overland flow, and provides necessary forage for the sustenance of a healthy mountain-valley agricultural economy. However, excessive grazing can cause depletion of rangelands which may have several harmful effects. It is essential to be aware of the environmental hazards involved in range and pasture development projects on mountain watersheds and know how to reduce them through integrated planning and management practices. The environmental hazards likely to arise in such projects can be either directly due to the development activities connected with implementation or from the grazing activity associated with the use of the developed resource. These impacts are listed first and then general guidelines are provided for minimizing the hazards.

Environmental impact of range and pasture mismanagement

Use of fire to clear unpalatable woody growth or for conversion of the existing shrub vegetation to grassland can affect overland flow, the chemical quality of downstream water bodies, soil erosion, and sedimentation of reservoirs. Such practices will also affect soil structure, soil moisture and soil temperature regimes, and cause a rise in pH with resultant effect on the micro-biological processes in soil such as nitrification, denitrification and mycorrhiza development.

If chemicals are used to eradicate unwanted growth, this may cause contamination problems with harmful effects on aquatic life. Some of the chemicals used may have residual and cumulative effects on other animals or their habitat.

The use of mechanical means to eliminate undesirable bush vegetation may cause excessive soil disturbance and expose the mineral soil to be washed downslope.

Guidelines for development activities

Fire must be employed with great care in the elimination of unpalatable growth or for conversion of brush vegetation to grassland. It should be used only where it will not jeopardize timber and other watershed resources. Adequate fire lines should be established before burning and ample help should be at hand to take care of emergencies.

Reseeding with desired and previously tested species should be done, as soon as it is feasible, to provide early ground cover and to avoid reinfestation by undesirable plants. In choice of species, consideration should be given to the fact that sod-forming grasses, reproducing by rhizomes or stolons, can withstand grazing better than taller grasses. These measures can be successful only by exercising an effective control on the use of land. Progressive fencing may be necessary to keep livestock out of the seeded areas to enable grasses to be fully established before grazing. Mixed species of grasses and legumes should be used for irrigation pastures. Shorter time needed to get pastures ready for grazing, greater yield, steady supply of green forage throughout the season, and a more varied diet for animals are some of the advantages from such seeding. However it should be noted that the improvement of land for use as grassland may affect the water supply position of downstream users. Thus, although seeding may increase forage production and reduce

silting of reservoirs eventually, the streamflow reaching the reservoir may be reduced considerably in arid areas.

Soil and water conservation practices help to reduce soil movement and overland flow. This will prevent delivery of sediment and associated nutrients to the streams. Contour furrows and pitting can be used effectively to promote water infiltration and to reduce overland flow and erosion. Such measures will encourage a greater supply of forage and an increase in the grazing capacity.

Water harvesting techniques can be used in the arid and semi-arid sloping areas to improve forage on rangelands. Diversion of water from perennial or intermittent streams can be used profitably for range and pasture development if suitable sites are available. Water spreading helps to reduce flood hazards and erosion losses.

Use of chemicals for eradicating brush cover should be minimized and replaced by mechanical methods. This will help to reduce the environmental impact on aquatic life.

Timely planning and execution of all activities is essential in development projects. Many of the beneficial aspects may be lost or greatly reduced if important segments of the field programme are delayed beyond the right moment and season of implementation.

The use of mechanized methods for range improvement should not be undertaken without consideration of the local capacity for absorbing advanced technology.

Environmental impact of grazing

Grazing can lead to increased soil compaction by livestock and a decrease in the infiltration capacity of soil. Trampling of the forest floor also diminishes the effectiveness of the organic cover in protecting the soil and conserving moisture. Effect on the density and composition of vegetation: there is likely to be an increase of undesirable species because of heavy grazing, accompanied by a sharp decline in the palatable and least resistant species; in savanna rangelands the spread of woody vegetation often occurs, and in lands bordering existing deserts over-grazing can lead to desertification. This depletion of the rangelands and pastures will affect the condition and quality of livestock and herbivores, causing nutritional stress, particularly on young animals.

A change in the composition of the populations of rodents and wildlife often occurs because of the changes resulting in plant species composition from heavy range use by cattle and other herbivores.

Excessive concentration of livestock will affect the stability of stream banks; and the animal wastes discharged from such concentration of animals may cause water pollution of nearby streams or of ground water in areas with rapid percolation capacities. Trampling of animals, especially cattle and horses, on steep slopes with clay soils and intensive precipitation causes landslides.

Guidelines for grazing practices

Good range management aims at maintaining the native range in optimum condition to sustain continuous productivity. By avoiding overuse, the range can be protected from excessive erosion damage. It should be remembered that poor management of a fertile and well-watered range can reduce its productivity to a level lower than that found in a well-managed natural desert. The following guidelines could be useful in minimizing the detrimental effects of grazing.

Good management of mountain rangelands and pastures yields better economic returns. In addition, the maintenance of good plant cover on a watershed has beneficial effects on erosion control. At the end of the grazing period a percentage of the herbage should be left unused and a reasonably good cover of litter maintained. This helps in controlling surface runoff and erosion, and keeps the weeds in check. Good range management is often good watershed management. Grazing animals that are held in limited areas over prolonged periods can adversely affect even the most resistant species through over-grazing and trampling. Adopt measures to secure better distribution of cattle on the range. Fencing, development of water ponds, and salting away from the concentration areas are the usual techniques to achieve this and are at times essential measures to relieve pressure on critical parts of the range. Any water development project on the rangeland should therefore be linked with the above-mentioned considerations.

Short-term profit gain from overstocking a range is often at the expense of long-term damage to the environment. The intensity of use should be carefully determined on the existing and the future carrying capacity of the range. Moreover, abuse of rangelands through overuse and overstocking may result in the extension of deserts into adjacent lands. It is essential to avoid excessive damage of the native plant cover in the delicately balanced mountainous areas of the world.

The deteriorating trend in rangelands can be determined by observing the various age classes of the species present on the range.

Measurements of range trend, based on an assessment of the evidence of vegetation change, can assist in proper range management of wildlands. Range condition and trend analysis should be done periodically to guard against range deterioration. Should the deterioration be bad recovery plant cover is possible on some depleted ranges by excluding the area from grazing use. However, the recovery of plant cover is slow in arid areas. More environmental concern and care is needed in grazing use of rangelands in the watersheds situated in such climates. Stock exclusion and seeding of depleted ranges can be quite effective in rehabilitating the plant cover in areas where the growing conditions are more favourable.

Efficiency of range use is important. More timely grazing of each range unit when the forage is most nutritious, and resting parts of each operating unit in turn can be helpful in stabilizing efficient range-livestock production. Deferred and rotating systems of grazing can provide additional forage through increased plant vigour. Avoid heavy use of grasses at periods when they are most vulnerable to grazing pressure. Such periods usually are at the start of the growing season and towards the end of the growing season when plants are storing food for next year's growth.

Controlling noxious plants has the desirable effect of providing full opportunity to the desirable forage plants to utilize the limited available soil moisture on a range. However, the use of chemicals in eradicating the least palatable woody growth on rangelands should be viewed with caution. Alternative methods of brush control should be explored so that the environmental impact of such practices may be kept as low as possible.

The type and location of animals can also be important; grazing by some animals, e.g. goats, can be more harmful to some portions of the watersheds than by other domestic livestock. Similarly, wild grazing animals can exercise selective pressure on other areas within a rangeland. An equal number of grazing animals of one species can be more damaging than a combination of species. Grazing by animals in some forested areas can be damaging to natural regeneration and young trees. Such grazing should be controlled by some type of fencing. Concentration of animals in confined feeding areas, such as near valley bottoms, can cause waste materials to pollute the nearby streams or ground water, if rapid percolation occurs. Precautionary measures should be taken to avoid such environmental impacts.

Animal husbandry projects often result in decrease of mortality rate

and, therefore, an increase in the herd. This could result in overuse of the range. Animal husbandry projects should be considered in combination with range development projects to avoid environmental damage resulting from the overuse of ranges.

DAM AND RESERVOIR PROJECTS

Most of the world's supplies of fresh water originate from mountain watersheds. In order to harness this water for the benefit of mankind, river basin developments are proceeding at an accelerated pace in all developing countries. The beneficial effects of such projects concern agriculture, industrial and domestic water needs, hydropower, fisheries, transportation, recreation, and flood control. However, the improvements to be achieved have often ignored any consideration of the ecological consequences of such developments. Although the benefits to the national economy and to the fulfilment of human needs may be substantial, it is important that the impacts of dam construction and water impounds be carefully examined. Ecological effects of such developments are not always immediately obvious. Many of the environmental impacts may be unforeseeable in terms of their long-range effects. The environmental hazards from dam and reservoir development projects result either directly from the dam construction activity or due to the inundation of forest and agricultural lands from water impoundment.

Environmental impact of dam construction activity

Such activity is often associated with the use of large machines for land clearing and transportation of building materials along stream or river margins. The extensive soil and rock disturbance related to diversion of water and preparation of building sites also contribute to environmental hazards. The likely impact of such activities is noted below.

Soil compaction near dam sites due to extensive engineering and human use will cause a reduction in the infiltration capacities of the worked area with resultant increase in overland flow which will accelerate soil erosion from the disturbed area because of the elimination of protective plant cover and increased exposure of mineral soil. This can also lead to accelerated sedimentation which may be damaging to downstream water bodies.

Fish may be affected by the altering of their downstream habitat due to modified flow and changed water temperatures while the physical barrier created by the dam may block the movement of those that migrate.

The change in river regime may not only deprive agriculture of the soil nutrients provided by seasonal flooding but also adversely affect forest flora and fauna dependent on such inundations while the release of peak flows in an emergency may lead to excessive river bank erosion and scouring of river bed.

Guidelines for dam construction activity

It will be worthwhile to avoid location of dams in areas where excessive erosion and silting resulting from dam construction activities may damage the spawning tributaries and fishery habitats. Wherever they are conducted such activities should avoid excessive soil entry. Where possible forest filter strips should be maintained along the stream and river banks to intercept the sediment that is generated.

It is necessary to seed and afforest all areas affected by dam construction and related acitivities as soon as the required works are completed in each of them. Timely revegetation of each disturbed site will reduce the chances of sill and gully erosion, and reduce the chances of excessive soil movement into the nearby stream or river channel.

Establish the need for fish-passing devices and fish-guidance structures in the planning stage of the project to facilitate movement of migratory fish.

A minimum flow may need to be maintained in the downstream river section to provide a usable and desirable passageway for fish and other aquatic organisms.

A multi-purpose dam may be a better investment for the development project than the building of a dam for a single purpose. Flood control, with resultant benefits to the downstream areas, and the development of fishery and recreational potentials, can be easily incorporated into the design at the planning stage. Dams built for hydropower may similarly serve the purpose of providing irrigation water to needy agricultural lands.

Environmental impact on water improvement

The inundation of the reservoir or lake area created by the dam can have irreparable consequences on some of the resources and

characteristics of the locality. Planning of certain activities may be helped by an awareness of the likely environmental effects which are both diverse and numerous.

The flooding of the lake area for water storage may lead to the loss of forest products including commercial timber. Moreover, if the trees are left standing they may obstruct the use of the lake for recreation. There are also risks to navigation due to floating logs or vegetation islands.

The decomposition of organic matter in the stagnated depths of the lake may increase acidity, or may lead to the production of methane gas, thus endangering hydropower and hydraulic facilities, or to the development of hydrogen sulphide, thus reducing dissolved oxygen content and harming fisheries.

Fisheries may further be affected: downstream by changes in thermal conditions, or in the lake itself by the change in habitat and the possible consequences of fertilizer or pesticide contamination of upland run-off.

The clearing of remaining vegetation and slash burning can cause water pollution problems due to the release of nutrients.

Human population may have to be evacuated and resettled. This raises some of the most important and serious problems connected with the project development. More specifically the clearing of land for resettlement may lead to increased sediment loads, which will reduce the storage capacity of the dam thus decreasing its useful span of life for irrigation and hydropower.

Ecological changes in the neighbouring area may be caused by both the fluctuation in the reservoir level and the rise or shift in the water table.

The larger surface area of the impounded water exposed to the direct action of the sun may result in increased evaporation losses—a critical factor in water-deficient areas.

The larger impoundments may alter the local micro-climate, while the weight of the water body may alter the seismity of the area.

The water bodies created may establish a habitat for disease vectors and nuisance insects or may suffer from the proliferation of undesirable aquatic weeds.

Problems may arise from the increased use of the area for recreation.

Flooding will frequently result in the loss of wildlife habitat.

The effect of water transportation systems replacing the established road routes may be beneficial in some cases.

Guidelines for water impoundment

Human problems related to evacuation and resettlement because of water impoundment should be given top priority.

It will be necessary to salvage excessive organic materials if the dissolved oxygen supplies are likely to be a critical factor. Oxygen levels sufficient for the survival, growth, reproduction, general well-being and production of fisheries must be maintained. Clearing of trees prior to impoundment of water has sometimes been carried out for improvement of fishing grounds and for removal of obstructions to fishing gear. In other situations, such clearing may cause removal of sheltering cover and the likely foraging grounds for fisheries. Clearing proposals, other than for salvaging of valuable merchantable timber, should, therefore, receive individual attention with consultation of a fisheries expert for each project related to man-made lakes.

As the multi-purpose dams represent substantial economic investment, it is essential to protect the designed storage capacity. Shoreline activities and resettlement of people in such areas may result in excessive sediment contribution to the man-made lake. Buffer strips of forest should be maintained along the shoreline to protect the reservoir from the adverse effects of grazing, high population density, and substrate movement. This may have to be accompanied by effective watershed protection in the critical areas.

In areas of high solar radiation, the accelerated evaporation rates of water impounded downstream should be carefully considered. The scarce water resource may readily be lost to the atmosphere, in such locations thereby negating the optimum benefits to be derived from economic investment. A relocation of the proposed site may offer a possible alternative.

Impoundment of water can be effectively used to exercise some beneficial effects on water quality. Storage helps to smooth out the seasonal variations in water quality. Long-term storage is likely to improve significantly the bacteriological quality. However, the stratification of water in deep reservoirs could result in deterioration of water quality in the bottom portion.

In areas prone to flood occurrence, one of the main effects of an impoundment is to smooth out the fluctuations in flow. Flood control can be achieved by keeping enough unused reservoir capacity to absorb flow peaks. Large surface area is more influential for fishery production than the depth or volume. Most fish avoid water in depths exceeding 20 metres.

The major adverse chemical, physical, biological and human effects of forests flooded by reservoirs will be exacerbated in projects where reservoir water is deep and still, retention time long, and spillway rarely used. Such problems will be considerably less in shallow or turbulent reservoirs where the retention time is short and water has rapid circulation.

Fertilizer and pesticide runoff from agricultural lands, weed and algae infestation, and water-borne disease can have substantial impact on freshwater fisheries. Necessary precautionary measures need to be undertaken in the planning stages to anticipate and control such problems from the fisheries and human use considerations.

Water depth and volume measurements should be used in assessing techtonic modifications which may likely be caused by the weight of the impounded water in vulnerable areas.

TORRENT AND RIVER CONTROL

Torrent and river control works are aimed at protecting downstream settlements and property from the hazards of flooding and bed load depositions resulting from the mass transport of materials dislodged in the upland catchments. The control measures are a combination of revegetation activities and engineering works.

Environment impact of torrent phenomena

The main effects of torrents are fluvial erosion (channel erosion, slope erosion), mass movements (landslips, landslides, earth and debris flow, slumps), sedimentation and inundation.

Human settlements located in alluvial fans, narrow valley bottoms of active torrents and in tracts subject to sedimentation can be affected by inundations, mud-flows and other torrential phenomena, causing the evacuation of the endangered population, the destruction of their property, and uncertain conditions for the productive use of the lands requiring emergency and remedial assistance and other social costs.

Torrents can damage roads when the alignment runs alongside or cuts across the torrent channel. The damage to the road may be by lateral or bank erosion, or by the surface and base erosion caused by the overflowing water. Road embarkments that have reduced the natural width of the torrent are particularly prone to such damage.

Damage can occur to bridges and culverts and water intakes by mud-flows and by the debris transported by torrents in extreme rainfall events as well as by scouring.

Landslides can cause destruction of roads and other goods and services in the area below; their scars can originate torrents and the deposit can provoke flow detention and the formation of impoundments that, upon waterlogging or rupture of the blocking mass of debris, may constitute very destructive mud-flows having tremendous tractive force.

Loss of aesthetic and recreational values can result from excessive damage to the landscape by the torrent.

Environmental impact of torrent and river control works

Effects of extensive disturbance caused during the construction of engineering structures: Excessive movement and careless handling of the needed earth and materials will result in greater sedimentation of the stream waters and downstream waterbodies. Deposit of debris in retention check-dams and debris basins may destroy spawning areas for fisheries. The dams themselves may impede fish migration.

Groynes, and other deflecting devices may cause bank erosion on the opposite side, and may cause other undesired effects in the fluvial dynamics if the river channel improvement measures are not carefully conceived to establish both a permanent river alignment and a steady flow without originating scouring. Excess flow dissipation devices will transfer and accrue downstream the effects of flashfloods and high flows.

Channel improvement works which consist in increasing the depth and reducing the length of the waterway will produce disturbance of the river bed and the aquatic environment and will be short-lived if the bedload is not significantly reduced through mechanical and biological treatment of the catchment area and of the channel upstream.

Guidelines

The torrent damage to forest roads can be avoided by locating them away from the stream channel, if possible. If the road has to be located alongside a torrent channel, it will be worthwhile not to constrict the natural cross-section of the channel. Where a channel must be crossed, width restriction should be kept to a minimum. Adequate protective

measures should be adopted for safeguarding roads and installations that have to be located in unsafe areas. Streambank protection can be achieved by bank revetments, rip-rapping, and training walls. Sills can provide protection against channel bed erosion and can protect banks and structural footings. Use of groynes can be made to divert the flowing water. Lined ditches, paged channels, and combination of streambank protection works with sills and check can be used for safe flood discharge.

Overflowing of a bridge or culvert can be avoided by providing sufficient drainage capacity. The design criteria for intense and most damaging storm events should be strictly applied. Much damage to the road and surrounding areas can result if a culvert or bridge is partially blocked by the transported debris. Avoid dangerous zones or vulnerable engineering sites. Protection of bridges, culverts, and paved fords can be carried out by a combination of engineering structures. Sills and check dams can be constructed at the downstream end of the abutments to reduce scouring and bed erosion. Check dams can be located upstream of bridges and culverts to trap sediment and debris and thereby prevent the hazards of being plugged and blocked.

Stabilization check dams can be used to stop channel bed erosion. These help to reduce the gradient of the stream between check dams and thus reduce the tractive force. A variety of designs for such dams is available and should be carefully selected for achieving the desired beneficial effects.

Bank and slope stabilization can be achieved by engineering works (training walls, check dams, walls and batterings). The potential slide area can also be kept stable by a drainage system that will keep it dry. This approach can also be used for stabilizing the mass of soil accumulated after the slide occurrence. It can be achieved by diversion of water on the boundary of the slide areas which may be contributed to by superficial and groundwater runoff from the upper reaches. In addition, steps should be taken to drain off superficial and subsurface water within the landslide mass. A variety of techniques is available to achieve these objectives.

Revegetation measures consisting of planting grass, brush and trees should be taken in hand to protect bare slopes and bank surfaces from erosion. Mulching, contour wattling and contour planting are some of soil and water conservation techniques used in the mountain areas.

Although flood embankments can successfully prevent inundation of adjoining settlements on a short-term basis, an integrated watershed

management approach has to be adopted for more permanent and lasting solutions to torrent problems. Engineering works for torrent control and flood control are short-lived without the biological treatment of the catchment area and of the channel and river banks. Structural measures should be essentially a supplement to biological measures which can impede or neutralize runoff on the slopes and reduce sediment coming from the tributary area.

Torrent control problems can be difficult and complex. The quantitative assessment of torrent erosion and bed load transport needed for effective planning can best be done with the help of a torrent control expert. In difficult situations, the advice of such an expert may be essential in the design of structures and works needed for effective torrent and river control. It is only through careful planning and execution that the tremendous environmental impact of torrents can be minimized.

RESETTLEMENT OF WATERSHED POPULATIONS

Human problems related to resettlement of people are among the most difficult and complex of all watershed problems. The need for such resettlement may often arise as a result of forced evacuations from watershed locations chosen for major developments, such as multipurpose dam construction and the resultant inundation of extensive forest and agricultural lands for water impoundment. Such movements of people are beset with considerable psychological stress and social strain and insufficient efforts are often made to ensure that the evacuees share in the benefits of the project. Problems relating to human settlements because of practices such as shifting cultivation are usually self-imposed and, therefore, devoid of the psychological pressures resulting from forced evacuations. However all human resettlements have considerable environmental impact. Human beings, constituting an essential element of this environment, are directly affected in many ways. The likely impacts inherent in the eviction and resettlement of rural populations may be noted first. These are problems which have been experienced in past relocation programmes relating to water impoundments in mountain watersheds and should be anticipated in the future.

Environment impact of resettlement of rural population affected by development projects in forest areas

Dasman, Milton and Freeman have listed the following human

problems related to forced evacuation and resettlement such as loss of agricultural, forest, or minerally productive lands, homes, villages, religious and cultural sites, and other community facilities (schools, health centres, etc.). These may be complicated by resource difficulties related to break-up of social units and families. Further hardship may be caused by inadequate notification to evacuees prior to inundation or insufficient compensation for losses (often based on faulty land valuation).

Resettlement projects often suffer from lack of funds, planning capability and trained personnel to implement and manage a successful resettlement programme and to retain and educate evacuees to cope with their new environment. Planners and responsible agencies often fail to investigate, fund and develop a range of viable options on which the people to be resettled are consulted and from which they may choose, for example:

i) relocation and retaining in urban areas;
ii) full-time fishing and aquaculture;
iii) relocation in new irrigated areas (if any) served by the reservoir;
iv) sufficient compensation, on an individual basis, to cover purchase of good land elsewhere; or
v) sufficient compensation to cover such purchase communally.

Difficulties can occur when moving people from fertile lowland agricultural areas to poor quality upland sites. This can be brought about by lack of adequate consultation with evacuees and research into what is needed or what is possible or from necessity because of political or other constraints; these difficulties include:

i) lower agricultural production associated with less productive soils and unfamiliar land use practices;
ii) exposure to new disease environments and intensification of existing diseases, particularly following a rise in population density;
iii) reduced crop diversity and loss of river fisheries, contributing to nutritional impoverishment;
iv) lack of potable household and irrigation water, and
v) fewer potential cash crops and loss of income.

There is a tendency towards selecting government forest reserve lands for resettlement which can lead to loss of valuable watershed protection and timber production.

Competition for land occupied by previous settlers—usually upland shifting agriculturalists or lowland farmers—will often result in

pressure on carrying capacity. Additionally for those remaining near the reservoir competition for cultivable land and for fishing opportunities from immigrants of more distant origin, who may be in a stronger position to launch new enterprises, may erode the new livelihood of the evacuees. There is often inadequate attention paid to population growth rates in resettlement areas and to providing birth control advice and assistance.

It is, therefore, evident that resettlement of dislocated peoples can often be the largest and the most complex issue related to water impoundment projects. A further problem may arise due to the effects of altered water regime on downstream populations. Loss of soil nutrients from seasonal flooding and increased channel erosion due to the release of high flood peaks can have severe impacts below the dam and thereby force eviction of affected people to be settled elsewhere. Downstream impacts of the Kariba Dam on the Nile River delta provide classic examples. Many other and telling examples exist elsewhere illustrating how resettlement projects could fail through the neglect of one factor or another.

Guidelines for minimizing the rural resettlement environment problems

Problems of human resettlement due to evacuation of people from areas needed for extensive development are most pressing and potentially costly. It is essential that human resource be helped adequately to become usefully adapted to the new physical, social and economic environment. The following guidelines may be useful:

Serious psychological stresses and social tensions can result from the evacuation of people from their familiar surroundings. Time, effort, resources, and considerable assistance and support are needed for the individual and institutional human adjustments. This aspect needs careful consideration and attention in the planning and execution stages of development projects.

The process of environmental and social adaption is facilitated greatly if the evacuees are relocated in a similar ecological situation. Such adaptation is less costly and has a higher chance of success.

The formation of community organizations and participation of people in selection of potential areas for resettlement, home sites, and in the planning and construction of housing and other facilities will assist the settlers in acquiring a personal significance in the new environment.

The task for clearing land for dwellings, cultivation, and other land use activities should be undertaken with great care.

It is essential that the evicted populations be provided with health control facilities for themselves and their domestic livestock. It may be necessary to arrange food supplies on a large scale in the initial stages.

Specialists with a broad inter-disciplinary background should be given special training in dealing with environmental problems. They can thus serve the need for educating evacuees for preserving the quality of the environment in their new pursuits and chores connected with resettlement in the upland areas. An educated, convinced public is a great asset in the success of the long-term effects of resettlement programmes.

Most of the human problems identified here have resulted from the causes mentioned in the majority of the cases. The cause for the failure of certain aspects of the resettlement programmes should be thoroughly considered while planning for new programmes in similar circumstances. Experience from other areas should be drawn upon to assess accurately and anticipate the likely problems. This will help considerably in improving the planning process and for the efficiency of the resettlement personnel.

A number of difficulties arise in getting the rural populations stabilized and involved in the watershed management projects. Such participation entails security of land tenure extension work, subsidies and other economic and legal incentives, and studies of social structure and behaviour. Often the inability to participate may be due to a lack of adequate opportunities. In the case of excessive population growth, family planning should also be considered for keeping a balanced man/land ratio.

CONCLUSION

It will be seen that when dealing with the environmental impacts of watershed management in mountain regions there are both many pitfalls and many opportunities that can be missed. It will also be seen that most of the remedial measures identified must be incorporated, if they are to be effective, in the conception and design steps of the projects and of planning procedures. In many cases later attempts may prove to be only cosmetic changes as the ecosystems under consideration are particularly fragile and complex and not easily susceptible to ameliorative action.

The guidelines for remedial or preventive measures which have been presented in this study are meant to be illustrative rather than exhaustive in character; there are no substitutes for local experience, foresight and prudence. We have only attempted to draw attention to the kind of considerations which must be kept centrally in mind. The objectives for which we strive in this subject area are multidenominational and interrelated, requiring a formidable array of diverse technologies and disciplines. It should be noted that although the guidelines presented here are essentially national in nature and scope, international co-operation and co-ordination to bring into play the different inputs required may often be necessary.

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