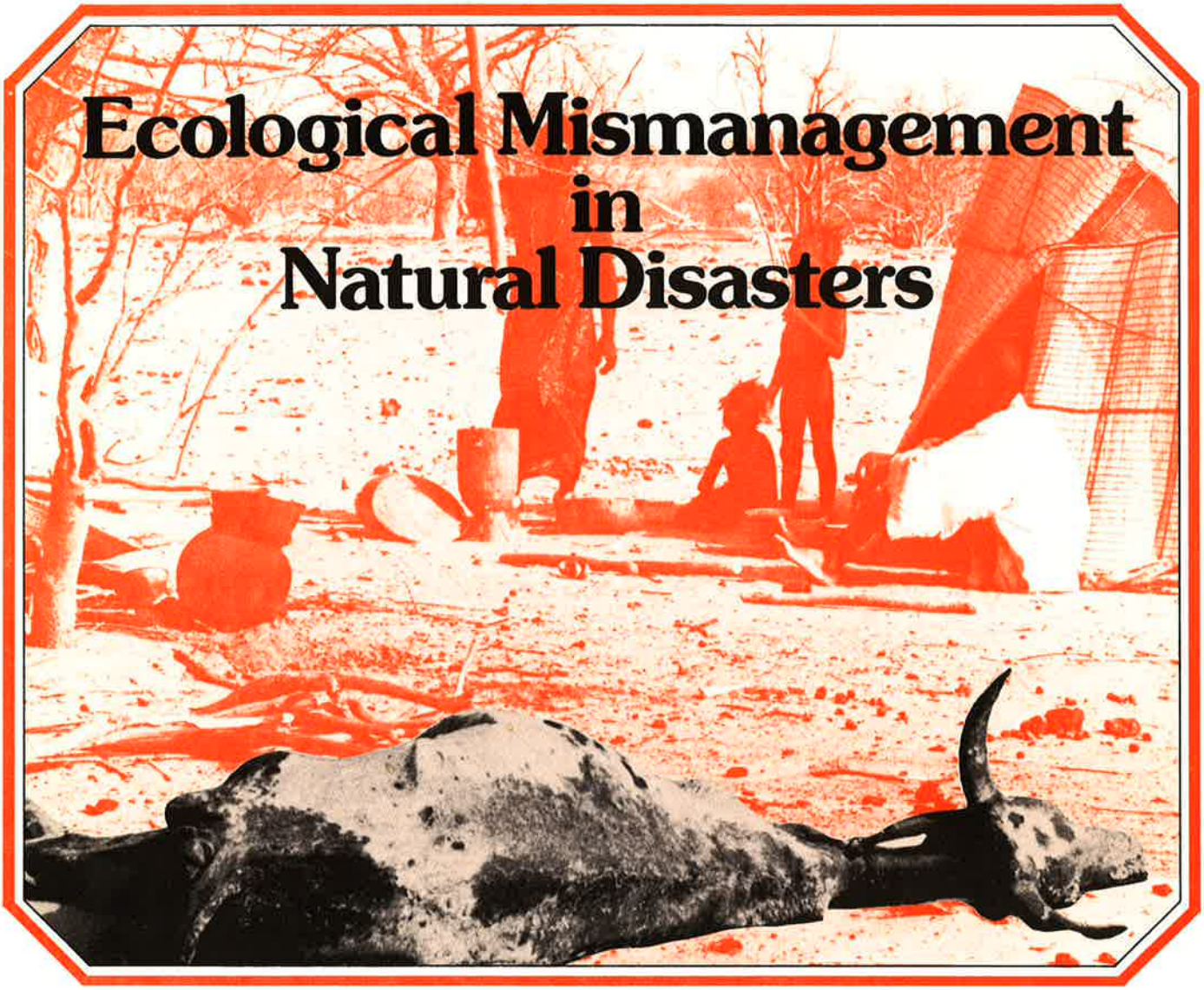
Ecological Mismanagement in Natural Disasters



By Prof. L. D. Pryor of
the IUCN Commission on Ecology
in cooperation with
the League of Red Cross Societies

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The League of Red Cross Societies

The League of Red Cross Societies is the International Federation of National Red Cross and Red Crescent Societies. It is one of the three components of the International Red Cross, the others being the International Committee of the Red Cross and the National Red Cross and Red Crescent Societies.

Its object:

to prevent and alleviate human suffering through the activities of National Red Cross and Red Crescent Societies and to contribute to peace.
it advises and assists National Societies in the development of their services to the community.
it organizes and coordinates international relief for victims of natural and manmade disasters, often launching world-wide appeals for aid. It also promotes the adoption of national disaster preparedness plans.

The League is the permanent liaison body for the 129 National Societies and acts as their spokesman and representative internationally.

Headquarters: Geneva, Switzerland.

IUCN Commission on Ecology

The Commission on Ecology of the International Union for Conservation of Nature and Natural Resources (IUCN) is a scientific commission of an independent, international, non-governmental organization. IUCN was founded in 1948 by Unesco and the French Government. The Union comprises today 57 governments as state members, 118 government agencies, and 315 non-governmental national and international organizations. This membership represents 111 countries.
The Commission on Ecology was established in 1954 and reconstituted in 1979. At present it has 140 members from 43 countries in all the continents, carefully selected for their national and international scientific status and expertise.
IUCN's Commission on Ecology provides scientific information and advice to ensure that action directed towards the sustainable use and conservation of natural resources, i.e. the implementation of the World Conservation Strategy, makes the best use of current ecological knowledge. The World Conservation Strategy, launched in 1980, provides an overall plan for action in this direction.

Through its Working Groups, the Commission gives particular attention to:

ecological problems of the open oceans,
continental seas,
coastal areas,
mangrove ecosystems,
coral reefs,
inland waters,
arid lands,
tropical rainforests.

It is concerned with problems relating to:

oil pollution,
environmental pollutants,
ecological assessment,
(re)introductions, animal migrations,
mountain and river basin management.

The Commission is also active in the field of human ecology, particularly in rural development and traditional life styles.

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The Australian National Parks and Wildlife Service
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PREFACE

The increasing intensity and frequency of human disasters is often related to ecological mismanagement and especially to that of vegetation through unwise clearing, burning and overgrazing. Corrective measures are generally feasible by instituting sound management but this must be based on good planning and be supported by adequate finance and a willingness to meet the social cost.

This Commission on Ecology Paper originated in discussions between IUCN and the League of Red Cross Societies, to determine areas in which they could together work on environmental issues.

Disaster Preparedness is a major programme area for Red Cross, although in the public's eye it is more often associated with post disaster relief. For IUCN, ecological mismanagement is a matter of prime concern.

It is the hope of both organisations that this Paper will serve as an initial contribution towards those efforts which urgently need to be taken to prevent those disasters which are of man's and not nature's doing.

That this task has been started is due to the contribution and efforts of Prof. Lindsay Pryor to whom we owe our gratitude for having made this Paper a reality.

KINDS OF DISASTER WITH AN ECOLOGICAL COMPONENT

Mankind suffers from time to time from disasters of different sorts, resulting in severe economic loss and disruption, and in many cases injury and loss of life. Some of these are man-made, whereas others are associated with natural phenomena. White (1974) points out that "average costs of property loss from extreme events in nature are increasing. Vulnerability to catastrophic events is mounting."

While developing countries in transition are those most at risk from severe dislocations, modernised industrial nations are highly vulnerable until they move into a post-industrial phase with an integrated public policy that takes into account the full range of hazards and the full range of possible social adjustments to them. With the world family becoming increasingly interdependent and with the spread of technology in production and communication, the world system becomes more sensitive to the impacts of extreme events.

To those who have given attention to problems of natural hazards, it is not surprising that some threats which have attracted larger attention are those of a rather exotic and wholly human fashioned character, such as the release of freon from aerosols and deodorant propellants and its effect on ozone. In contrast, less attention is paid in the public press to some well established and recognised threats to the quality of soil, water and air. Examples are the deterioration of soils under shifting cultivation and following irrigation. The lessons are similar. Action tends to come in the wake of perceived crisis—whether or not actual—and at that time the groundwork laid by scientific research may have a profound effect upon whether the hurried action is for good or ill.

Many disasters (but not all) are related to natural causes and those which are, often have a component stemming from ecological mismanagement, which exacerbates the level of damage. Where it can be demonstrated that a manageable ecological component is involved, it follows that improved management can be expected to go far in reducing the damaging impact. There are good grounds for believing that sound ecological management often might prevent disaster altogether where, under current conditions, disasters will occur from time to time. While national and international responses to disasters have generally been after the event (even though this may be very soon after), increasingly it has been seen that preventive steps, where these can be taken, are highly desirable to complement relief action.

An attempt is made here to indicate some of the areas where sound ecological management of natural resources could have a significant effect in reducing the level of disaster and thus point the way to programmes which would help alleviate future risks and minimise levels of damage. A scrutiny of records shows that major disasters have been associated with an array of events, including floods, drought, fire, earthquake, volcanic eruption, landslides, avalanches, locusts, wind storms (hurricane, tornado), rodent invasion, tsunami, refugees and displaced persons, political hostages, epidemics (smallpox and cholera), and armed conflict (League of Red Cross Societies, 1978). These are the principle categories to which disasters have been allocated. Of those which are triggered by natural pheno-

◀ In West Java, Indonesia, a recent landslide caused by deforestation made 3000 people homeless. Courtesy: Alain Compost.

mena, some such as volcanic action, earthquakes, windstorms (Brikmann, 1975), tsunami (Bolt *et al.*, 1975), are mostly not appreciably affected by ecological management, although forward planning of preventive measures including warning systems may allow amelioration of the effects and constitute a highly significant segment of preventive action. Other disasters such as flood, drought, fire, landslides and avalanches are often clearly related to conditions which sound ecological management may substantially circumvent; while biological events, such as locust plagues, are known to be responsive to preventive ecological manipulation. It is these latter categories of disaster in which ecological mismanagement is a most potent causal factor. Since this is subject to influence, a way is open for beneficial manipulation and adjustment, which will lead to ultimate benefits which may at times even remove the risk of disaster altogether.

Identifying the problems and the provision of the means for making adjustments are essential steps to improve the position. Preparation of plans of action and adequate funding will be prominent components in this process.

LONG-TERM ECOLOGICAL EFFECTS OF HUMAN ACTIVITY

A fundamental issue in ecological management centres on the rapidly and ever growing human population and its impact on the environment. This broad issue has already received much attention and must continue to do so. No thinking person can be unaware that this is a fundamental problem confronting mankind. *Growth Without Eco-Disasters* (Polunin, 1980) sets out many of the aspects related to this issue. The combined development of agriculture and livestock grazing has brought enormous changes to the world vegetation, which in the extreme is represented by the difference between initial forest and cleared open fields with or without cultivation. In a more subtle way however the influence of grazing and other land-use practices upon vegetation has also led to great changes, even if these are not quite so dramatic as the first and correspondingly less readily appreciated. These and other human activities have now been recognised very widely as trends with serious damaging consequences which generate an urgent need to conserve effectively the living world and its natural resources; an aim which the International Union for the Conservation of Nature and Natural Resources was founded upon.

Some of the broad issues raised at Reykjavik (Polunin, 1980) must remain forcibly before us at all times. For example, the possible consequences of an increase in the carbon dioxide level of the atmosphere has been much commented upon and is an area which, together with the population explosion, might be termed phases of ecological management which are associated with the survival of mankind.

These fields have been widely discussed elsewhere, but are outside the scope of this study which seeks to focus on extremely important, but somewhat less extensive, effects which are correspondingly more amenable to immediate manipulation than those particularly fundamental questions that mankind in time must also solve on a global basis if he is to survive.

In a narrower framework one can find many examples where ecological mismanagement has a significant effect upon the intensity of natural disasters, and where it is believed that it is possible to make contributions without complete change in basic social and government structures, which would alleviate a number of these problems. Examples of the possibilities are embodied in some of the recommendations from Reykjavik: (Polunin, 1980)

> "We must learn far more about the interferences which ecosystems can tolerate without suffering irreversible depredation, and about the exploitation that they can support (without losing their continuing function of producing) the required resources. To these ends considerable segments of all ecosystems should be set aside for subsequent ecological observation, monitoring, and study. The biotic life-support system must be sustained in every possible way throuhout the world.
>
> Further action should include the establishment of trees or other appropriate vegetation to cover soils —either to regenerate or to recreate damaged ecosystems.
>
> The exploitation of the remaining tropical forests for timber for the rich countries should be restrained, and other ways found to help the 'developing' countries to balance their financial budgets. As there is little to be gained from agriculture on soil that was formerly occupied by rain forest, the destruction of forests for agricultural extension by current technologies in these areas should be abandoned as counterproductive."

WHAT ARE DISASTERS?

Situations generated by natural causes which are often sudden in onset and which endanger life or the means of supporting life, and are often associated with widespread injury and death, are generally designated natural disasters

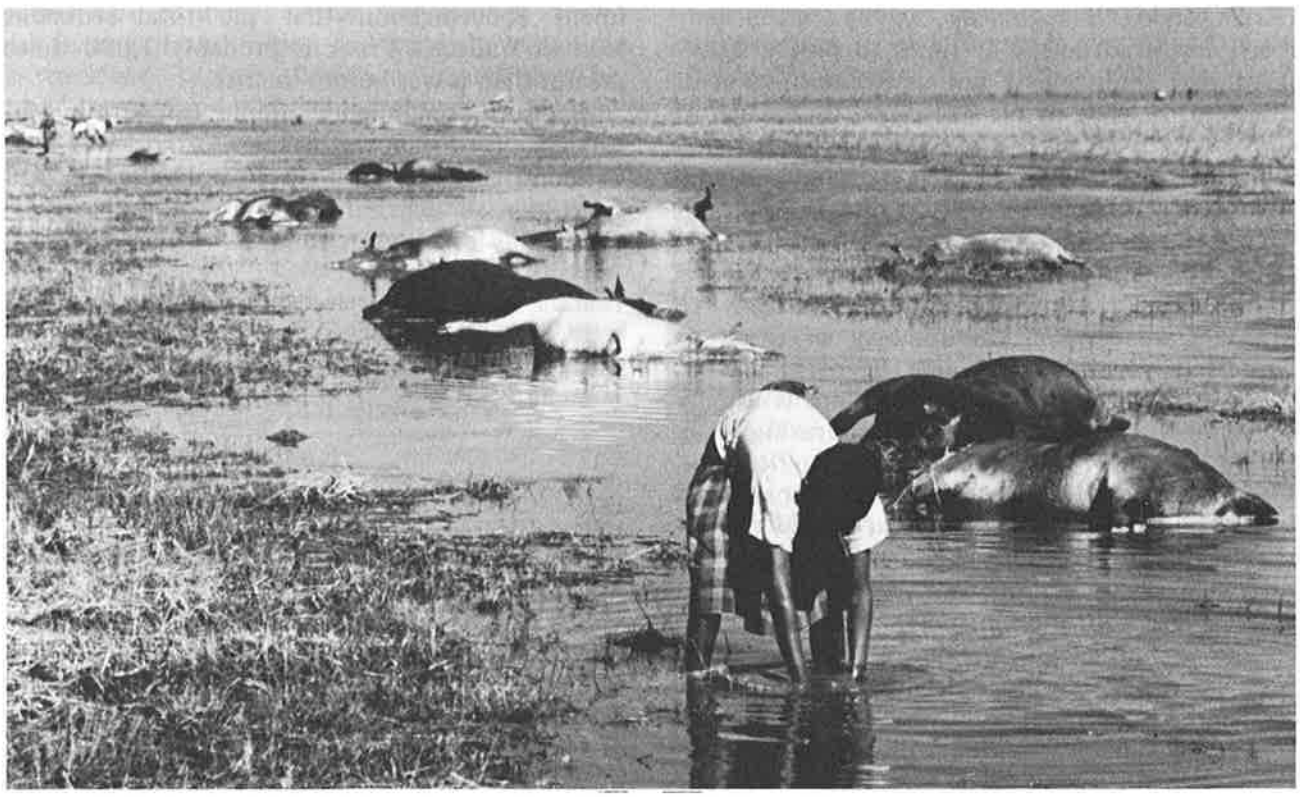
(White, 1974). The reduction of effects of various kinds of disaster may be achieved by forward planning in such matters as the precise location of urban settlement or the establishment of precautions by a warning system or similar devices. When a disaster has occurred there are steps which will ameliorate its effect and the worldwide activity of relief organisations in providing these services has been one of the principal ways up to the present of alleviating their effects. In most natural disasters events are usually triggered by some natural phenomenon which itself is not controllable by man. It is the magnitude of the effects of such phenomena that is largely responsive to manipulation and it is that to which attention is directed. Areas in which the opportunity for improved ecological management exists are numerous (d'Albe, 1970). An important one is flooding (Coleman, 1953), closely associated with which is the effect of grazing in catchments. Fire in vegetation (Cooper, 1963) and drought (Lovett, 1973) may be placed in this category also. The set of events with relatively lesser effects as a rule, but which are subject to ecological manipulation are the control of landslides (Burton and May, 1972; Sorenson *et al.*, 1975), avalanches (USDA, 1968), beach and coastal erosion (Foster, 1974), and biological imbalance associated with plagues, such as locusts. In windstorms it is generally the associated rain which leads to disaster although some reduction of damage may at times be effected even with this natural phenomenon.

FLOOD

A thorough study of the influence of man on the hydrological cycle together with guidelines to policies for the safe development of land and water resources has been given in the Unesco 1974 review, dealing with the status and trends of recent research in hydrology. This study emphasises the need for positive land-use policies with regard to various classes of landscape and also in developing countries with regard to "unplanned proliferation of subsistence agriculture without the means or the discipline to protect natural resources". (Unesco, 1974)

It is pointed out that until rain or snow reaches the ground, water does not, at this stage of technological development, effectively come into the range in which choices by man can influence the results. Whether water, once on the ground, becomes "a productive resource or a destructive hazard, depends very largely on man's management of vegetation and soils". (Unesco, 1974)

It is pointed out that the means to secure the benefits and avoid the disasters are already within man's knowledge and experience. Effective



Coping with disaster: flood in East Pakistan. Courtesy: United Nations/André Bureau/Sigma

control requires the management of resources and the development of policies to a level which has often been reached in and even now prevails in highly developed areas, but which are lacking in many parts of the world. In a majority of cases changes in river flow have been associated with deforestation in the catchment (Chao, 1979). In a broad sense, the hydrological effects of forests are now fairly well appreciated, although because this is an expression of the interaction of very many factors, there are many details still to be elucidated and there are substantial variations in water flow patterns according to different conditions in various regions which often imply substantial riders to the general statements.

The effect of vegetation on the hydrology of catchments, but especially that of forests, is prominent (Anderson *et al.*, 1976). The beneficial effect is largely that of regulation of flow, rather than total water yield and it is widely acknowledged that the total yield may be reduced by the presence of vegetation which actively transpires water as part of its life function. In a sense this is a price to be paid for having the regulatory effect on water flow. This regulation of run-off and stream flow is perhaps one of the most important elements in relation to flood disasters. Even with effective regulation of flow, there are still opportunities for modifying the yield by alternatives in patterns of forest management (Kriek and O'Shaughnessy, 1975), which may reach levels sufficient at times to play a significant part in living, if not in the mitigation of disasters. In view of the likelihood that much of the vast area of the world's surface still forested will be deforested in coming decades, the consequence of this in leading to disastrous floods cannot be over-emphasised (Chao, 1979; Rao, 1981). In fact a great deal of the adverse effects of ecological mismanagement in relation to disasters stems from the removal of forest or woodland vegetation by one or other means. Associated with forest removal, there is usually the added effect of fire and over-grazing, even where there is no other form of agriculture. The imbalance in the hydrological cycle produced by these changes can be very great indeed and yet the various stages from the sound sustained yield management of forest to over-exploitation of forests, or complete cutting and removal, and excessive burning and grazing are all associated with the likelihood of extreme floods in areas served by catchments originally covered by forests. If this is coupled with other types of flood control work of a structural kind, the likelihood of major disaster is excessively increased and most of this risk is man-made (Arnold, 1974).

An example of the effect of fire is provided by the experience of the Snowy Mountains Hydro-Electric Authority in the Australian Alps (Brown, 1972). Here a major uncontrollable forest fire in inaccessible rugged country burned out the catchment areas of Wallace's Creek and the Yarrangobilly River, of 41 and 224 km^2, respectively. These catchments had been gauged for some eight years previously, with detailed sampling of suspended soil load. After the fire the flow pattern changed abruptly, with sharp flow peaks from the burned-out areas. Rainstorms, which from previous records would have been expected to give rise to flows of 60–80m^3/sec (cumecs), produced a peak of 370 cumecs. The suspended sediment content at a flow of 60–80 cumecs has been increased by 100 times in comparison with the soil content before the fire. A storm occurring some seven months after the fire gave the highest sediment concentration recorded at Wallace's Creek. At a flow of 95 cumecs the concentration was 14.4 percent by weight, equivalent to 115,000 tons per day. This concentration is high by world standards. On the same day the River Yarrangobilly, with a flow of 47 cumecs, yielded an equivalent sediment load of 45,000 tons per day. The Snowy Mountains Hydro-Electric Authority estimates from the increased flow rate and increased sediment concentration that the total sediment load in Wallace's Creek is probably 1,000 times greater than it was before the fire.

Another Australian example (McArthur and Cheney, 1965) shows in the Cotter River near Canberra higher values than would be expected from rainfall distribution in the period 1911–1962. This is set out in Table 1.

TABLE 1. Increased streamflow following widespread fires in the Cotter Catchment (1911–1962)

Year	Calculated flow from monthly rainfall (ac. ft.)	Actual flow (ac. ft.)	Percentage increase
1917	146,000	260,000	78
1918	40,000	134,000	235
1923	63,000	133,000	108
1926	56,000	157,000	180
1939	115,000	164,000	43

Sound ecological management will frequently involve the maintaining of a sustained yield situation, with levels of disturbance which are below a critical threshold which will trigger disasters. Where severe damage has been caused by past use, there are opportunities for return to something like the original status in terms of

disaster risk by re-establishing forest of a type sometimes more or less like the original, or in other cases, by a crop from which the impact can be made comparable to the original situation in terms of water flow from the catchment.

The effect of reconstitution of forest is dramatically illustrated by the well-known experiment in USA actually repeated in time. This was reported by Hibbert (1965) from the major forest research station at Coweeta in eastern United States where the clear-felling of a forest, repeated after a 23-year interval for regrowth, gave almost precisely the same hydrological response.

Although there are great variations and at times conflicting evidence, the way in which corrective treatment can reduce flooding risk is illustrated by one example from the Tennessee Valley. The 88 acre (0.35 km^2) Pine Tree Branch Watershed was selected in 1941 as representing a large area of critically eroded land under a 50 inch average annual rainfall. The land had been abandoned after agricultural failure. The stream flow behaviour was studied from 1941 to 1945 under the existing conditions and then intensive remedial soil conservation measures were carried out. Contour furrowing, diversion ditching and gulley-stopping was accompanied by plantation of the whole valley with pine (mainly Loblolly Pine) on the contour. The effects on water yield have been consistent. The total annual water yield over the calibration period was 10 inches. After plantation a steady rise in evapotranspiration and a steady reduction in overland surface flow was recorded. The groundwater run-off remained almost unchanged. Peak flows have been reduced by 90 percent and sediment yield by 96 percent. The overall water yield for the 1954–57 period was 46 percent less than that in the 1942–45 period. Comparisons with neighbouring watersheds confirmed that the total yield has been approximately halved. Thus, a flash-flood regime with very high sediment transport has been replaced by a steady flow of half the quantity of clean water.

BARRIER BEACHES AND DUNES

These situations often provide examples of such planning mismanagement. The misuse of coastal areas by destruction of foredunes and the associated vegetation often in the interests of recreational development often introduces a hazard not appreciated at the time of development. The original beach and foredune system is a relatively stable situation in which wave energy from storms is dissipated (Foster, 1974). The kind of change introduced by such development not only increases the disastrous effect of major storms but exposes more people to them.

AVALANCHES

In general, the level of disaster associated with avalanche, measured by loss of human life, is not as great as many other natural disasters, but in some areas where avalanche combined with other activity such as earthquake and landslides results have been grave, both in loss of life and property loss.

The 1962 avalanche near Yeongay in Peru, which affected the city, resulted in some 20,000 deaths (Penaherra de Aguila, 1970). Much of the amelioration of the effects of the avalanche is by avoidance of such in planning so that settlements are not located in avalanche paths. Alternatively, various kinds of precautionary measures including the triggering of avalanches when conditions become unstable are used to reduce disaster risk. Moreover, the experienced traveller in avalanche-prone areas will become aware of the safety precautions which minimise the risk of suffering from avalanche (Voight, 1979). One of the important aspects of minimising avalanche damage is to recognise avalanche paths. Perhaps the most significant element in ecological management which affects the risk of avalanche damage is deforestation, just as re-establishment of the forests is one of the most effective methods of reducing the likelihood of avalanche in particular areas. The stability provided to the snow mass by established trees is sufficient in many cases to reduce the risk of avalanche to nil, and while a forest stand may be flattened by a large avalanche, if it is in its pathway it predisposes the site to resist such damage if it is undisturbed and to prevent the initation of an avalanche (Chuenkov and Vlasov, 1978).

This situation was recognised long ago in Switzerland (Forstwesen, 1981) and in Austria, where laws were introduced to prohibit clear cutting of forest stands in some areas, and subsequently much attention has been given to the re-establishment of forests, slow though this may be in alpine sites, as a remedy (Aulitsky, 1965).

Frequently in alpine situations in zones where for one reason or another the forest has been removed and where re-establishment will result in desired stability, the action of deforestation is one of the telling examples of serious ecological mismanagement which is associated with such disasters.

Landslide (background) following temporary cultivation in mountainous terrain, Nepal. Courtesy: L. D. Pryor

LANDSLIDES

This phenomenon is somewhat related to avalanches in that the trouble arises from soil mass movements which can be triggered in various ways (Sorenson *et al.*, 1975). Some of these occur as part of the natural erosion process, particularly in mountainous country, and the trigger may frequently be natural, such as by an earth tremor. On the other hand, the likelihood of landslide and associated damage may be greatly increased by mismanagement (Zaruba and Merd, 1969). In steep forested slopes, even under conditions of high rainfall, there is general stability. This stability is assured if forest cover is continuously maintained, but the indiscriminate removal of the forest stands can, if followed by high rainfall, lead to disastrous results (Gray, 1970). Since activity of this kind is frequent in areas of low population density, the disaster in terms of human life loss may frequently not be great, but the soil erosion intensification, upset of hydrological balance and economic loss may be very substantial indeed. The principal cause of the damage is due to excessive removal of trees and other vegetation, as well as soil disturbance (Swanston, 1971). The limits to which harvesting can be carried out on a sustained basis in such situations can usually be spelled out with technical precision and it becomes essentially a management matter as to whether this is applied effectively and at the same time permitting some harvesting.

A very good example of ecological mismanagement is provided in relation to landslides in New Zealand in the Wairarapa area of the North Island. There are some geological formations of slightly consolidated marine sediments which extend substantially through this Wairarapa area northeast of Wellington. This land was originally forested with a rather low rain forest characteristic of that part of New Zealand. Over very large areas this has been completely removed and there is no sign at all of the original vegetation which was almost intact 100 years ago. Land has been developed primarily as pasture for close grazing by sheep and to some extent cattle. In recent decades following periods of heavy rainfall,

extensive soil slumping has occurred wherever these beds are underlying the surface soil. In many cases this is of small consequence though a source of loss to individual farmers, but in some cases it has been extensive and at times sufficiently large to be called a disaster or potential disaster in a number of areas. In the forested condition these soils were generally stable even under high rainfall, and it is clear that deforestation and replacement by pasture grass and clover has led to its vulnerability. It is possible that a return to the indigenous forest would correct the trouble, but this is not economically feasible in the current situation and control is exercised by what one might call an ecological method of replanting trees. Those widely used in this have been various poplars and willows which, although exotic to New Zealand, thrive in these situations and they can be handled by using long stemmed cuttings that are transported sometimes by helicopter where access is difficult. These will spread and grow on susceptible sites giving the desired stability. This corrective treatment is a well established practice in the area (Van Kraayenoord, 1980). The treatment is costly and the overall situation indicates the way in which previous mismanagement has caused costly damage even if it has not been associated with disaster to the extent of loss of life.

WINDSTORMS

Hurricanes, tornadoes, typhoons or cyclones of great magnitude are generated by conditions at present outside human control. They comprise one of the categories of extreme natural disaster much of which is associated with the heavy rain and flooding which often accompanies them or by heightened tides.

The direct effect of wind can be reduced by advanced planning—in the location of buildings and in their design, and in this aspect the phenomenon is comparable with earthquake, volcanic action and tsunami.

There are certain aspects of ecological management which may bear on the situation and which would then alleviate it.

The mismanagement of forest can make it more or less wind prone so that good cultural practice can lessen the effects of high wind in reducing uprooting of trees and consequent direct damage and subsequent risks such as fire in debris.

A good example of this in cultivated forest is provided from Western Australia where there were stands of planted pine in various stages of thinning at age 20 years when cyclone Alby struck, showing how lack of thinning increases susceptibility.

Cyclone damaged forest showing surviving trees acting as a trap for flying debris. Indescriminate removal of such trees would constitute a mismanagement which could have lethal effects, Darwin (Australia) after cyclone "Tracy", 1974. Courtesy: L. D. Pryor

A thinning experiment was terminated at age 20 when cyclone Alby destroyed all eight plots in the unthinned treatment and four of the plots in the lightly thinned stands, but caused only minor damage in the heavily thinned stands.

A study of the after-effects of cyclone Tracy in Darwin in 1974 indicates that by good management of tree vegetation, disastrous effects of a cyclone can be reduced, especially by the interception of flying debris although care is needed to avoid planting or retention of trees where later uprooting might constitute a hazard. Differences in performance of different species to wind stress are significant in vegetation management, tree planting and design (Shoobridge *et al.*, 1975).

DROUGHT

In *The Future of Arid Lands* (White, 1956), H. L. Shantz comments upon the human extension of desert lands now widely referred to as desertification. Human activity, from prehistoric times to the present, by grazing herds has removed much of the scant cover of nutritious plants in semi arid and arid areas. As use becomes still more intense this removal has been added to by the needs for fuel for domestic use. Although climatic changes have sometimes been cited as causes of desertification, there is compelling evidence that over-use is the primary factor (Eckholm *et al.*, 1977; Owa, 1979).

In the milder climatic parts adjoining the truly arid areas, those which may be called semi arid zones, extension of dry land agriculture into increasingly arid parts in striving for sustained production has often led to disastrous development and eroded lands (Heathcote, 1969). There are numerous examples of this situation and they are rapidly increasing.

The disaster of drought is one of the most painful inflicted upon man (Houran, 1975). The onset is slow and the results last for a long time. Current events in Africa bear testimony to this perhaps most tragic of human disasters. The vegetation and soils of arid lands, and semi arid lands are, if undisturbed or only lightly harvested, usually quite stable under existing conditions, but compared with many other types of landscape and vegetation they are extremely fragile so that they are rapidly degraded with but little over-use.

The social and political elements involved in the use of many areas of arid land are also profound in the extreme, and the means for implementing changes to lessen the impact of drought

Drought in Upper Volta. Courtesy: United Nations/FAO/F. Botts.

are clear enough, but often exceedingly difficult to apply. Ecological mismanagement by the over-use of semi arid and arid lands is certainly amenable to manipulation, particularly in those regions in which desert conditions are primarily man-induced. Where the social and economic situations make it easily feasible it has been found possible to reverse the trend. One of the interesting recent examples is in the Gascoigne area of North-west Western Australia where social and economic conditions make it fairly easy to arrange the trial. After survey, it was considered that the stocking rates of sheep and cattle were too high to maintain a balanced situation. There had been rapid deterioration of the vegetation leading to much bare land, increased erosion by both wind and water, and general decline of productivity. The population of this area is quite low and it is subject to close government control within an economic framework which is not of a critically low level for the land users. It was decided that the stocking should be reduced by 50%. This programme was carried out with suitable control observation areas being established to monitor the results. The outcome was dramatic. In a relatively short time there was a significant recovery in the vegetation towards a condition of stability which implied that most of the disability would be eliminated by accepting a lower production level per unit area. That level, of course, would

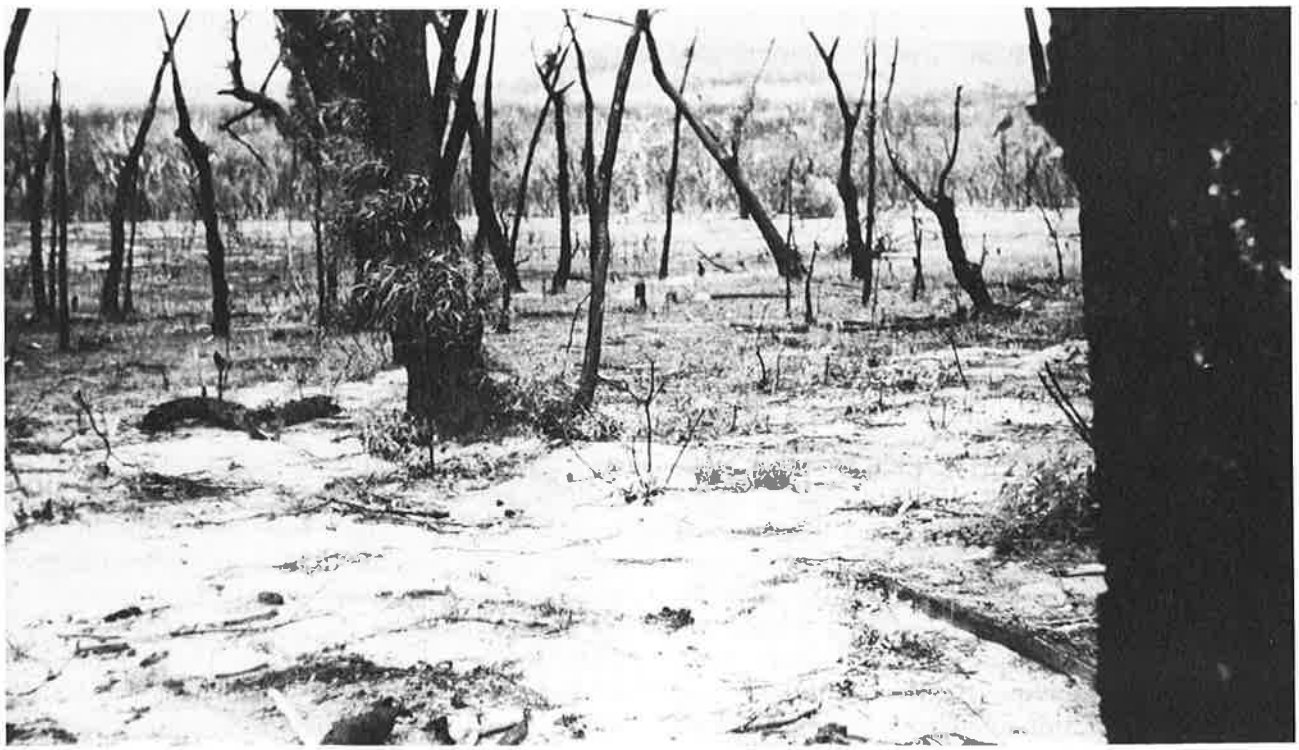
be a sustained level. This change would involve some economic and social rearrangements, but in this case they were fully feasible without any great economic hardship in the short run and the promise of continued long-term stable production.

In some arid areas also forestry has an important place in recovering the productivity of areas, one of which is the establishment of woodlands and shelter belts to reduce or even eliminate the widespread destruction by fuel getting associated with ecological regression. Forestry in these cases is concerned with small trees widely spaced. In arid or semi arid areas these stands are fragile, and can easily be reduced to a useless degraded condition by over-use, but by suitable regulation natural regeneration can usually be achieved often with no more than grazing relief. If spontaneous growth does not occur readily, this can be aided effectively with relatively simple treatment. In man-made desert areas we have to accept the fact that people living there have to produce their own requirements locally. In many cases the technical means for maintaining or even increasing production from resources under these conditions is known. The people themselves often have a tradition which allows them to manage a viable community if some of the pressures, particularly over-population, can be cushioned or reduced so that the impact is not translated to gross mismanagement of the land. The social and economic constraints are often stupendous but unless tackled and solved a repetition of the drought disasters of the past is inevitable, with massive loss of life and incalculable human misery.

FIRE

Fire in vegetation has been associated with substantial disasters often associated with considerable loss of life as a direct consequence. Fire, especially forest and bush fires, have occurred and been well documented particularly in North America and Australia (Albine, 1976; Cheney, 1976). Fire has always been present everywhere in the environment particularly as the result of ignition from lightning strikes, but most fire undoubtedly is still associated with man, and man has used fire as a powerful tool in managing his environment from the dim past. There are numerous examples of hunting and gathering societies using fire to facilitate capturing game or modifying the vegetation to favour the proliferation or aggregation of game. Fire also has been one of the most potent tools available to man in moulding the habitat whether this has been according to a carefully planned programme or not.

The ecological effects of fire on vegetation are very substantial whether the vegetation



Severe defoliation and temporary destruction of understory in Eucalyptus forest following extreme wild fire, South East New South Wales (Australia). Courtesy: L. D. Pryor.

concerned be forest, shrubland or grassland and whether high risk be infrequent or the reverse and the vegetation fire prone or otherwise. But the time scales of the dynamic ecological processes which are associated with the use of fire and particularly in its frequency and intensity vary greatly according to particular locality and vegetation type. The risk of disaster from the direct effect of fire varies too in the same way. There have been detailed studies of fire behaviour particularly in North America, Australia and to some extent in Africa. One of the most important factors affecting intensity, given that there are climatic conditions favourable to the spread of wildfire, is the fuel load on the ground. In the absence of fire this continues to increase until it reaches a more or less stable level as accumulation and decay loss are in balance. When the fuel load is at its peak the potential for the highest intensity fire exists. Fuel load can be reduced by management, whereas most other factors giving predisposition to fire such as weather and topography are not. There are some types of vegetation in which fire is a regular feature and indeed there are some ecological groupings of both plants and associated animals which are displayed only at a particular period as the vegetation passes through its cyclical phases of development following severe fire. There is considerable debate about the way in which fire should be used in a completely controlled social situation and views tend to be polarised between those who advocate deliberate planned burning and consequent fuel reduction and those who seek complete protection.

Some protagonists of the wilderness concept claim that a fire arising from natural causes (usually lightning), should not be controlled; that this represents an intrusion by man into the wilderness domain.

This may have been the case formerly, but under the conditions of an overpopulated world in most localities no distinction as to their control is either desirable or feasible.

As with a number of other hazards, the risk of human disaster as a result of wildfire can be lessened by the siting of settlements and residences in locations where the fire is slight compared with places where it can be discerned as potentially substantial. Moreover, safety precautions can be taken both in the style of building or more particularly in shelters which will allow people to escape death in severe fires. Detailed understanding of fire behaviour and dissemination of this knowledge is an important element in reducing the risk of disaster to those who may be placed, from time to time, in danger from fire, but it is not the heart of the problem which has an ecological base. The most difficult situations are posed by a topography which makes access difficult, where there is a high fuel load and when there are periods of extreme weather conditions of high temperature, low humidity and high winds. Some vegetation types such as tropical rainforest are generally immune to fire if undisturbed, except perhaps at very long intervals. But disturbance, natural or man-made, to the extent of allowing desiccation and producing a flammable fuel load may change that. One of the most susceptible types is the sclerophyll vegetation in different parts of the world, occurring either as sclerophyll forest or shrubland of the chaparral or maquis type in areas where there are usually prolonged dry seasons. Where the fuel demands of the local people lead to extensive collection from undergrowth and litter, the risk may be very substantially reduced, but as social changes occur, as they have in the last decades in southern France, the conditions for disastrous fire have been intensified with greater residual fuel loads and indeed there have been recent occasions in which fire disasters have occurred in the Mediterranean region of France. The controlled use of fire itself is the principal tool in management which can circumvent or minimise the risk of a disaster from the same cause, and it is in the hands of authority to minimise greatly the risk of a fire disaster if not eliminate it altogether by the prudent use of fire in ecological management (McArthur and Cheney, 1965).

Some of the worst fire disasters can be said to flow from previous ecological mismanagement.

The second and less direct effect of fire in disaster is the greatly increased run-off which occurs in catchment areas after a severe fire. The changes following burning have been well documented on occasions, with run-off changes in peak flow amounting to perhaps more than 500%. In spite of this increase in peak run-off following burning it is nevertheless susceptible to a considerable degree of variation according to the intensity of the fire and the extent to which the ground litter is consumed and the low shrubs and other plants destroyed. Fires which have a natural origin may differ in intensity and it is also possible to manage planned deliberate burning in such a way that the intensity can be regulated and so the extent to which the risk of heightened flooding follows. The manipulation of the use of fire is an area in which there are many examples of ecological mismanagement and it is an area in which skill can be developed. If good practices are applied, not only is the

risk of disaster from the direct effects of fires themselves diminished, but especially the likelihood of heightened peak floods can be reduced. There is very good experimental evidence to support this view. Cases in forest are cited above. In another vegetation type the hydrological effect of fire on dry chaparral rangeland was effectively measured in Arizona where in 1959 a hot wildfire consumed the shrubs and herbage on four watersheds whose vegetation, water yield and sediment yield had been recorded for the previous three years (Glendening, Pase and Ingebo, 1961). This type of scrub grazing occupies some 5 million acres (20,000 km^2) of Arizona. In the three years prior to the fire the cumulative total rainfall was 67 inches. This gave a yield of only 2.85 inches of water with 50 tons of sediment per square mile. In the 21-month period after the fire 51.3 inches of precipitation gave a water yield of 16.05 inches with 21,519 tons per square mile of sediment. On two other basins the sediment yields were even greater being 50,000 and 64,000 tons per square mile respectively, from steep slopes and immature granitic soils. Re-seeding with lovegrass (*Eragrostis curvula*) was unsuccessful in the first year after the fire.

GRAZING

The grazing of domestic stock is subject to regulation but the intensity of grazing is often generated simply in response to survival. Where grazing intensity is higher than a sustained yield programme can permit, there is progressive degeneration of the vegetation which may in the extreme, lead to complete denudation (Baker and McPhee, 1975; Van Dyne and Van Dyne, 1981).

In more recent times the accentuated intrusion of man into the environment has critically altered populations of wild animals. It is the reduction of populations which at first usually attracts comment but the increase in populations following a degree of suppression of predator regulation or by favouring population increase as by the provision of more watering points by dams and wells can lead to grazing intensities which are similarly beyond the sustainable level.

Even in the more robust vegetation types in better watered areas and where growing conditions overall are better, very serious degrade can result even where there is forest or woodland. In many ways the effect of over-grazing is like that of fire, both of which can cause the complete loss of components of the vegetation as is shown

Excessive soil erosion and run off caused by over-grazing. Successful recovery is shown in the grazing exclosure beyond the fence, Nepal. Courtesy: L. D. Pryor.

by the long-term experiments with fire in the Miombo woodland in Zambia. It can also reduce the litter and undershrub components in forest which, together with trees, are so important in regulating stream flow to a relatively ineffectual level so that the peak run-off from excessive grazing may approach that which follows a very severe fire. The reduction of grazing to a level which allows sustained management and yet retains the benefits of the vegetation in ameliorating flood peaks on the one hand or halts the trend to desertification on the other is one that is in the hands of society. At the same time the pressures which generate the urge to graze heavily often arise from social conditions and survival needs that are intractable to change and difficult to steer from the disaster course on which they are headed (Albertson and Tomarek, 1957).

It is in this situation that ecological knowledge must be added to and coupled with economic, planning, legal, social and financial aspects if future disaster is to be mitigated.

LOCUST PLAGUES

These are one of the oldest scourges of man which have induced hardship, famine and death. The classical studies of B. P. Uvarov (see The Future of Arid Lands) have shown that the build-up of critical populations of the insects depends upon the availability of habitats with vegetation mosaics as between grassland, steppe shrubland, forest or bare areas, denuded of vegetation.

Uvarov points out that:

> "...The general effect of human interference has been to destroy the original uniform structure of vegetation and to create a mosaic in which the more arid habitat was particularly encouraged to expand, together with its grasshopper population. The importance of such increase in the ecological aridity of the area lies in the fact that outbreaks of grasshoppers are usually associated with a series of dry years. The effects of dryness in favoring grasshoppers are, naturally, greater in an environment which is partly arid naturally, or made so by man. A feature of mosaic habitats, particularly those created by man, is their instability, as the relative extent of their arid and more humid parts is likely to vary from year to year. This has an important effect on grasshoppers, which are very mobile insects. Even in most equable conditions, they move from the food-shelter habitat to the oviposition sites, but when the contrasts are very strong such movements extend and become migrations, leading to a concentration of the insects in crops."

Sound ecological management of vegetation could reverse these trends.

Disaster triggered by other forms of biological imbalance including a wide range of plant pests and diseases can be traced to ecological mismanagement. This can be corrected with varying ease according to the factors involved.

SOIL EROSION

In situations as the above associated with drought, fire and grazing or even locusts, a long-term recipe, perhaps one of the most critical of all for disaster, is generated by accelerated soil erosion which begins to approach the consequences of overpopulation in magnitude. Better ecological management of vegetation apart from reducing the intensity of sudden disastrous events will almost always have the long-term result of reducing soil erosion and sedimentation rates. Under the best circumstances this reduction may approach the base level.

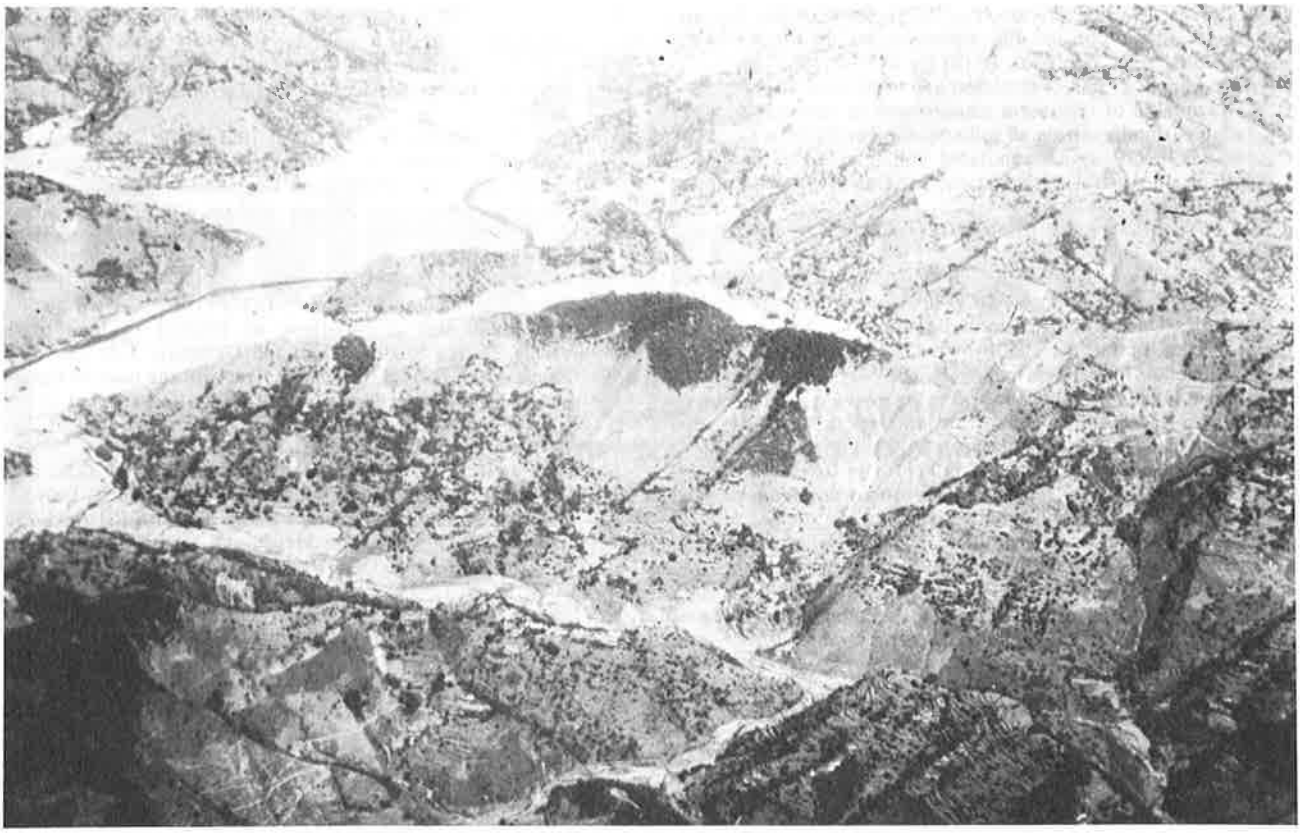
Failure to regulate soil erosion must approach the significance of overpopulation effects in future human survival (Pimentel *et al.*, 1976).

CONCLUSION

The Principal Sources of Ecological Mismanagement in Relation to Natural Disaster

Human disaster is often closely linked to the heightening of the effects of natural events which result from treatment of vegetation. If the natural vegetation or something like it cannot be sustained then a cultivated landscape which retrieves some of the values of the natural types and, as far as possible, approaches the natural situation, is to be sought. Such methods frequently require a high level of technical input and very substantial financial support. Unfortunately there are many parts of the world where this may not be possible for some time. It may be that a skilfully man-made landscape can circumvent the likelihood of natural disasters to an extent as great or even greater than the natural scene. When that kind of situation emerges society is able to take care of itself without outside support.

On the other hand, perhaps the most obvious consequence of mismanagement is the indiscriminate removal of forest. This is one of the prime causes for the increase in disastrous floods in many parts of the world. It is often linked to subsistence agriculture. A further effect is the use of fire in association with some activities and another is excessive grazing, all of which add up to the same outcome. Even in the process of formation of man-made deserts, it is devegetation by grazing, cutting and burning which produce



A very heavily deforested country with excessive erosion and accumulation in the river, Nepal. Courtesy: L. D. Pryor.

some of the most serious consequences. Much of this activity is related to human overpopulation.

Of somewhat lower magnitude, removal of forests will increase the predisposition to avalanches and landslides. Balanced management of vegetation, be it grassland, shrubland, woodland or forest, with sustained yield harvesting is the first consideration in hazard reduction. Where it is too late to apply such methods the re-establishment of vegetation by reducing or eliminating the destructive pressures where this is possible, is next sought and finally, the establishment of a vegetative cover by direct planting and cultural methods can largely lead to a similar corrective result.

It is evident that where conditions which predispose disaster have developed consequent on the mismanagement of vegetation the risk can be lessened in time by establishing sound ecological management and reconstituting the vegetation. In many cases this implies re-establishment of vegetation and this must be often as cultivated forest. Effective organisation and adequate funds together with significant social and economic adjustment are essential to achieve this in most places in the world where critically dangerous conditions have been produced by foregoing ecological mismanagement.

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