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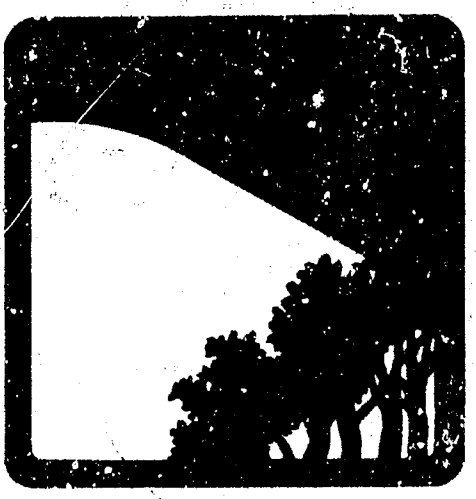
The Effects of Forest Land Use on Erosion and Slope Stability



Report of a Seminar*
by
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East-West Center

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FOREWORD

This report summarizes a seminar on "The Effects of Forest Land Use on Erosion and Slope Stability" held at the East-West Center (EWC) from 7–11 May 1984. It was jointly sponsored by the East-West Environment and Policy Institute (EWEAPI), the International Union of Forest Research Organizations (IUFRO), the New Zealand Forest Service, and the United States Forest Service.

This seminar was one of the activities within the forest watershed land-use project of the EAPI Program Area in Forest Lands Policy. It grew out of contacts established with a network of forest watershed scientists following a 1981 workshop on "Watershed Forest Influences in the Tropics." Colin O'Loughlin, a fellow at the EWC and scientist at the New Zealand Forest Research Institute, Christchurch, New Zealand, and Raymond M. Rice of the Redwood Sciences Laboratory of the U.S. Forest Service in Arcata, California, worked with Lawrence S. Hamilton of the EAPI as the Planning and Organizing Committee. For EAPI, it was one event in a series of forest watershed activities.

For IUFRO, it was an outgrowth of activities by the Subject Group S1.04–00, "Prevention and Control of Torrent Erosion, Floods and Mud Flows, Snow Damage and Avalanches." Specifically, two working parties—S1.04–03, "Land Slides and Their Stabilization," and S1.04–04, "Erosion Control by Watershed Management"—were involved.

The seminar represented a first attempt by the IUFRO to bring societal factors into the forum, along with the biophysical. In addition, through the resources and contacts of the East-West Center, many scientists from tropical developing countries were able to participate in this seminar—an aspect not achieved until now. IUFRO meetings have tended to be almost exclusively attended by developed world scientists because of the expense of attendance and the location of the conferences, which generally have been in Europe or in the United States. The Hawaii location was much more conducive to participation by Asia-Pacific professionals. Sixty-six scientists from sixteen countries were involved. A list of participants is included in this report.

The four and one-half day meeting included a half-day field trip to an area on Oahu exhibiting serious slope instability and past mass wasting. D. Mueller-Dombois of the University of Hawaii, who had studied this area, led the excursion. Poster displays by ten participants showed problems and research being conducted in six countries.

Following an overview by O'Loughlin, the abstracts of papers prepared by the authors are presented.

The seminar proceedings with complete papers has been edited by O'Loughlin and his colleague in New Zealand, Andrew J. Pearce, and has been distributed to conference participants. This report has been produced at EWC so that the results of this meeting are readily available to other watershed professionals in the Asia-Pacific region as part of our program in technical interchange.

Lawrence S. Hamilton
Research Associate

OVERVIEW

Over the past two decades much research has focused on slope processes and slope erosion in steep forest environments of the Asia-Pacific region. Most of this work has been carried out in moist, temperate steepland forests in the western United States, Japan, and New Zealand where mass wasting is a dominant process (Swanson and Swanston 1977; Swanston 1981; Tsukamoto et al. 1982; Tanaka 1976; O'Loughlin et al. 1982). Removal of forest vegetation and construction of roads, more than any other activities of humans, have been shown to raise seriously the incidence of landsliding and the acceleration of erosion rates in the western United States and in New Zealand. Studies have been conducted to understand the relationships between forest disturbances and slope stability and erosion, including soil mechanics of slopes and development of simple slope models (Swanston 1970; O'Loughlin 1974; Gray and Megahan 1981), importance of tree roots in slope stability (Burroughs and Thomas 1977; Ziemer 1981b; O'Loughlin and Ziemer 1982; Wu et al. 1979), and soil-water regimes (Swanston 1967; Ziemer 1981a). Despite these research efforts, much remains to be learned about the mechanisms of tree root reinforcement, mechanisms of failure in residual soils and other regolith materials, and the role of forests in modifying soil pore-water pressures, before reliable and meaningful predictions of slope responses to forest changes can be made. Some of these problems were considered during the seminar on "Erosion and Sediment Transport in Pacific Rim Steeplands" held in Christchurch, New Zealand, in January 1981. The seminar revealed other serious gaps in our ability to understand and predict geomorphological processes, particularly on the fate of sediment after it passes into stream and river channels. The recent growth in the number of reservoirs associated with development projects has increased the concern about accelerated rates of sediment delivery to tropical river systems.

Compared with temperate forest environments, the erosion processes and rates operating on tropical forest steeplands are relatively unknown, which is a cause of great concern to tropical forest managers. Extensive deforestation of steeplands and other major disturbances associated with road construction and agricultural development have revealed that tropical forest slopes are fragile and are susceptible to accelerated mass wasting and other forms of erosion (Gupta and Tejwani 1980; Leigh 1973; Douglas 1967; Burgess 1971; Dunne 1979). Whereas the importance of surface erosion under undisturbed temperate rain forests is generally regarded as secondary importance to mass wasting, evidence from the Philippines (De Vera 1981), Papua New Guinea (Pickup et al. 1981), Indonesia (Wiersum 1983), Thailand (Watnaprateep 1980), Malaysia (Leigh 1978), and Hawaii (Yamamoto and Anderson 1973) indicates that surface erosion is the dominant soil movement process in many undisturbed tropical forests.

A large part of the present erosion-sedimentation problems in tropical forests appears to be related closely to a shift from small-scale technologies by rural societies (such as shifting cultivation or elephant logging) to large-scale technologies, including forest-based industries using heavy equipment and extensive roading. Although Western technology has

been adapted quickly to enable efficient and rapid exploitation of tropical forest resources, Western developments of erosion prevention and pollution control have not undergone the same transfer and adaptation.

Thus, representatives of the IUFRO and the EWEAPI decided it was timely to bring together researchers, foresters, and land managers from a number of countries to outline their management-related erosion problems and discuss future research and development requirements. This seminar attracted 66 participants from 16 countries.

Three main topics were addressed during the conference:

- societal factors affecting erosion and slope stability in mountainous areas,
- physical and biological factors affecting erosion and slope stability, and
- management for the prevention and control of erosion and slope stability problems.

THE INFLUENCE OF SOCIETAL FACTORS ON EROSION AND SLOPE STABILITY

The influence of socioeconomic factors on forest erosion is a topic that has not received much attention. Because erosion and slope stability problems are generally perceived from biological or geological/geomorphological viewpoints and sociological influences are usually disregarded, the organizing committee for the seminar decided there was a need to examine the role of societal factors on erosion, particularly in tropical regions. Furthermore, recently an awareness has developed that societal factors are often the basis of the degradation of tropical forest lands. A few of the factors leading to the accelerated removal of forests and concomitant increases in erosion in tropical regions are

- rapid expansion of rural populations, thereby creating an increased demand for crop and grazing land and for firewood;
- large influxes of migrating people into rural areas, such as the intrusion of refugees into Thailand;
- construction of highways into formerly inaccessible hill and mountain country, enabling rural communities to occupy new land; and
- failure of rural farmers to adopt conservation stock management and agricultural practices to lessen impacts on soils.

Large government and private company-financed schemes, such as construction of major transmountain highways in Taiwan and Malaysia, construction of multipurpose reservoirs and associated roads and forest clearance as in India and the Philippines, and large-scale conversion of forest to agricultural plantation crops (oil palm and cocoa in Malaysia) have had serious impacts on forest land erosion and sediment yields and on local communities.

Six seminar papers addressed some of these problems. It was fitting that the Himalayan region was the focus of three papers as there are no other steepland regions in the world where natural and human-induced erosion occurs at such high rates over extensive areas and where the relationships between local community activities and erosion are so dramatically evident. In his keynote address Gilmour* described the wide-scale degradation of Nepal's mountainlands resulting from traditional agricultural practices and extensive deforestation to provide additional agricultural land and fuelwood. A present population increase of more than 2.5 percent and the increasing number of tourists and visiting "trekkers" are continuing to place the remaining forest areas in jeopardy.

Attempts to reforest eroding mountainlands by "top-down" government efforts have not been altogether successful in the past because the local rural Nepalese have shown sturdy resistance to such schemes and have offered no protection to young plantations. In the Middle Hills of Nepal, a more enlightened approach to rehabilitate eroding land is based on close consultation with local communities to gain their cooperation and support for large-scale tree planting and forest protection schemes. Gil-

*See Paper Summaries for authors and titles of presentations.

mour and Applegate were emphatic that full involvement by the local communities in the planning phases, establishment and management of tree nurseries, and planting and protection of young tree crops from grazing animals is desirable and necessary to ensure that reforestation programs are successful.

The success of a reforestation program in the Chautara Forest Division northeast of Kathmandu and recent government legislation, which enables government land to be given to local communities for forestry purposes, has led to an expansion in pine plantation establishment. Gilmour and Applegate left little doubt that the rehabilitation of eroding Nepalese mountains will depend on overcoming the sociological problems that accompany attempts to introduce new watershed rehabilitation practices in areas used by the highly independent mountain communities.

Tejwani also used the Himalayan region to illustrate causes of land degradation and to suggest strategies to foster watershed rehabilitation. He attributed more than 50 percent of the landslides in the Indian Himalayas to road construction and much of the other accelerated soil loss to deforestation and overgrazing. Rectification of the mountain land degradation is being tackled on a large scale under the National Soil and Water Conservation program, which runs in a series of five-year plans.

The rapid deforestation of Thailand primarily to provide additional agricultural land, poor agricultural practices with little or no regard for basic soil conservation principles, road construction, and mining are prime causes of the high regional erosion rates and sedimentation problems in rivers and streams. Henderson and Rouysungnern illustrated in their presentation on erosion and sedimentation in Thailand that large differences in erosion rates and sediment yields are found under different vegetation covers (Table 1).

Henderson and Rouysungnern foresee that socioeconomic schemes involving resettlement hill villages with improved facilities and extension services in hygiene, agriculture, horticulture, and marketing, combined with a variety of natural resource development programs, will lead to better management of the land resource and to consequent reductions in erosion. Land classification projects, reforestation projects, agroforestry projects, and improved fire protection will be important parts of the development program.

The erosion and sedimentation increases accompanying land-use changes in Thailand appear to have much in common with the problems being experienced in the Indian State of Kerala as outlined by Nair. Recent land-use changes in the Idukki catchment, primarily conversion of forest to plantation crops (cardamon) and to cultivated land, have led to serious accelerated soil loss. Unfortunately, these land-use changes conflict sharply with the original objectives of various government departments, which emphasized watershed protection and power generation from a reservoir in the lower Idukki catchment. Evidently exacerbation of the problem will continue as the rate of privatization of public land grows and population increases.

Like the Middle Hills in [illegible] and the Idukki catchment in India, the [illegible] mountains

Table 1. Soil Loss in Tonnes per Square Kilometer per Year

0	10	100	1000	10,000	100,000
Natural forest, flat paddy			forest, rubber plantation, orchards, paddy	rubber plantation, orchards, field crops, forest and field crops	field crops, forest, and unstable shifting cultivation

in Northern Morocco suffer severe erosion and sedimentation problems, mainly because of the pressures exerted on the land by rapid population growth. Overgrazing, deforestation, and intense cultivation all contribute to high erosion rates, which exceed 200 t/ha/year in some areas. Tayaa and Brooks presented a detailed account of the erosion causes and the societal problems that require resolution before sustainable erosion control programs can be developed. The communal and fragmented ownership of lands, the high social significance of livestock, and the unequal distribution of costs and benefits of various proposed watershed rehabilitation schemes among various affected parties are major obstacles to the development of erosion control programs.

The case studies mentioned are linked by common threads. Recent rapid, rural population increases accompanied by deforestation, overgrazing, increased road building, and expanding areas of land under nonconservation agricultural use have led to accelerated erosion and sedimentation rates that often threaten the viability of reservoir development projects. Efforts to plan and execute watershed management or rehabilitation projects are hampered, not so much by a lack of technical know-how but by an inability on the part of planners, advisers, or government managers to deal with the complex societal problems encountered when attempts are made to change the traditional relationships existing between rural communities and the land.

PHYSICAL AND BIOLOGICAL FACTORS AFFECTING EROSION AND SLOPE STABILITY

Many physical and biological factors influence erosion and slope stability on forest lands, but a smaller number of key factors dominate in the control of soil and slope stability. These can be grouped into

- climatic factors such as rainfall intensity and duration and temperature changes;
- other water erosive forces (runoff, snow melt);
- soil factors such as soil strength parameters, particle size distribution, clay content and clay type, infiltration capacity, soil drainage condition, porosity, organic content and depth, stratification, and lithic contacts;
- physiographic factors such as slope steepness, slope length, and slope roughness;
- vegetative factors such as cover density and type, forest litter thickness, tree root distribution, and strength of tree roots;
- human-related factors in wood harvesting, such as road and track construction, tree felling, and loading slopes with fill material, or in clearing for conversion to other land uses; and
- animal-related factors, such as overgrazing or overbrowsing by domestic livestock or wild animal populations.

Considerable research has focused on determining how these factors combine and interact to influence erosion so that methods of predicting the location of erosion and erosion rates can be developed. In the opening keynote address of this seminar, Dunne pointed out that more progress has been made in these respects in agricultural environments than in forest environments, partly because the economic incentive to conserve soil has been greater and of longer duration in agricultural regions, and partly because surface erosion processes on agricultural lands are more easily observed and measured than the relatively infrequent, discrete, and violent mass wasting processes that characterize many forested

landscapes. Dunne also indicated that eroding areas or areas that can be studied experimentally on agricultural or rangeland slopes are easier to define than on forested slopes. Furthermore, the mechanics of surface erosion processes have been more rigorously investigated than the mechanics of mass wasting.

Eleven papers examined and six posters displayed a range of slope and forest influences on erosion. Another four papers concentrated on the effects of upland erosion and landsliding on stream channels and stream sediment transport.

The keynote address for this section presented by Tsukamoto and Kusakabe showed that, by applying a simple infinite slope model to four recognizable slope types, the presence or absence of a discrete subsoil and the distribution of tree roots are the main determinants of whether soils on recently deforested slopes are likely to fail. The slope analyses indicated that granite slopes with discrete impermeable subsoil layers are most susceptible to failure. A more complex plastic deformation slope failure model was applied to a theoretical slope to examine the influence of lateral tree roots on slope stability. Under the assumed conditions of slopes and root distributions, lateral roots appear to have greater influence on stability than do vertical roots.

The importance of tree roots in the control of soil stability was accorded less significance than water by Schroeder and Brown, who studied the effects of a large storm on slope stability in two coastal Oregon watersheds. The study showed that slides in clearcuts move greater distances and cause more damage than failures in intact forest. In their study area, the largest landslides originated on roads and landings where soils had been sidecast onto the natural slopes. Stability analyses showed that fills are likely to fail by a circular arc failure or slump mechanism under conditions of strength loss due to saturation. Schroeder and Brown emphasize that simple stability analyses, combined with common sense, can provide a guide for improving road construction practices and road locations so that damage from mass wasting can be reduced.

LaHusen, who described the characteristics of management-related debris flows in northwestern California, was also able to provide recommendations for improving road and skid-trail locations and designs to prevent or reduce slope failures. Of the 40 hillslope debris flows studied by LaHusen, all originated in and consisted mainly of sidecast fill materials. Most of the failures occurred where roads or trails crossed swales or headwaters of ephemeral drainages. To lessen slope failures from roads, LaHusen suggested that the width of roads or trails be reduced and hillslope contours be followed closely to reduce the amount of fill placed in swales. Good drainage should be provided through or under road prisms in swale areas.

Soil strength and soil water conditions are the two main controlling factors in the stability of slopes. The recent interest in assessing slope stability in a probabilistic manner encouraged Schoenemann and Pyles to describe the shear strength of residual soils from a statistical viewpoint. Their method, which involves a two-stage use of regression to establish prediction limits about a best estimate of soil strength parameters C' (soil cohesion) and 0' (soil friction angle), appears to suffer from the disadvantage that the variability is forced upon variable C'. Nevertheless, the method appears to be useful for relatively uniform residual soils but would be difficult to apply in shallow, stony steepland forest soils permeated by tree roots where stone content and root content have important influences on soil strength.

The difficulties involved in predicting sediment yields, and the frequencies, from locations and sizes of future landslides in forested terrain are well recognized and, as Dunne pointed out, progress in developing prediction methods is likely to be slow. Three different approaches to the problems of prediction were outlined by Thomas and Trustrum, Ziemer, and Shimokawa, respectively. A fourth paper by Burroughs was also concerned with predicting landslide hazards.

Thomas and Trustrum adopted a mathematical approach for predicting landslide development on deforested hillslopes in New Zealand. Careful study of past landslide distributions,

their size, the weather (rainfall) conditions at the time of failure, and the relationships existing between landslides and ephemeral stream channels enabled the development of a landslide simulation model capable of indicating landslide occurrence, extent, and severity under various conditions of terrain and precipitation.

The response of progressive hillslope deformation to climate, presented by Ziemer, was concerned with the slow, mass wasting phenomena of creep and earthflow. Borehole deformation rates in deeply weathered cohesive soils in northern California were correlated with precipitation using a precipitation index. Predictions of long-term hillslope movements were carried out using measured deformation rates and a frequency analysis of a long-term precipitation record.

Shimokawa discussed the spatial and temporal patterns of shallow landslide occurrence in three forest study areas in Japan. Although his thorough investigation was aimed primarily at clarifying the complex processes of landslide revegatation and soil formation on scars, the associated information Shimokawa produced on landslide recurrence intervals provides a good basis for predicting future landslides. A similar approach was adopted by Smith et al. in their study of vegetative succession, soil development, and forest productivity on landslide sites in the Queen Charlotte Islands, British Columbia. The rates of increase in vegetative cover and soil-humus cover on landslide scars are chiefly functions of age of scar and slope position. Organic surface accumulation, vegetative cover, and tree productivity average consistently less than in similar aged, logged stands.

The papers by Shimokawa and by Smith et al. particularly are useful because they add significantly to the dearth of information on landslide scar recovery rates. Wolman and Gerson (1978) indicated that the geomorphic effectiveness of extreme events that initiate landslides is related to the rate of recovery of the scars, as well as to the total amount of initial mass wasting. Notably, revegetation rates on landslide scars in the humid tropics appear to be rapid compared to rates in temperate regions.

Surface erosion processes in forest environments are not accorded the attention these same processes receive on agricultural lands as outlined by Dunne. Overland flow and surface erosion processes were reported in two papers. Heede's excellent study of overland flow and sediment delivery on 31 small, instrumented subdrainages on Arizona forest land showed that the rates or intensities of overland flow and surface erosion were low, even on sites influenced by logging. Heede reported that overland flow and sediment are generated on distinct source areas, a finding that does not easily fit into the concepts embodied in Horton's model of overland flow. Heede found that overland flow and sediment production were nullified where undisturbed forest floors associated with buffer zones occurred downslope of source areas.

Under somewhat different environmental conditions on Iriomote Island, southern Japan, Sato et al. showed that clearing forest and subsequent cultivation greatly increased surface runoff and soil loss. They attributed the changes to an increase in dry soil-bulk density, a decrease in soil permeability, and an increase in weathering of the exposed soil after clearing.

The linkages between hillslope processes and channel processes are often neglected in studies of erosion and stability of forest lands. This neglect is unfortunate because the major costs to society resulting from slope or headwater degradation are often not concerned with on-site loss of soil or productivity (although this can be important as emphasized by Thomas and Trustrum) but with the changes that occur in sediment quantities, water quality, and bed and bank processes in downstream channels.

Grant et al. presented a method for assessing the effects of timber harvesting on channel morphology based on measurements of slope and channel characteristics on aerial photographs. They were able to distinguish a relationship between upstream management histories and channel changes, which accompanied a large 1964 storm in 37 fourth- and fifth-order streams. Landslides from roads and clearcuts were the most effective causes of channel

change, a view that was shared with Beschta who discussed the channel responses to accelerated mass erosion in the Middle Fork Willamette River, USA (the same watershed considered by Grant et al.), and the Kowai River, New Zealand. The dominant responses were increases in channel width, which accompanied aggradation after both watersheds experienced large storms (Willamette 1964, Kowai 1951).

In the poststorm longer terms, Beschta detected slight channel width decreases in the Middle Fork Willamette River basin between 1967 and 1980, indicating a slow recovery toward premanagement channel conditions and a slow downstream migration of a bedload sediment wave of the Kowai River.

The effects of an extreme event in 1982 on streamside landsliding and channel change were also discussed by Coats and Collins. Large inputs of sediment to Zayante Creek, Santa Cruz Mountains, California, caused marked changes in bedform, but channel changes were not as extensive or of the same magnitude as those described by Grant et al. and Beschta in the Middle Fork Willamette River.

Klein examined the response of upland stream channels to removal of road fill from former stream crossings in Redwood National Park. Channels adjusted to rehabilitation by downcutting, lateral cutting, and changing their longitudinal profiles. The presence of large organic debris was an important factor in controlling scour and developing a stable stair-step longitudinal profile configuration.

The papers dealing with physical and biological processes covered many processes and responses under mainly temperate forest conditions. Just how relevant the content of the presentations may be under tropical forest conditions is difficult to judge, though one surmises that the processes are the same but that timing and extent may differ substantially. The slope models and processes and prediction methods discussed by Tsukamoto and Kusakabe, Ziemer, Shimokawa, Heede, and Schroeder and Brown probably will have wide-ranging relevance.

MANAGEMENT FOR THE PREVENTION AND CONTROL OF EROSION AND SLOPE STABILITY PROBLEMS

The establishment of tree crops on degraded slopes and eroding streamside areas is an effective and relatively cheap method of mitigating erosion, especially if the tree crops can be used commercially later toward maturity. Undoubtedly, reforestation of degraded lands in tropical regions will become important, especially in the eroding hills and mountainlands of Southeast Asia and in the Himalayas. Thus, the experiences of temperate climate countries in the development and management of protection plantings should be of interest to tropical forest managers and soil conservators. Four papers presented concerned the use of trees for slope rehabilitation and protection.

The rehabilitation measures undertaken by the government of Korea on the degraded mountain slopes near Anyang (near Seoul) were described by Belt and Woo. Planting of forbs, grasses, and trees (*Pinus rigida*, *Alnus tinctoria*, *Robinia pseudoacacia*, and *Juniperus kordy*), combined with construction of stone-buttressed terraces, has been effective in draining and stabilizing slopes. More extensive establishment of coniferous plantations for slope protection and, in some cases, wood production has been achieved in New Zealand's eroding steeplands. O'Loughlin indicated that young plantations begin to substantially increase slope resistance to shallow mass movements and surface erosion between five and

ten years after establishment. However, forest covers have not been effective in containing retrogressive slumping around the headwalls of actively eroding gullies and large landslides.

The paper by Omura and Hara, also concerned with trees and slope protection, described the results of a physical slope model experiment in which the fence or debris-holding effects of two trees in different configurations and spacings were investigated.

Wiersum discussed the soil protective value of various tropical agroforestry systems and particularly examined the role of trees in preventing erosion. Wiersum concluded that surface erosion rates under various agroforestry practices can range across four orders of magnitude and that some of the highest rates occur under clean, weeded tree crops or tree plantations where litter has been removed. He further concluded that the key to conserving soil does not lie in the presence of the trees themselves but in good soil and water management practices.

Several papers outlined methods for reducing or avoiding adverse impacts resulting from logging or roading activities. This approach to soil conservation is the best because if prevention can be achieved, then rehabilitation using costly techniques is not required.

Sauder considered that careful design of logging settings and more intensive planning and consultation between research managers could reduce the incidence of landslides in coastal British Columbia clearcuts on steep slopes. Improved design, construction, and location of roads also were required to reduce road-related failures—a conclusion similar to that of Henderson and Witthawatchutikul in their study of the effect of road construction on sedimentation in a forested catchment at Rayong, Thailand. Cassells et al. also defined many watershed forest management controls and protection provisions to reduce erosion, sedimentation, and adverse effects from harvesting in Queensland's rain forests. Techniques such as careful prelogging planning, retaining streamside buffer strips, ensuring that road locations and designs are favorable for minimizing earthworks, and timing the logging operations so that they do not coincide with the wet season are requirements built into timber sale agreements in Queensland.

The importance of roads as a source of sediment in forest steeplands has stimulated much road-related erosion process and control research over recent years. Burroughs et al. described the results of one experiment aimed at gauging the relative effectiveness of surfacing materials in reducing sediment yields from roads. The hydrographs and sediment graphs from various road surfaces are being used to refine a road sediment model that can be used to predict runoff and sediment yield from roads.

Burroughs also outlined the development and use of a landslide hazard rating model for shallow soils in the Oregon Coast Range. The model incorporates estimates of ground-water rise, soil shear strength parameters C (cohesion) and 0 (friction angle) for different soils, and the influence of tree roots. Other similar models are being developed in the United States, Japan, and New Zealand but most seem limited in their application, because the processes and factors of importance in landslide initiation are often imperfectly understood and remain unmeasured.

The methods being used in Japan for zoning debris flow vulnerable areas and new developments in this field were explained by Mizuyama et al. The use of past records of debris flow deposition patterns and forms, the use of detailed topographic information on flow deposition areas, and the use of information and assumptions about the velocities, flow mechanisms, and deposition mechanisms (hydraulic approach) have been used for zoning high hazard areas. Recent developments include the use of carefully constructed scale, physical models of deposition areas in laboratory simulations of debris flow events in which deposition patterns can be observed and the use of a theoretical combination model based on hydraulic principles and a random walk model. The use of Japanese experience in zoning hazard areas could be useful in Indonesia where control of *lahar* mudflows is a problem (Smart 1981).

Debris dams and other types of debris retention structures have been used in many countries for controlling sediment flow in unstable river and stream channels. The presentation by

Liu and Lin, which described the problems created by debris dams, particularly of scour downstream of the structures, reinforced the often-expressed opinion that the construction of expensive concrete dams for storing sediment in unstable channels can exacerbate rather than improve channel instability conditions.

In his keynote address on management for protection and control, Pearce discussed the interactions and relationships between researchers and managers and planners. He emphasized the need for researchers (1) to establish credibility with managers by increasing the utility of their advice, (2) to develop commitment for undertaking appropriate types of research required in applied research, and (3) to use common sense when confronted by conflicting goals, excessive demands for information, or the need to decide whether an expensive and time-consuming study is required to solve a management problem. Communication between researchers and managers was also the focus of an innovative presentation by Rice et al. They offered managers a method of choosing an acceptable degree of landslide risk in regulating timber harvest, whereby the managers had to make their value system explicit. This can then be compared with societal values in the area of concern, and if there are disparities, social forces will retard or prevent the implementation of the management plan.

GENERAL IMPLICATIONS

As is often the case in multinational technical conferences, this conference was dominated by presentations based on studies in temperate forest environments, although a deliberate attempt was made to secure participation of scientists and managers from tropical countries. The relevance of temperate forest studies to tropical forest environments, in this case on erosion and slope stability, requires a little more than casual passing comment. Pertinently, some of the differences in biophysical parameters that control erosion, between humid temperate steepland forests and humid tropical steepland forests, are examined here.

Climate

Although total annual rainfall in many humid temperate forest and humid tropical forest regions are similar (the range in both environments commonly extends between 1500 and 3500 millimeters), the tropics experience considerably higher short-term rainfall intensities. Furthermore, the spasmodic occurrences of typhoons in such countries as Taiwan (Lin 1984), the Philippines, and Fiji have significant influence on erosion. The heavy rains and floods associated with the monsoon in Southeast Asia also strongly influence erosion and sediment transport on a seasonal basis. Temperatures, of course, are higher in the tropics at the same elevations.

Slopes and Soils

Slope morphologies do not appear to differ in a persistent manner between tropical and temperate forest steeplands. For instance, the highlands of peninsular Malaysia are dominated by slopes ranging between 25 degrees and 50 degrees, a slope range that encompasses most forested hill and mountain country in northwest North America, New Zealand, and southeast Australia. Soils, however, vary sharply between the two environments. The extent and depth of weathering is generally much greater in the tropics, and the shallow, stony forest soil overlying an impermeable high strength substratum or bedrock typical of temperate forests is not common in humid tropical forest steeplands. The organic forest floor layers, which typify humid temperate

forests, often are not well developed in humid tropical forests. In the tropics, particularly at altitudes below 2000 meters, soils and subsoils tend to be deep and show gradual changes in strength, permeability, texture, and moisture content with depth.

Forests

Forest structure and composition are much more complex in humid tropical regions, and revegetation of disturbed or bare areas progresses at a more rapid rate than in temperate forests. Despite the deep weathered profiles, many but not all tropical trees appear to have very shallow root systems. High temperatures, humid conditions, and a great abundance of soil insects and soil fungi presumably lead to rapid rates of tree root deterioration after death or removal of tropical forest trees. Similarly the deterioration and breakdown of forest debris, stumps, and exposed litter left in the wake of logging progress more rapidly in the tropics.

Impacts of Forest Operations

The immediate impacts of forest harvesting and road building on soils and slopes in the humid tropics are generally larger than in temperate forests. Poor road location planning, little emphasis on protecting streamside vegetation and other obviously sensitive slope areas such as ephemeral gully channels, and construction of dense logging track networks often cause a high degree of disturbance and soil and sediment movement during and after tropical forest logging operations. Administrative control over logging operations is usually much more difficult to achieve.

The differences between tropical and temperate forest regions are likely to create disparities in the rates at which erosion processes operate, but the processes themselves should not show substantial differences between the two types of environments in similar precipitation regimes (Hamilton with King 1983). However, very few detailed forest erosion process studies, identifications of sediment source areas, or landslide inventories have been attempted in humid tropical forest regions. Despite Pearce's opinion that landslide inventories are a research technique that has outlived its usefulness, this approach could yield information of great value in tropical forest lands. For instance, on many logged-over tropical steeplands, landslides are not considered to represent a problem. The highlands of peninsular Malaysia are a good example. Here landslides are not widely recognized as a problem, although there have been a few studies done by the forestry department. Landslide scars also revegetate more quickly, and their conspicuousness rapidly diminishes with time after failure. Low (pers. com. 1984), however, suggests that revegetation is usually only creepers rather than deep-rooted vegetation and that these scars are not stabilizing rapidly. Studies of the type undertaken by Sauder and by Smith et al. in British Columbia and by Shimokawa in Japan are required in tropical forest regions.

Logging road failures are a major problem in many Southeast Asian steepland forests. On deep fills, slump failures of the type described by Schroeder and Brown are common features after monsoon rains as, for example, in the situation described by Henderson and Witthawatchutikul in Thailand. The application of simple stability analyses using appropriate locally collected soil physical data could lead to better road designs and, in this respect, Schroeder and Brown's paper has direct relevance to tropical areas.

Generally there is a dearth of information on soil physical properties; nature, location, and frequency of landslides; and the water relations of soils on steep slopes in tropical forest areas. The development and use of slope stability prediction models, such as the landslide hazard rating model outlined by Burroughs, is a technique unlikely to be adopted for tropical forest management planning. However, there does exist a need for studies of soil strength properties, infiltration rates, water-table responses to rainfall and tree root distributions, strengths and rates of strength loss after tree felling so that a better understanding of the factors controlling slope stability on tropical forest slopes can be attained.

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PAPER SUMMARIES

Keynote Paper

The Prediction of Erosion in Forests
by Thomas Dunne

Various methods of erosion prediction exist for answering the different types of questions concerning erosion. The limitations and potential of current methods are reviewed. The most flexible and promising methods involve documenting and predicting, through field surveys and simple physically based models, the several mechanisms that mobilize sediment, transport it downslope, and store it temporarily during its passage downvalley. Up to the present, however, these sediment-budget studies have emphasized documentation and prediction by extrapolation. Further research needs to be concentrated upon computation of these processes from some easily measured physical attributes of landscape and climate. Examples of recent work of this kind are given.

The Influence of Societal Factors on Erosion and Slope Stability

People, Forests, and Erosion: Experiences from the Middle Hills of Nepal
by Donald A. Gilmour

The situation in the hill regions of Nepal is typical of that occurring in many developing countries. A high and rapidly expanding population is placing heavy pressure on all available land. The forests, which provide most of the country's energy needs, have been overused for centuries, and recent population growth and political actions have hastened this depletion. The Himalaya is an area of active orogenesis with high rates of natural erosion and mass wastage. Peoples' use of the land has exacerbated this situation and increased the level of environmental degradation. Attempts at rehabilitation must take account of the social framework in which the people live and include local people in the planning and management of any rehabilitation scheme.

Erosion and Sedimentation in the Rif Mountains of Northern Morocco
by M'Hammed Tayaa and Kenneth N. Brooks

Severe erosion and sedimentation problems in the Rif Mountain region of northern Morocco result from population pressures on the land that typify many other developing countries. Intensive grazing and cultivation of largely community-owned lands in steep watersheds cause high rates of erosion, in some areas exceeding 200 t/ha/year. Watersheds are delivering sediment to downstream reservoirs at rates of 20 to more than 70 m^3/ha/year. This paper examines some of the biophysical and societal factors that influence both the problems and the opportunities for developing sustained erosion control and rehabilitation programs.

Erosion and Sedimentation in Thailand
by Gregory S. Henderson
and Samarn Rouysungnern

The state of erosion in Thailand is alarming when the sediment levels in waterways are set in their global perspective. The results can be re-

lated to fairly recent patterns of deforestation and subsequent land use in ecologically fragile (mountain) areas. The consequences of soil erosion are negative at site and, in the long term, effect changes in ecosystem cycles and the hydrologic regime. Proper land use suggested by integrated management schemes are needed for improvement of the forest resource.

Community Forestry as an Option for Containing Environmental Degradation: A Case Study from Nepal
by Donald A. Gilmour
and Graham B. Applegate

The forests of Nepal, which supply most of the country's energy requirements, are being depleted rapidly, resulting in large-scale environmental degradation. In the early 1970s it was claimed that without community awareness and participation in conservation, the degradation would continue. Hence, community involvement in forestry was perceived as a means of establishing and managing forests to provide much-needed forest products for the people and at the same time reversing the processes of forest depletion and environmental degradation. The Chautara experience has shown that a successful community forestry program depends on a knowledge of the technical aspects and the societal framework in which the program is to operate.

Land-Use Conflicts in the Catchment of Idukki Reservoir: Their Implications on Erosion and Slope Stability
by C. T. S. Nair

In densely populated humid tropical regions, land-use conflicts are very serious. The effect of changes in ownership on land use and how such changes enhance soil erosion are discussed in this paper based on the situation that exists in the Idukki catchment in the Indian State of Kerala. Factors that have contributed to land-use changes and how these have led to accelerated erosion in the catchment are described. Agencies concerned with land management are preoccupied with short-term objectives and, in the pursuit of these, watershed protection is completely neglected.

Biophysical and Socioeconomic Causes of Land Degradation and a Strategy to Foster Watershed Rehabilitation in the Himalayas
by K. G. Tejwani

The Himalayas are the "Greatest Physical Feature of the Earth" extending through five countries; they are one of the youngest mountain ecosystems in the world and the youngest in the Indian subcontinent.

The Himalayas are now universally recognized as "coming down" (e.g., the Mangla and Tarbella reservoirs in Pakistan are being silted up at twice the designed inflow rates; in India, reservoirs built on the rivers originating in the Himalayas receive sediment up to three times the designed inflow rates; in Nepal, the midlands—originally woodlands—now only have 10 to 15 percent forest; if Nepal were still under natural condition, the number of then occurring slides will be 74 percent of the presently existing total; and in India more than 50 percent of landslides in the Himalayas are attributed to road construction activity).

Macro and micro profiles of the forest grazing and agricultural lands in relation to land degradation are described. The condition of all these land uses is highly unsatisfactory, which contributes to land degradation in the entire mountain ecosystem.

The institutional base available for facing these challenges and the approach to rehabilitate the lands and increase production and promote ecological stability are discussed.

Physical and Biological Processes Affecting Erosion and Slope Stability

Vegetative Influences on Debris Slide Occurrences on Steep Slopes in Japan
by Yoshinori Tsukamoto
and Osamu Kusakabe

The objective is to clarify what types of geology and what types of slopes are most vulner-

able to debris slides and what explanations are needed for them. Granite is most hazardous. The infinite slope model was applied to the classified four slope types. The effect of forest cutting is greatest on a slope with a transition layer typical of granite slopes and has a sharp increase of soil strength, low permeability, and high restriction to tap root growth. A plasticity solution was also applied to debris slides to evaluate the effect of lateral roots to slope stability.

Statistical Description of Shear Strength in Residual Soils
by Mark R. Schoenemann and M. R. Pyles

Any probabilistic approach to slope stability assessment requires an adequate statistical description of soil strength. Current statistical methods of strength description are unsuitable for this purpose. A statistical technique of soil strength description is developed here, which is appropriate for the probabilistic assessment of slope stability. The technique is applied to two sets of strength test results, representing soils derived from a variety of initial materials. Geostatistical techniques are used to characterize the spatial variability of soil strength and to assess the adequacy of the sample data sets for representing each population.

A Simulation Model of Soil Slip Erosion
by Vernon J. Thomas and Noel A. Trustrum

A simulation model is being developed to give the occurrence, extent, and severity of soil slips on cleared forest hillslopes in New Zealand. Using records of past erosion events, including the spatial and temporal distribution of scars (recorded by using remote sensing techniques and digitized for computer analysis), the model has been used to make preliminary projections of the course of future erosion on hillslopes. Some refinements will need to be included to ensure an adequate representation of erosion patterns. When these refinements are added, the model will provide a useful tool for evaluating the economic impact of future erosion.

Response of Progressive Hillslope Deformation to Precipitation
by Robert R. Ziemer

To document a relationship between progressive hillslope deformation and precipitation, boreholes on the Redwood Creek basin in northern California were surveyed semiannually from 1974 to 1982. Regressions were calculated between borehole displacement and an antecedent precipitation index (API) variable. Values for the API variable were obtained by summing daily API values over the time between borehole surveys, if the daily API value exceeded some threshold. The coefficient of determination, r^2, was maximized by calculating a series of regressions with various API recession factors and thresholds. The "best" regressions had a recession factor of 0.99 and a zero threshold. Results suggest that creep and earthflow rates increase in response to precipitation and that graywacke and schist terrain respond to similar mechanisms of movement.

A Natural Recovery Process of Vegetation on Landslide Scars and Landslide Periodicity in Forested Drainage Basins
by Etsuro Shimokawa

Topsoil-slide landslides are periodically repeated as a principal factor of slope development in forested drainage basins. The subject of this study is to estimate the recurrence interval of this type of landslide. The investigations concerning the natural revegetation, the spatial and chronological distribution of landslides, and the reformation of topsoil on the landslide scars were made in the research areas situated at southern Kyushu, Japan. The recurrence interval of landslides is estimated to be at least 200 years in the Shibisan, 12 to 30 years in the Kiire, and about 1000 years in the Koyojigawa, depending on geology, topography, and other factors.

Vegetative Succession, Soil Development and Forest Productivity on Landslides, Queen Charlotte Islands, British Columbia, Canada
by Richard B. Smith, P. R. Commandeur, and Michael W. Ryan

Forty-nine landslides aged 1 year to 155 years and surrounding terrain were studied in the Queen Charlotte Islands to clarify vegetation and soil development and impacts on forest productivity. The upper two-thirds of slides had significantly higher bedrock exposure and shallower soils than adjacent terrain. This, coupled with the initial destruction of vegetation, resulted in a greater extent of exposed soil and a lower cover of vegetation than in adjacent logged areas for at least 60 years. Because of lower growth rates caused by relatively poor soil conditions and competition by red alder (*Alnus rubra* Bong.), production of wood on slides to 60 years was estimated at only 30 percent of that produced in similarly aged logged stands.

Debris Torrents, Precipitation, and Roads in Two Coastal Oregon Watersheds
by W. Lee Schroeder and George W. Brown

After the 5 December 1981 storm, a 5- to 7-year event, at least 221 new landslides were observed on the Palouse and Larson Creek watersheds in the central Oregon Coast Range. Engineering analysis indicates that such a storm provides sufficient water to induce landslides on cohesionless coastal soils, especially in uncompacted sidecast fills, which produce the largest slides. Fill failures are more likely to result from loss of soil strength due to increasing degree of saturation than from internal seepage. However, seepage from uncompacted fills may remove the toe and, by backward erosion, create a vertical face of sufficient height to initiate a slump. Numerous slope failures in both clearcuts and adjacent standing timber suggested that water, not deteriorating root strength, was the major factor initiating the observed landslides.

Sediment Source Areas Related to Timber Harvest on Selected Arizona Watersheds
by Burchard H. Heede

Subdrainages were instrumented for volumetric measurements of overland flow and sediment delivery after timber harvest on three coniferous watersheds. In all watersheds, overland flow and sediment delivery were of no practical importance, but significant differences existed where the forest land was disturbed by logging or monitoring activities, or roads, or where erosion pavements existed. Where undisturbed forest floor was located downslope from source areas, sediment was caught by the buffer strip because of increased infiltration. In contrast to the Hortonian model, generation of overland flow and sediment in these forested areas took place in discrete source areas and not universally on the watershed.

Social Influences on Innovation in the Avoidance of Logging-Related Landslides
by Raymond M. Rice, R. B. Thomas, and D. J. Furbish

Social influences on a technological innovation are demonstrated in a case study. The innovation is a statistical approach to regulating timber harvesting on potentially unstable lands by estimating the risk of logging-related landslides. A linear discriminant function estimates the probability that logging a particular geomorphic site will result in a debris avalanche; and an algorithm determines what constitutes, from the land manager's viewpoint, an acceptable degree of landslide risk—given the resource values at stake. The innovative process consists of three phases: conception, acceptance, and implementation. During each phase, social influences act to promote or retard the technological innovation.

Characteristics of Management-Related Debris Flows, Northwestern California
by Richard G. LaHusen

An inventory of landslides in the lower Redwood Creek basin, California, showed that

erosion due to shallow landslides has been accelerated by logging-road and skid-trail construction. The analysis of landslides occurring during the 1981–82 rainfall season showed that all 40 debris flows originated from roads or skid trails on slopes with gradients of at least 30 degrees. Furthermore, 90 percent of the inventoried features originated less than 30 meters below a major convex break in slope, and 87.5 percent of the failures occurred in poorly drained soil having a mottled horizon less than 1 meter from the surface. These site characteristics commonly occur at the headwaters of ephemeral drainages or in streamside gorge slope positions. Results of this study are being applied in an erosion control program to selectively identify road reaches with high failure potential.

Soil Loss and Runoff Characteristics of Shifting Cultivation Land on Iriomote Island
by Koichi Sato, Yuji Sakurai, and Keiji Takase

Surface runoff and soil loss investigations were carried out to estimate the effect of shifting cultivation on erosion. Three types of experimental plots were reclaimed. The amount of surface runoff increased two to four times that of natural plot, and peak discharge showed about three times. Consequently, a high degree of soil loss occurred in these plots.

River Channel Responses to Accelerated Mass Soil Erosion
by Robert L. Beschta

Long-term channel adjustments to accelerated hillslope erosion were evaluated from aerial photographs for two river systems (i.e., the Middle Fork Willamette River, USA, and the Kowai River, New Zealand, which drain steep mountainous terrain. Hillslope erosion rates in both basins have been altered by land-use practices and the occurrence of an extremely large flow event (recurrence interval ≥ 100 years). Results indicate that active channel width is a sensitive indicator of channel aggradation, channel adjustments are most pronounced at or immediately downstream of sediment inputs, and channel changes caused by sediment inputs are relatively persistent. Sediment, and not peak flow, caused the most pronounced changes in channel characteristics.

Streamside Landsliding and Channel Change in a Suburban Forested Watershed: Effects of an Extreme Event
by Robert N. Coats and Laurel Collins

A rainstorm with a recurrence interval of up to 150 years caused extensive debris avalanches, flooding, and stream channel changes in the San Lorenzo River Basin, California. Landslide mapping, sediment sampling, and repeated channel surveys suggested that although the effects on stream channels were significant, they may be less persistent than effects on hillslopes. Damage to property and fish habitat from the storm suggested the need for continued efforts to improve land-use planning.

An Approach to Evaluating Off-Site Effects of Timber Harvest Activities on Channel Morphology
by Gordon E. Grant, Michael J. Crozier, and Frederick J. Swanson

The authors present a methodology and develop a new quantitative aerial photograph interpretation technique for assessing channel response to various off-site effects associated with timber harvest activities. The degree of channel enlargement, associated with a 100-year storm event in the Oregon western Cascades, is related strongly to upstream logging activities. The nature of the response relates to the mechanism by which sediment and water are introduced to the stream. Of the five types of initiation site (axial landslide, riparian landslide, forest growth, clearcut, and road) for channel enlargement, axial landslides were overwhelmingly important in their occurrence and influence.

Channel Adjustments Following Logging Road Removal in Small Steepland Drainages
by Randy D. Klein

The excavation of road fill from stream crossings on former logging roads is a major part of the watershed restoration program in Redwood National Park. Channel adjustments in response to winter stormflows were measured on 24 excavated stream crossings to identify important physical and hydrological variables. Organic debris was found to be important in controlling channel scour in the study reaches. Minimization of channel scour subsequent to stream crossing excavation is highly dependent upon successful relocation of original channel structural elements (organic debris, boulders). Median diameter of inorganic channel bed armor, which developed during the study period, was related inversely to the frequency of occurrence of organic debris dams within each reach. Interactions between critical power (resisting forces) and stream power (driving forces) are discussed for observed channel adjustments.

Management for the Prevention and Control of Erosion and Slope Stability Problems

Management for the Prevention and Control of Erosion: Credibility, Commitment, and Common Sense
by Andrew J. Pearce

In introducing the theme of management for erosion control and protection, the role of researchers in providing information for developing management strategies is examined. Researchers must consider why and how research should be undertaken to solve or improve erosion problems and also to consider some of the interactions between researchers and managers and planners who either do or don't use researchers' results. Management, based on relevant and up-to-date information from researchers, was the topic for two days at the conference. In this context, the applicability of research results and whether they are used are prime criteria for evaluating the success of researchers' efforts.

Many of the issues raised by such a self-examination can be grouped under the three headings of the title: credibility, commitment, and common sense; and a combination of these qualities seems vital if researchers are to achieve a fourth quality—confidence. Researchers are called upon to address questions that are credible to managers and other interest groups. Without credibility and managerial confidence in researchers and their results, much of the time and effort that goes into applied research can be wasted. Some of the problems that can arise are illustrated by views and examples drawn from the experiences in New Zealand. New Zealand, however, is not alone with these difficulties; there are lessons of wider applicability within what may appear to be local or site-specific experiences. Researchers must strive for improved credibility, for careful and considered commitment of time and effort and for widespread use of common sense, if they are to assist managers in achieving the objectives summarized in the title of these sessions.

Soil Disturbance from Logging in Southern Chile
by J. A. Gayoso and A. A. Iroume

This study is concerned with some of the mechanisms that shape the erosive processes on an Andic Dystrochept soil in Southern Chile. The study is located in a high rainfall area and steep terrain. Logging operations and clearcuts have taken place without prefixed skid trails. Data from experimental sample plots provide an opportunity for evaluating the influence of vegetal cover and slope in the volume of transported particles and surface runoff. The quantification of the amount of soil removed by logging operations made with a skidder was evaluated from the trail. The results will allow improved decision making for logging equipment selection, logging systems, and cutting systems and timing under soil conservation-erosion control criteria.

Rehabilitation of Unstable Slopes Using Structural and Vegetative Measures
by George H. Belt and Woo Bo-Myeong

Because of relatively steep slopes, shallow granitic soils, and reduced vegetative cover, landslide hazard is high in some drainages near Seoul, Korea. When frontal weather associated with typhoons causes heavy rainfall, surficial landslides frequently occur, resulting in severe property damage and loss of life. The Korean government has stabilized these slopes using terraces buttressed by dry masonry walls and drained by stone-line central channels. Recommendations for revegetating these terraces and estimating their effectiveness in reducing ground-water rise are presented. Suggestions for research projects useful in identifying areas of high landslide hazard are also given.

A Model Experimental Study on the Fence Effect of Two Trees Against Debris Flow
by Hiroshi Omura and Kimio Hara

Some experiments were carried out to estimate the catchable fence effect of a pair of trees against rockfall and small debris flow using a model slope system that is 4 meters long, 2 meters wide, and 35-degree oblique angle. There were clear differences in sediment caught, depending on the arrangement of the trees.

Utilizing Alternative Logging Methods to Reduce Mass Wasting
by Edward A. Sauder

Three studies examined ways to reduce mass wasting by using alternative logging methods. Examination of slope failures in logged areas showed that failure-prone sites can be identified; road failures were primarily caused by overloading steep slopes and by poor road-drainage practices; and yarding disturbances appeared to contribute to several failures within clearcuts. Examination of current yarding operations showed levels of yarding disturbance can be reduced if settings are designed carefully. More intensive planning and consultation between resource managers can reduce the number of logging-associated slope failures. On marginally stable slopes, the roads must be recognized as an integral part of the logging system.

Surface Erosion Under Various Tropical Agroforestry Systems
by K. Freerk Wiersum

This paper evaluates the soil protective value of different agroforestry systems. The effect of trees grown in combination with agricultural crops on rainfall erosivity, soil erodibility, and soil surface protection are examined, and quantitative data on surface erosion in various forest and tree crop systems are reviewed. This review concluded that individual trees cannot be expected to exert the same protective effect as undisturbed forest ecosystems. The key to controlling erosion in agroforestry does not lie in the presence of trees themselves but rather in good management practices, either of trees or by application of additional soil conservation technologies.

The Effectiveness of Stilling Ponds and Concrete Blocks in Dissipating the Overflow Energy of Check Dams
by Liu Chiun-Ming and Lin Yuan-Lin

A check dam has been used to control sediment in the upstream area of Taiwan. However, this action always fosters the channel scouring in the downstream reaches. A stilling pond and concrete blocks were used to minimize this undesirable erosion. The objectives of this study were to measure the deformation of channel cross sections below the stilling pond and the stability of concrete blocks and then to evaluate if these dissipaters were effective in energy dissipation and erosion control. This study suggested that the length of the stilling pond was underestimated and that the arrangement of concrete blocks should be modified.

The Effect of Road Construction on Sedimentation in a Forested Catchment at Rayong, Thailand
by Gregory S. Henderson
and Poongsak Witthawatchutikul

The extent to which road construction causes greatly increased sediment production in Huay Ma Feung Stream was investigated in the rainy season of 1983. Storms produced simultaneous peaked, suspended sediment and discharged hydrographs with maximum values at 28,000 mg/liter and 1.46 m^3/s, respectively. Bedload accounts for more than 80 percent of the total load of 10,494 t/km^2. Sedimentological evidence and prevailing soil hydraulic properties indicated that the bulk of sediment originates from roadside gullies, slumps, and landslides. Roadside technical improvements and road construction guidelines are necessary to prevent increased sediment production.

Surfacing to Reduce Erosion of Forest Roads Built in Granitic Soils
by Edward R. Burroughs, Jr., Fred J. Watts, and D. F. Haber

A sprinkling infiltrometer was used to measure the relative difference in sediment yield from 15.3- to 30.5-meter isolated lengths of forest road. Sediment yield was reduced by a factor of 4.3 for gravel surfacing, 3.2 for dust oil, and 28.7 for bituminous surfacing relative to an unsurfaced road. Gravel spread in the ditch reduced sediment yield by a factor of 2.3 relative to an unprotected ditch. A rutted unsurfaced road produced twice the sediment as a smooth unsurfaced road.

Landslide Hazard Rating for Portions of the Oregon Coast Range
by Edward R. Burroughs, Jr.

An empirical model was developed to estimate ground-water rise over a hyperbolic-shaped bedrock surface in debris avalanche terrain as a function of measurable site characteristics. Data on soil shear strength (0 and C) were based on published results of triaxial tests. Root strength was the sum of the passive resistance to sliding of an alder soil-root mass and the residual strength of Douglas-fir roots as they decline with time after clearfelling. Driving and resisting forces were calculated for a soil block using estimated values of ground-water rise, soil shear strength, and root strength.

Effectiveness of Introduced Forest Vegetation for Protection Against Landslides and Erosion in New Zealand's Steep'ands
by Colin L. O'Loughlin

Forests act in many ways to enhance slope stability and reduce erosion rates, but the mechanical reinforcement provided by tree root systems is the major factor enhancing stability. A qualitative examination of the development of exotic conifer forests and their influence on slope stability in four eroding steepland environments showed that young forests begin to substantially increase slope resistance to shallow failures and surface erosion between five and ten years after establishment. However, forest vegetation is not generally effective in containing retrogressive slumping around headwall regions of actively eroding gullies and large landslides.

Methods for Zoning Debris Flow Vulnerable Areas
by Takahisa Mizuyama, Hiroshi Ikeya, and Ryohei Imamura

An outline of the main conventional methods for recognizing areas endangered by debris flow movement and deposition is presented. Two new approaches are also discussed: (1) the use of scale models to determine the deposition range of debris flows and (2) the application of a combination model based on a hydraulic approach, together with a random walk model.

Watershed Forest Management Practices in the Tropical Rain Forests of Northeastern Australia
by David S. Cassells, Donald A. Gilmour, and Michael Bonell

In northeastern Australia, the wet tropical rain forests historically have been viewed

largely as a barrier to closer settlement, and until recently the community gave little thought to their conservation or management. In the past 10 to 15 years, however, there have been dramatic changes in community attitudes, and the rain forests are now highly valued for their intrinsic environmental qualities. In this changing socioeconomic environment, forest management operations must meet increasingly strict environmental standards, particularly on the protection of soil and water resources. This paper outlines the evolution of the watershed management controls now routinely applied to all state forest harvesting operations in this rain forest region.

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