# Watershed Management for Disaster Mitigation and Sustainable Development in Taiwan

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**Abstract.**—Heavy torrential rains during the typhoon season, steep topography, young and weak geologic formations, erodible soils and improper land uses are factors contributing to disasters associated with erosion, landslides, debris flows, and floods in Taiwan. With steady public and government support over the past 5 decades, Taiwan's watershed management program in which soil and water conservation is a dominant component has helped to alleviate impacts of disasters and enhance sustainable management of land and water resources. The program is periodically evaluated and revised according to scientific and technical advances, and rapid political and social-economic changes on the island to meet the rising diverse needs and expectations of the people. To help resolve conflicts and gain consensus related to watershed management policy and issues, public input can be solicited through properly designed and implemented public education and involvement initiatives.

## Introduction

Few places in the world experience the watershed management problems and challenges resulting from combined hydro-meteorological extremes, and political, social-economical and cultural complexities like Taiwan. Heavy torrential rains during the May-October typhoon season, young and weak geological formation, erodible soils, frequent earthquakes, and improper land uses are factors contributing to disasters associated problems related to severe erosion, landslides, debris flows, and floods.

Watershed management and soil conservation programs have received continuous and growing public and government support since the early 1950s, due to clearly demonstrated increasing needs. However, political, social-economical and cultural conditions in Taiwan are changing rapidly in recent years, and the mission and program planning of watershed management should be timely revised accordingly to meet rising new needs and aspirations of people. Proper land uses are essential to a successful watershed management program for disaster mitigation and sustainable development. But dense population, land scarcity, and other political, social-economic conditions, and traditional ideas are not very favorable to strict implementation of a land use planning and regulation system. Therefore, there are tough and rewarding challenges in Taiwan's future watershed management program. This paper examines the problems, issues, and roles and challenges for watershed management in Taiwan in terms of its mission to foster stewardship of land and water resources for disaster mitigation, sustainable development, and integrations with other government service to meet diversed needs and expectations of the people.

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## Physical Environments, Land Uses and Watershed Problems

### Physical Environments

Two-thirds of Taiwan are rugged mountains and hills (table 1). Most mountainous areas are very steep, with slopes usually exceeding 45%. The average annual rainfall is 2,500 mm, with more than 3,000 mm in some high mountain regions. About 80% of the rainfall is concentrated in the May-October typhoon season. Approximately

Table 1. Land Resources in Taiwan.

| | Area (ha.) | Percent (%) |
|---|---|---|
| Plains | **948,797** | **26.4** |
| Slopelands | **2,653,899** | **27.2** |
| *Hillslopes* | *980,819* | *27.2* |
| *Mountain forest lands* | *1,673,080* | *46.4* |
| Total | **3,602,698** | **100** |

3 typhoons pass through the island annually, and often bring more than 100 mm/hr or as much as 1,000 mm/day of rainfall. For example, 1,987 mm of rainfall was measured over a 48-hour period during Typhoon Herb in 1986 at one high elevation climate station in central Taiwan (figure 1). Other important environmental characteristics include young and weak geological formations, erodible soils and frequent occurrence of earthquakes.

## Land Uses

According to the third forest resources and land use inventory in 1995 (table 2), about 59 % of the land area are covered with forests. Comparison of slopeland uses in Taiwan for different time periods is given in table 3. Fifty percent of slopeland crops grow on slopes steeper than 30%. According to slopeland inventory in 1998, there were still 110,000 ha of cultivated land requiring conservation treatments. Nearly all the slopeland soils are subject to serious erosion when exposed. This problem is aggravated by cultivation on steep slopes.

Table 2. Land Use Inventory in Taiwan of 1995 (Taiwan Forestry Bureau, 1995).

| Land use | Area (in 1,000 ha.) | Percent (%) |
|---|---|---|
| Forested lands | 2,102.4 | 58.5 |
| *Conifers* | *438.5* | *12.2* |
| *Conifer-hardwoods* | *391.2* | *10.9* |
| *Hardwoods* | *1,120.4* | *31.2* |
| *Bamboo* | *152.3* | *4.2* |
| Agricultural lands | 831.9 | 23.2 |
| *Peddy* | *264.8* | *7.4* |
| *Upland-farming* | *235.0* | *6.5* |
| *Others* | *332.1* | *9.2* |
| Other lands | 657.2 | 18.3 |
| *Grassland* | *143.5* | *4.0* |
| *Urban and industrial* | *217.8* | *6.1* |
| *Water area* | *201.3* | *5.6* |
| *Others* | *94.6* | *2.6* |
| **Total** | **3,591.5** | **100.0** |

## Landslides and Water Quality Degradation – Major Watershed Problems

Very few areas in the world experience landslide problems of the magnitude and extent of those in Taiwan (Dils 1978). Watershed field investigations throughout the island have indicated a close relationship between the presence of extensive landslides and the serious siltation problems of reservoirs (table 4) and streams. Landslides contribute large amounts of sediment and debris to water courses, which create many problems downstream such as raised streambeds, damaged hydropower generating facilities, reduced carrying capacities of irrigation canals, and rapid siltation of reservoirs. Therefore, a major goal of watershed management is to help reduce the heavy siltation in streams and reservoirs. Agricultural uses of hillslopes in reservoir watersheds with heavy application of fertilizers and pesticides also contribute to serious water degradation (table 5).

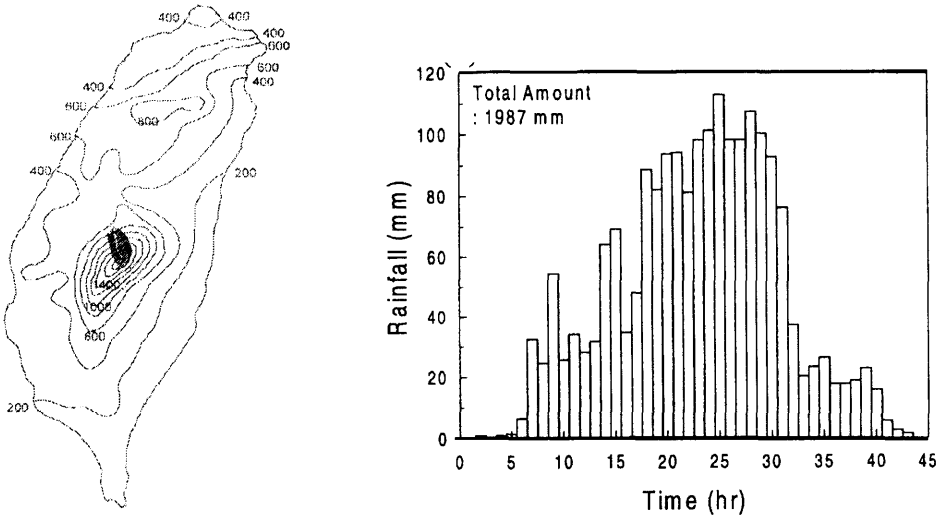


Figure 1. (a) Spatial distribution of total rainfall amount and (b) hourly rainfall at Alishan Climate Station during Typhoon Herb in Taiwan, July 31 - Aug 1, 1996.

Table 3. Comparison of Slopeland Uses for Different Periods in Taiwan.

| Land Use | | 1974~1977 Inventory (1) | | 1985~1988 Inventory (2) | | 1997~1999 Inventory (3) | | Land Use Change (3)-(2) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Area (ha) | % | Area (ha) | % | Area (ha) | % | Area (ha) | % |
| Cultivated | Fruit Trees | 115,716 | 11.9 | 154,356 | 15.5 | 136,363 | 15.0 | - 17,993 | - 0.5 |
| | Peddy Rice | 72,081 | 7.4 | 37,504 | 3.8 | 17,156 | 1.9 | - 20,348 | - 1.9 |
| | Upland Crops | 147,899 | 15.2 | 79,801 | 8.0 | 49,384 | 5.4 | - 30,417 | - 2.6 |
| | Others | 2,489 | 0.3 | 1,885 | 0.2 | 64 | 0.0 | - 1,821 | - 0.2 |
| | Subtotal | 338,185 | 34.7 | 273,546 | 27.6 | 202,967 | 22.4 | - 70,579 | - 5.1 |
| Forest and Grassland | Forest | 406,779 | 41.8 | 458,970 | 46.2 | 465,052 | 51.3 | 6,082 | 6.1 |
| | Bamboo | 95,268 | 9.8 | 111,910 | 11.3 | 71,127 | 7.8 | - 40,783 | - 3.5 |
| | Grasslands | 41,028 | 4.2 | 43,013 | 4.3 | 32,961 | 3.6 | - 10,052 | - 0.7 |
| | Subtotal | 543,075 | 55.7 | 613,893 | 61.8 | 569,140 | 62.8 | - 44,753 | - 1.0 |
| Others | | 92,934 | 9.5 | 105,272 | 10.6 | 134,118 | 14.8 | 28,846 | 4.2 |
| Total | | 974,194 | 100.0 | 992,711 | 100.0 | 906,225 | 100 | - 86,486 | |

Table 4. Mean Annual Sediment Data for Major Reservoirs in Taiwan.

| Reservoir Name | Watershed Area ($km^2$) | Mean Annual Sedimentation ($m^3/km^2$) | Erosion Depth (mm) | Observation Period (Year-Month) |
|---|---|---|---|---|
| Shimen | 763 | 2773 | 2.77 | 1963.5-1987.11 |
| Techi | 582 | 1971 | 1.99 | 1973.9-1987.11 |
| Wushe | 205 | 5937 | 5.93 | 1955.12-1988.2 |
| Ming-Te | 61 | 4118 | 4.12 | 1970.6-1975.6 |
| Sun Moon Lake | 334 | 522 | 0.52 | 1934-1984.5 |
| Tsen-Wen | 481 | 7830 | 7.83 | 1974.5-1987.12 |
| Pai-Ho | 27 | 14882 | 14.9 | 1965-1984.8 |
| Ah-Kung-Tien | 32 | 13350 | 13.4 | 1953-1971 |
| Wu-Shan-Tou | 60 | 26660 | 26.7 | 1920-1984.12 |

# Review of Watershed Management Program in Taiwan

The physiographic, geologic, and climatic conditions make the mountain slopes of Taiwan extremely sensitive to disturbance (Koh et al. 1988; Wu et al. 1995). Road construction and forest clearing followed by improper land uses on hillslopes often accelerate the occurrence of landslides and debris flows (table 6, Cheng et al. 1997).

To combat landslides and other watershed problems, the government has, for 50 years, implemented a gradually expanding watershed management program, starting with two selected reservoir watersheds, Wushe and Akundien. Components of the watershed management program normally include forest management, soil conservation on cultivated hillslopes, road stability maintenance, land use regulation, landslide prevention and treatment, and stream channel stabilization work. Landslide control and stream channel stabilization generally account for the largest proportion of the watershed protection and restoration budgets. In recent years, watershed management has been extended beyond reservoir watersheds to other drainages, particularly those areas with a recorded history of disastrous damages caused by sediment-carrying floods. The total expenditure increased steadily as the program expanded over the years (figure 2).

Table 5. Calson's Eutrophication Index (TSI) for Major Reservoirs in Taiwan.

| Reservoir Name | 1993 | 1994 | 1995 |
|---|---|---|---|
| Fetsui | | 40.85 | 36.0 |
| Shimen | 45.56 | 55.76 | 42.75 |
| Te-chi | | 47.90 | 40.75 |
| Wushe | 45.44 | 40.42 | 41 |
| Tseng-Wen | 51.0 | 49.81 | 40.75 |
| Wu-Shan-Tou | 45.06 | 50.88 | 44.50 |
| Pai-Ho | 51.36 | 56.20 | 49.00 |
| Ah-Kung-Tien | 75.08 | 80.79 | 69.50 |
| Feng-Shan | 77.53 | 74.56 | 75 |

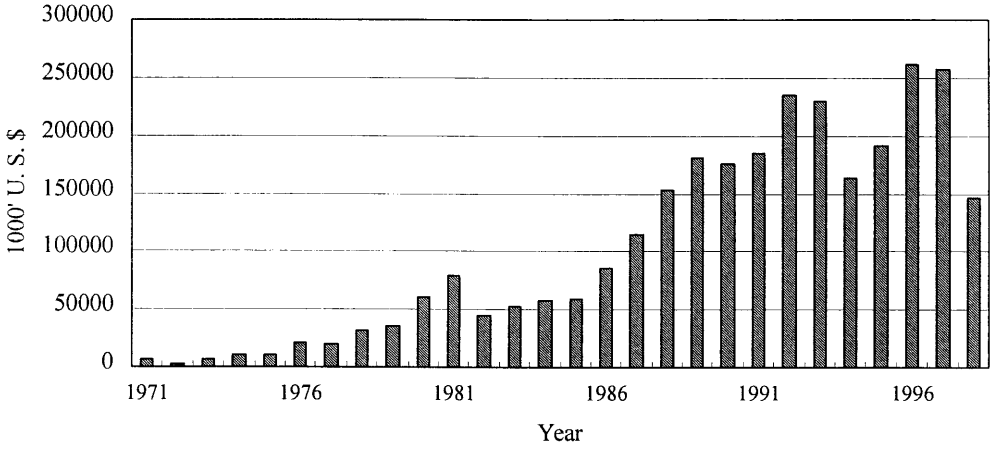


Figure 2. Expenditure on Watershed Management in Taiwan (1971)

Table 6. Selected debris flow events in central Taiwan (from Cheng et al., 1997).

| Debris Flow Location | Date | Rainfall Event | Impacts on Life and Property |
|---|---|---|---|
| Tung-Men, Hualin | 23 June 1990 | 475 mm / 3 hr | 29 deaths, 6 missing, 7 injured, 24 houses destroyed, severe road damage |
| Er-Bu-Keng, Nantou | 31 July - 1 Aug. 1996 | >700 mm in less than 2 days | 5 deaths, 10 houses & 3.8 ha fruit orchard destroyed |
| Tung-Fu, Nantou | 31 July - 1 Aug. 1996 | >1300 mm in less than 2 days | 2 deaths, 18 houses destroyed or damaged |
| Shen-Mu Village, Nantou | 31 July - 1 Aug. 1996 | >1600 mm in less than 2 days | 5 deaths, 6 injured, 8 houses destroyed, 3 ha fruit orchard damaged |

Landslide prevention and treatment measures usually include excavation of unstable materials, proper drainage, restraining structures such as retaining walls, buttresses, piling, and rehabilitation of devastated slopes by appropriate engineering and revegetation techniques according to the specific site conditions. Stream channel stabilization measures often involve the construction of check dams, submerged sills, bank protection dikes, and stream regulation works.

Despite continuous watershed management efforts for many years by structural and nonstructural means, the people of Taiwan continue to experience landslides, debris flows, and floods. Consequently, natural resource managers and engineers are under strong pressure to do a better job to safeguard the safety and well being of the people on the island by designing and implementing an effective watershed management program.

# Important Specific Issues in Managing Taiwan's Watersheds

As a result of unfavorable environmental conditions, and rapid social-economic and political changes in a maturing democratic country like Taiwan, watershed problems have become increasingly complicated. Several important specific issues should be properly addressed to ensure effective management of Taiwan's upland watersheds.

## Land Users' Reluctance in Adopting Soil Conservation Measures for Slopelands

Many slopeland farmers and users are reluctant to adopt conservation measures, because of high production cost and low profitability in slopeland agriculture as a result of labor shortage in the rural area, rapid appreciation of Taiwan's currency, and strong competition of overseas agricultural products after the relaxation of import restriction.

## Cultivation of Steep Mountainous Areas

Financial incentives in recent years have been favorable for the cultivation of high elevation tea, betel nuts (figure 3), fruit trees and mountain vegetables. Consequently, many forested slopes have been cleared and cultivated illegally, in many instances. During the initial stages of converting forests to other uses, the soils are exposed and disturbed, leading to soil erosion rates exceeding 220/t/ha/yr (Wu 1998). The replacement of forest cover with agricultural crops also reduces the stability of hillslopes. However, regular patrol, detection, monitoring, and administration of land use changes and problem sites on the ground have been a difficult task due to steep, inaccessible, and

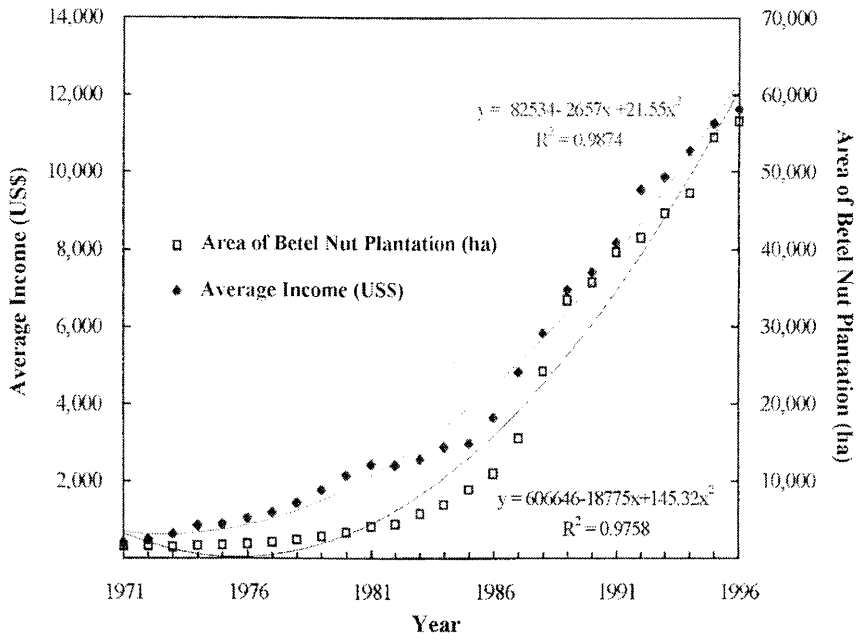


Figure 3. Comparison of Annual Area of Betel Nut Plantation with Average Per Capital Income in Taiwan (1971-1996).

dangerous terrains in many headwaters watersheds. Consequently, modern techniques such as remote sensing, geographic information system (GIS), and even the remotely piloted vehicle (RPV) are being applied with various degree of success.

## Nonagricultural Uses of Hillslopes and Cumulative Effects

Because available plain lands are limited in Taiwan, it is unavoidable that even forested hillslopes are in demand for various nonagricultural uses such as residential and recreational developments. For example, among 81 golf course applications that were approved in the 10-year period after 1983, many were constructed on slopelands that originally were forested. Construction activities increased water-born sediment, and the resulting golf courses do not have the same hydrologic attributes of the original forests.

Removal of forests for permanent conversion to other uses on steep and rugged hillslopes pose serious slope stability problems, as well as opening up previously inaccessible areas to greater development activities such as urban encroachment and expansion of recreational areas. Of particular concern are the cumulative watershed effects of these land use changes and development activities. Improper nonagricultural uses of hillslopes in recent years had resulted in severe disasters with significant property damages and loss of lives.

## Modifying Natural Systems and Human Behavior

Coping with landslide, debris flows, and flooding problems has involved extensive use of engineering measures throughout the island. Hillslope stabilization structures, debris flow control structures in mountain drainages, and concrete channels with energy dissipaters are common. The emphasis on structural solutions to protect people from landslides, debris flows, and floods has sometimes resulted in a false sense of security by downstream communities. In addition, channelization and associated stream alterations from headwaters to floodplain areas poses questions concerning impacts on downstream flooding in contrast to natural stream systems with their riparian vegetation intact. Solutions most likely will include modifying both the natural systems and human behavior on the watershed. Modifying natural systems to mitigate disasters requires a good understanding of their processes and governing factors, and an understanding of how mitigation actions impact the environment. Modifying human behavior requires an understanding of human systems and participation of social scientists as principal players. It is important to have a solid understanding of the roles of forest cover, other vegetative measures and engineering methods as components of an integrated watershed management approach.

## Poor Inter-Departmental Coordination

Implementation of the protection forest policy since 1901 has certain watershed management benefits. However, protection forest system cannot be implemented in isolation from policies governing the use and management of all watershed lands in Taiwan. Protection forests must be managed in concert with production forests, national parks, private and other lands to achieve objectives of streamflow regulation, erosion control, and other environmental protection purposes (Koh et al. 1988).

In a maturing democratic country like Taiwan, policy decisionmaking requires careful consideration of overall political and social implications. Policy implementation depends on whether there is an effective coordination among government agencies and various sectors and interest groups. For example, at the Wu-ling Farm in headwaters area of Ta-chia river in central Taiwan, the Vocational Assistance Commission for Retired Servicemen (VACRS) promotes high-elevation fruit and vegetable farming due to its high profitability. This farm has been criticized by conservation groups and the public for its unrestrained exploitation of environmentally sensitive hillslopes, resulting in siltation problem of downstream Techi reservoir and detrimental impacts on water quality of Chichiawan Creek, a protected ecological area. However, VACRS operations are closely tied to the lives of military veterans, and, therefore, the problems caused by the farm have been difficult to resolve due to political considerations.

# Comprehensive Program Evaluation for Improved Watershed Management

A comprehensive program evaluation is required to ensure all aspects related to watershed management are considered for improved program planning, priority determination, and effective implementation of projects and initiatives for identified problems and issues.

## Legislation, Policy and Institutional Arrangements

The Soil and Water Conservation Act and the Statute on the Conservation and Use of Slopeland Resources provide the legislative basis for watershed management. The management of forested and non-forested watersheds is the responsibilities of several organizations, each with their own agendas. The Watershed Management Division of Taiwan Forest Research Institute and universities share the major responsibility for conducting watershed research.

The number of different agencies involved with watershed management, each with their own respective missions, roles and priorities is problematic. Either some type of effective coordinating mechanisms or organization is needed, or one agency should be charged with the overall responsibility for watershed management. It is suggested that such arrangements be made at the highest level of central government. With adequate resources and expertise, a clearly defined mission, and well-defined roles and responsibilities, the coordination and management of Taiwan's watersheds can be improved.

Some policy, legislative, and administrative aspects must also be considered and included for effective implementation of watershed conservation and management program. For example, proper policies must be formulated and necessary legislation amended to retire from production some cultivated slopelands with highly erodible soils. Mechanisms should be developed to provide adequate compensation for owners of lands targeted for retirement. Mandatory compliance legislation should also be put in place that requires land owners to carry out a conservation plan within a certain time limit and conduct necessary maintenance for their erodible slopelands, if they are to remain eligible for government benefits such as price and income supports, crop insurance, and free or low-interest loans.

## Technical and Scientific Challenges

As in other parts of the world, a good deal of public confusion exists on just how forests and forest management practices affect water resources and water-related disasters. On one hand, some believe forests somehow act as storage reservoirs that can store water during the flood season (somewhat true for deeper soils, but with a limited effect on major flood events) and then release water during the dry season (which is false). Furthermore, some still attribute forest cover with the ability to attract rainfall, which has been shown not to be the case worldwide (Bosch and Hewlett 1982; Whitehead and Robinson 1993). Claims that betel nut trees can transpire more than 10 m of water annually have come forth with no scientific support. In addition, the popular press commonly attributes flooding disasters only to improper land use and contends that natural forest cover can prevent floods from occurring.

In light of local and overseas watershed study results (Bosh and Hewlett 1982; Hsia and Koh 1982; Whitehead and Robisun 1993), some conclusions regarding forest watershed management can be reached. However, more efforts should be in researching and developing knowledge and techniques for watershed conservation and management.

Forests provide the most desirable cover on upland watersheds to meet most soil and water conservation objectives, but no matter what type of vegetative or structural measures are implemented, they have limited effects on disasters caused by extreme hydro-meteorological events. The extent to which forest cover and other vegetative and structural technologies can mitigate the adverse effects of floods, landslides, debris flows, and droughts should be properly determined (Brooks 1998).

Forests represent the best vegetative cover type for producing high quality surface water and groundwater. Nutrient budgets for natural hardwood stands have been conducted (Liu and Sheu 1997), but further research is needed for the various forest types on the island. Forest clearing in headwater watersheds to augment water supplies during the dry season is not realistic, given the above concerns and the inability to predict the timing and magnitude of streamflow changes (Hsia and Koh 1982; Koh et al. 1988).

Articles in the popular press have claimed that betel nut plantations result in excessive water losses through evapotranspiration on one hand, and aggravate conditions for landslides and debris flows on the other hand. As a result, studies have been established to address the soil and water conservation effects of this particular land use change (Wu 1998). The proliferation of betel nut plantations on mountain slopes is probably an issue that has to be first resolved in political and social and economic arena.

The improved knowledge base must be developed for making rational decisions regarding nonagricultural development and the cultivation of highly profitable cash crops on environmentally sensitive and fragile slopelands. There is still much to be done in developing solutions for the problems of slopeland farms as non-point sources of pollution and for better integration of land and water management activities on a watershed scale.

Studies should be undertaken to assess the usefulness of buffer strips to: (1) improve and protect stream and riparian habitats, (2) remove nutrients from runoff and overbank floodwaters, and (3) improve the stability of reservoir shorelines and stream banks. There is also a need to create an interdisciplinary "Watershed Research Group" to address the watershed management issues of buffer strips, nutrient management, land use management, habi-

tat protection and water quality (Agpoa et al. 1996). Interdisciplinary studies must emphasize social-economic and human aspects of watershed management problems and issues.

The effectiveness and socioeconomic benefits of the watershed management program must also be properly evaluated. One method that can be used is to determine whether the actual annual sedimentation rate exceeds the design value at the time of reservoir construction. The other approach is to estimate savings in rehabilitation costs due to reduced severity of disasters after completion of watershed protection projects.

### Social-Economical and Political Perspectives

The significant and rapid changing socioeconomic and political conditions in the past five decades have altered the needs and aspirations, as well as public policy decisionmaking and program implementation processes. These significant changes include (1) the increasing wealth of the people and nation as a result of rapid industrial development and fast growth in international trade, (2) the decreasing importance of agriculture in the national economy, (3) a growing proportion of well-educated and environmentally conscious people, and (4) a maturing democratic political system.

The highly educated, affluent and environmentally conscious population is becoming more concerned and vocal about issues related to conservation of nature and resources as well as environmental protection. People also demand to be better informed of and involved in the whole spectrum of problems, issues, and decisionmaking related to environmental protection and natural resource management. Conservation and environmental issues are often raised in recent national and local elections.

To help resolve conflicts in a democratic society on policy and issues related to watershed management, public input is solicited to gain consensus through public participation and consultation. The involvement of a well-informed, knowledgeable public can directly or indirectly contribute to goal setting, policy formulation, priority determination, and program implementation for watershed management. Of particular importance is the support and participation of every citizen to ensure effective implementation of proper land-use planning and regulation based on land capability classification which is the key to sustainable watershed management. Therefore, a properly designed and implemented public education program is essential to ensure that the general public, politicians, conservation groups, educators, and the media are all knowledgeable about the interrelationships and complexities of issues, problems, and governing factors related to watershed management, on basis of results from studies on impact of land uses on soil and water resources. Equally important is the need to educate the decisionmakers and the population at large about the need to limit urban expansion in areas vulnerable to the hazards of typhoons, and the limitations that human have in controlling the magnitudes of disasters caused by extreme hydro-meteorological events. This sub-program should make effective use of regular school education system as well as mass media such as televisions and radios.

Volunteers made up mainly of school teachers, university students, housewives, and retired people can form a major part of the public involvement sub-program. However, consideration should be given in the future to new initiatives, such as setting up localized conservation youth crops and specific community groups under cooperate sponsorship and government technical assistance to carry out small worthwhile special watershed conservation management and projects during weekends or the winter and summer vacations.

Effective extension of watershed management measures and techniques is currently in program implementation in the field. Publication of information materials such as the periodically updated and revised Soil and Water Conservation Handbook (COA et al. 1992) is useful to extension work and standardization of conservation methods and techniques used by field practitioners.

## Future Prospects of Taiwan's Watershed Management Program

### Integral Partner in Government's Overall Program of Providing Goods and Services

The mission of watershed management program for the 21st century should be determined on a broader perspective to reflect the rapidly changing social-economic and political conditions of Taiwan. The program should be an integral partner in achieving the nation's overall goals of nature conservation, environmental protection, and disaster prevention and minimization. In other words, it should be integrated with the government's other efforts to provide goods and services responsive to a rapidly changing nation with diverse needs and aspirations, and to improve the income and welfare of farmers and rural communities. Several recent sub-programs of the watershed conservation and management program of Taiwan are already reflecting these new roles and new challenges (table 7).

Table 7. Sub-programs of Watershed Management and Soil Conservation in Recent Years.

| Program Goals | Sub-Programs |
|---|---|
| *Environmental Protection, Disaster Prevention and Minimization Sustainable Management of Soil and Water Resources* | a. Integrated watershed protection and flood control,<br>b. Urgent disaster prevention on slopelands,<br>c. Reservoir watershed conservation,<br>d. Conservation of soil and water resources for small and medium-sized watersheds. |
| *Enhancing the Income and Welfares of Farmers and Rural Communities by Improving Agricultural Production and Living Conditions in the Rural Areas* | e. Farm road construction and improvement,<br>f. Assistance for slopeland agricultural management,<br>g. Slopeland conservation and utilization load,<br>h. Integrated development of farming communities.<br>i. Conservation and landscape management of riparian zones along streams. |

## Environmentally Sound Slopeland Agriculture Renewal

A top priority in the watershed management program is to design and implement an environmentally sound initiatives for slopeland agriculture renewal. A prosperous and healthy agricultural sector remains essential to maintain the social, political, and economic stability of Taiwan. Despite of its current decreased economic importance, slopeland agriculture can be diversified with new initiatives that are both profitable and sustainable with minimal detrimental impacts on the environment.

Innovative ideas and initiatives are important to a renewal program for prosperous and sustainable slopeland agriculture. For example, some selected hillslope landscapes with proper conservation and infrastructure facilities might be developed into alternative sightseeing and recreational spots for the enjoyment of both residents and vacationing tourists from urban areas. Some traditional farms or orchards are already being converted to recreational farms especially in scenic areas with certain success. The responsible government agencies provide assistance in designing farm houses, landscapes, and suitable amenities such as fish ponds, camping grounds, flower beds, selection of grass and plant materials, and construction of farm roads. Visitors to these farms can enjoy camping, fishing, picking fruits, or drinking tea while staying at recreational farms (Chuang et al. 1992). The visitor can also engage in more educational activities such as observing how tea is grown, harvested, and processed.

## Enhancing the Income and Welfares of Rural Communities

Implementation of watershed management projects located mostly in the rural areas can help generate much-needed short-term employment opportunities and, through purchasing required goods and services locally, provide supplementary incomes and revenues for the farm families and communities in areas adjacent to the project sites. This can help reduce social conflicts and promote political stability by a more equitable distribution of national wealth.

## Improving Land Use Planning and Regulation

Another top priority for watershed management in the new century is to solve the problems of improper cultivation and non-agricultural developments of steep hillslopes by better planning and effective control and regulation of land uses based on land capability classification. Effective land-use regulation is closely related to strong law enforcement and proper compensation and incentives. However, for a country like Taiwan, whose people traditionally dislike the interferences from governments and regulations and have not yet understood sufficiently their citizen's rights and responsibilities in a maturing democratic society, any "strong" law enforcement attempts will encounter objections from individuals or organized groups. It is, therefore, important to start the basic work of implementing a well-designed law education program that gradually will have beneficial impacts on land use control and regulation which is essential key to sustainable watershed management.

## Assisting Asia Pacific Countries in Watershed Management

The knowledge and practical experiences of Taiwan in dealing with watershed problems may be valuable to

other countries, particularly those in the Asia Pacific region. It is, therefore, an important new challenge for Taiwan to play a greater role in assisting other Asia Pacific nations in problem identification and solution development for both agricultural and non-agricultural uses of slopelands. Successful establishment and operation of a center for international assistance in watershed management must be high in priority among many new initiatives. This can also help enhance international cooperation and friendship between Taiwan and countries in the Asia Pacific region.

## Conclusion

Hydro-meteorologic extremes, steep topography, young and weak geologic formations, earthquakes, erodible soil, and improper land uses are factors contributing to the frequent occurrence of erosion, landslides, debris flows, and floods during heavy torrential rainfalls in the May-October typhoon season at many locations in the mountainous watersheds of Taiwan. Therefore, watershed management for disasters mitigation and sustainable development is an matter of great importance that has steady and strong public and government support.

Protecting people against the hazards of landslides, debris flows, and flooding in Taiwan generally involves developing appropriate institutions and policies, and suitable methods targeted for identified issues and problems. However, the rapidly changing political and social-economic conditions in the past 50 years have affected the needs and aspirations of the people as well as the public policy decisionmaking and implementation processes. Therefore, it is important that watershed management programs are periodically evaluated and revised according to scientific and technical advances to foster watershed land stewardship for optimum benefits in term of disaster mitigation, sustainable development, and integration with other government services to meet diverse needs of the people and the nation. Major challenges are to develop initiatives and projects in forest management, bioengineering, and combinations of structural and non-structural conservation measures to achieve watershed management goals.

Efforts must also be concentrated on controlling human behavior on watershed as much as attempting to modify the natural system with biophysical conservation measures. Moreover, the success of watershed conservation and management depends strongly on a properly designed and implemented public information, education and involvement sub-program to help generate and sustain public's awareness, appreciation, support, and participation of the watershed management program. After all, watershed conservation and management is everybody's business. Only with all-out efforts of the whole nation, can the goal of watershed management for disaster mitigation and sustainable management of our land and water resources be achieved.

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