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FORESTRY POLICY IN BALI, INDONESIA

By

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Forest reserves cover some 125,000 hectares in the island of Bali, or about 21 per cent of its total surface area. Forestry policy makers, seeking to conserve this area of forest, have had to contend with severe pressures to open up more land and make it available to a land-hungry population. They have been very successful over the past decade or so in maintaining conservationist policies in Bali, and are even making some headway in achieving an expansion of the total area under forest. This paper will review some of the salient features of contemporary forestry policy in the island, and will attempt an assessment of its success.

THE PHYSICAL ENVIRONMENT OF BALI

Situated to the east of Java, Bali covers an area of approximately 5,600 km^2. Running east-west through the island is a core complex of young volcanic mountains, flanked to the north and south by sedimentary deposits derived chiefly from the volcanic complex. The volcanic core may be divided into three distinct sections. It is fairly continuous in the western part of the island at a moderate elevation of about 1,000 metres. In the central portion of the island this continuous belt of elevated upland gives way to two distinct calderas, Bratan in the west and Batur to the east. These calderas have rim elevations of 1,500 metres or higher. Each contains one or more crater lakes, as well as some level land on the floor of the caldera. To the east the volcanic core is represented by two very distinct peaks of volcanic origin, Gunung Agung, the island's highest point at a little over 3,100 metres in altitude, and Gunung Seraya, an isolated peak forming the extreme eastern end of the island.

Soil conditions are quite different in each of the three sections. In the west the volcanics tend to be impermeable lavas and breccias (Marinelli & Tazieff, 1968), and as a result run-off is rapid. Soil development in this part of the mountain region is limited, and consequently there has never been sharp competition for land for agricultural activities. In the central portion of the island the two calderas have attracted intense agricultural settlement. The calderas are made up partly of lavas, but more generally of ignimbrites. These have provided the parent material for fertile easily worked soils, and have also provided permeability which has facilitated water supply and management not only within the calderas themselves, but throughout the lowlands to the north and to the south of the calderas (Marinelli & Tazieff, 1968; Rampino & Self, in press). The eastern third of the mountain range is dominated by Gunung Agung, a composite cone which last erupted in 1963. The lowlands both to the south and the north are high-risk areas, not only in the event of eruptions, but also in response to the threat of continued fluvial redeposition of volcanic debris (Sandy, 1964).

The island has a tropical climate, with a rainy season between November and April and a dry season for the remainder of the year. Rainfall amounts tend to be somewhat higher on the southern coast of the island than on the northern side – 1,700 mm as opposed to a little over 1,000 mm – and the dry season is pronounced. In the mountains of the interior the dry season virtually disappears, and rainfall is also noticeably higher, reaching 3,000 mm in places (Schmidt & Ferguson, 1952). Since the permeable rocks of the central portion of the mountain chain act as aquifers delivering water through springs to the lower agricultural regions, it is vitally important that good hydrological management practices prevail, and that in particular a good vegetation cover be maintained throughout the catchment areas.

FOREST RESERVES OF BALI

Forest reserves were first demarcated in 1927 by the Dutch administration, and were established

for the purpose of protecting watersheds. It was believed that such measures were necessary to avoid encroachment by cultivators and wood gatherers in the catchment areas. It was also recognized that although demarcation of reserves was an important first step, it was not of itself sufficient. Deterioration of the forest cover had been going on for a long time, and it was considered necessary to replant some of the areas designated as reserves. This was especially true of areas close to regions of active vulcanism. The eruption of Gunung Batur in 1917 caused widespread damage to forest areas in the vicinity, and it was only by the late 1920s that the severity of the problem was recognized and replanting programmes were begun (de Voogd, 1935).

Table 1 and Figure 1 list the distribution of forest reserves in Bali. They cover only a small portion of the central mountains with the important catchment areas. By 1927, when reserve designation was begun, settlers had already made substantial inroads in the forested hillslopes, leaving only limited areas available for inclusion as forest reserve. To the east, on the slopes of Gunung Agung itself, settlement was discouraged because of the danger of volcanic activity, although villages crowded as close as possible to the foot of the mountain. A substantial area of forest reserve was demarcated in this zone, but the vegetation cover was sparse, and the quality of the forest low. In the western mountainous part of the island where very little settlement had ever taken place, it was possible for the Dutch to designate a large area of reserve, and this remains the most extensive forest zone in the island at the present time. Only minor changes to the area of the forest reserves have been made since their initial establishment.

The quality of the forest within these reserves varies markedly. In the reserves of the central and the western mountain zones the tree cover is usually

TABLE 1. AREAS OF FOREST RESERVE IN BALI, 1980

NUMBER OF RESERVE	NAME OF RESERVE	AREA (ha)
1	Puncak Landep	590
2	Gunung Mungsu	1,134
3	Gunung Silangjana	415
4	Gunung Batukau	15,390
5	Munduk Pengajaran	613
6	Gunung Penulisan	5,401
7	Gunung Batur-Payang	2,640
8	Gunung Abang-Agung	14,068
9	Gunung Seraya	1,111
10	Prapat Benoa	1,392
11	Yeh Ayah	492
12	Yeh Leh-Yeh Lebah	4,029
13	Gunung Sangiang	48,830
14	Gunung Bakungan	1,000
15	Kintamani	194
16	Prapatagung	4,600
17	Banyuwedang	9,400
18	Candikusuma	13,700
19	Sangeh	10
	Total	125,009

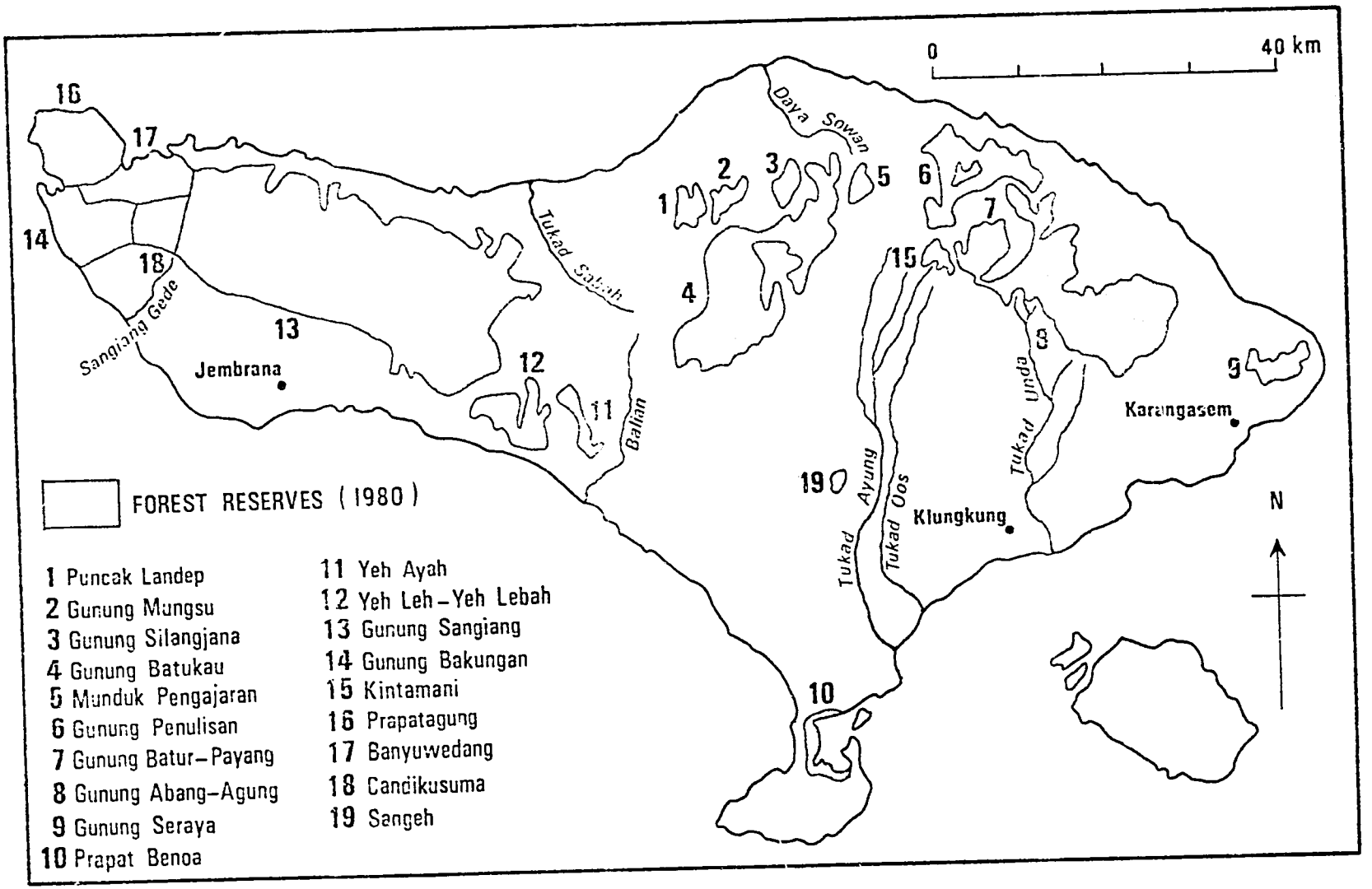

Fig. 1. Distribution of forest reserves in Bali.

complete, and the forest community stable. Such high quality forest accounts for 84 per cent of the area included in these forest reserves. The bulk of the remaining sixteen per cent is accounted for by the Gunung Abang-Agung reserve where, especially since the eruption of 1963, forest cover is very sparse.

A number of different types of forest may be differentiated.

(1) *Montane forest.* Most of the forest areas at or above 1,000 m in altitude are in this category. It includes the reserves at Gunung Batukau, Pengajaran, Penulisan and Gunung Batur. Because of their altitude these reserves all have precipitation in excess of 2,500 mm annually. Common tree species include *Podocarpus imbricata, Casuarina junghuhniana, Crypteronia paniculata, Eugenia polyantha, Thanglitia glauca, Pometia* sp., *Ficus* spp., *Laportea stimulans* and *Disoxylum* sp. The Dutch carried out several plantation programmes in these reserves with species such as *Altingia excelsa, Bischofia javanica, Eugenia polyantha, Magnolia Blumei, Agathis lorantifolia, Pinus merkusii* and *Michelia champaca.*

(2) *Monsoon forest.* This type of forest is found where precipitation is lower than the previous type, and where, in addition, there is a more pronounced dry season. It occurs at altitudes up to about 1,000 m, especially on the northern side of the island. The northern parts of Gunung Sangiang, Gunung Bakungan, Prapatagung and Banyuwedang have this forest. Species commonly ecountered include *Lagerstroemia speciosa, Cypteronia paniculata, Pterospermum javanicum, Planchonia valida, Palaquium* sp., *Duabanga moluccana, Dysoxylum* spp., *Calamus* spp., *Manilkara kauki, Schoutenia ovata, Vitex pubescens, Grewia koordersiana, Kleinhovia hospita, Zizyphus mauritiana, Sleichera oleosa, Zanthoxylum rhetsa* and *Phidia indica.* The reserves at Banyuwedang and Candikusuma contain small areas of savanna. *Imperata cylindrica* constitutes the grass component, and among the tree species present are *Borassus flabellifer* and *Acacia leucophloea.*

These monsoon forests contain quite extensive areas replanted to species with some commercial potential. Some 6,150 hectares are devoted to plantations, and the following species are frequently encountered: *Tectona grandis, Manilkara kauki* (a tree much used by the wood-carvers of Bali), *Melaleuca leucadendron,* (from which a pungent oil is extracted), *Dalbergia latifolia, Wrightia calycina, Diospyros celebica, Leucaena glauca, Acacia auriculiformis* and the legendary *Santalum album.*

(3) *Coastal forest.* Coastal forest constitutes portions of several of the western forest reserves, such as Prapatagung and Banyuwedang. Coastal forest is also found in Prapat Benoa, the only remaining forest reserve in the southern part of the island. Traditionally these areas of coastal forest have been heavily exploited by the villagers living nearby, and it is probable that forests were formerly much more extensive than now. Common species include *Rhizophora apiculata, Ceriops tagal, Bruguiera parvifola.* In the coastal sections of Banyuwedang these same species occur, along with *Avicennia marina.*

It is possible to regard several of the smaller reserves in Buleleng on the northern slopes of the central mountain chain as transitional between montane and monsoonal forests. For example the reserves at Puncak Landep, Gunung Mungsu and Gunung Silangjana with altitudes of approximately 1,000 m, have a higher total precipitation than the monsoonal forest areas lower down, but they do not have such a pronounced dry season. The village of Munduk, located close by at an altitude of 730 m, reports an average 128 days of rain per year and a mean annual total in the region of 2,400 mm, compared to 50 days and about 1,000 mm close to the northern coast. Various species of *Dysoxylum, Pometia, Laplacea, Eugenia, Aglaia, Grewia, Ficus* and *Palaquium* are frequent. The *Podocarpus* characteristic of the higher altitude forests, is, however, notably absent.

The small size of these reserves, coupled with their proximity to agricultural settlements devoted to cash crops such as coffee and cloves, has rendered them vulnerable to cutting. Villagers have tended to cut not only whatever remains of the natural forest, but have also done extensive damage to new plantings. The Dutch endeavoured to start plantations of *Dalbergia latifolia, Aleurites moluccana, Adenanthera microsperma* and *Cassia siamea* at Puncak Landep; *Dysoxylum, Bischofia javanica*

and *Pometia* sp. at Munduk Pengajaran; and *Cryptеronia paniculata, Casuarina* sp., *Junghuhniana* sp., *Pinus, Eucalyptus urophylla* and *Shima noronhai* at Gunung Penulisan. In general, all these attempts were failures due to interference by nearby inhabitants. In some cases, as in Silangjana in 1964, man-made fires have caused extensive damage, necessitating further work on replanting.

Natural disasters have also taken their toll in some of the other reserves. Following the eruptions of Gunung Agung in 1963 severe damage was done to the reserves at Gunung Abang-Agung and at Gunung Seraya. Destruction in these areas was almost total.

FORESTRY POLICY

In pre-colonial times effective control over unoccupied lands was exercised by the rulers. Permission was needed before a group of settlers could move into an empty area to establish a new village, and although there is little evidence to suggest that the rulers had any particular management principles in mind for the use of the forested areas, indiscriminate occupance of important watershed control areas was prevented.

Under the Dutch forestry policy became the responsibility of the government. The reserves numbered 1 through 14 in Table 1 were proclaimed in May 1927. Kintamani and Prapatagung were added during the 1930s, and Banyuwedang and Candikusuma in the next decade. Since then changes have been minor. A few areas have been excised from the reserves, usually under pressure from development interests. A small reserve at Sangeh was added during the 1970s. This area had long been considered a protected area, having been declared a 'natuurmonument' by the Dutch in 1919 on account of its fauna and flora. *Dipterocarpus trinerfis* is found in this area.

As well as demarcating reserves the Dutch initiated a series of improvement measures. Replanting was carried out in several of the reserves, especially those at higher elevations in the mountain zone. At Bedugul, in Bratan caldera, an arboretum was established, forerunner of the present-day 129 hectare Kebun Raya.

As early as the 1930s, however, it became obvious that concentration of efforts on the reserves alone would not be sufficient to control damage due to forest depletion. Many areas outside the reserves were vulnerable to soil erosion, and hydrological management of Bali's water resources required forest protection on a wider basis. A policy was therefore adopted of seeking to identify critical erosion-prone localities outside the reserves where plantation should take place, even if only on a very small scale, to provide ecological safeguards. It was hoped in addition that nearby villagers could be educated to the point of understanding the need for such plantations, and persuaded to manage them successfully as sources of at least a limited supply of firewood.

Dutch policies were continued into the independence period. But by the late 1960s and the 1970s it was evident that some revision of the policy was necessary. Bali's population continued to grow, exerting pressure on the forestry reserves. Pressures were also increasing for timber cutting permits. In addition, substantial damage had been done to forest reserves by the eruptions of 1963, and little had been done in the way of rehabilitation.

A series of workshops was held in the late 1960s and 1970s to consider future policy options. One of the first recommendations adopted was to ban any further commercial cutting in Balinese forests, and this measure was promulgated by the Governor in May 1970. In 1977, coincident with the promulgation of a Forestry Law by the central government in Jakarta (Kartawinata, 1981) three principles were enunciated to constitute the base of future forestry policy in Bali:

(1) Forestry should serve agriculture by seeking to protect the soil, and by conserving the hydrologic quality of watersheds.

(2) Forestry should assist in the development of tourism, domestic and international, by providing a series of nature reserves accessible to visitors.

(3) Forestry should endeavour to ensure an adequate supply of forest products for all of the island's needs, including the specialized needs of the carving and craft industries expected to grow

under the influence of an increasing tourist industry.

From these principles there emerged a set of working policies summarized as follows:

(1) Policies within the forest reserves. These entail establishing a forestry 'zoning' plan, designating different areas for different functions. For example, some reserves or parts of reserves will be classified as tourist zones, others as nature reserves, others as watershed protection zones. Different management programmes will be prepared for each functional type. Replanting will also continue on a substantial scale.

(2) Policies outside forest reserves. Outside of the forest reserves areas would be identified as critical in terms of risk of erosion. Areas so identified would be the object of local replanting.

We shall review various aspects of these forestry policies in more detail, and examine their implementation in several of the major forest zones in the island.

FOREST ZONING *(Penatagunaan hutan)*

The notion of forest zoning is not new to Bali, but present plans involve a more thorough application of policy than previously. During the Dutch period the main functional zones recognized were 'productive forest', in which cutting for commercial purposes was allowed, and 'conservation areas', subdivided into 'normal' and 'strict' categories. Permits were issued for felling in the 'productive forest' zones either to individuals or companies, and resulting revenue considerations were important in determining management decisions. Most of the replanting work done in the island took place in these zones and was designed to maintain their productive level. A small amount of felling was permitted in the 'normal conservation' areas, but commercial and revenue considerations were not paramount. In the 'strict conservation areas' felling was not permitted at all. The areas covered by the different categories are indicated in Table 2.

The categories adopted as a result of the decisions of 1977 are as follows:

(1) Productive forest *(hutan produksi)*. Commercial exploitation of forest resources, planted or natural, can be envisaged in these areas. At the present time, however, very few permits are being issued.

(2) Conservation forest *(hutan lindung)*. The primary purposes served by forest in this category are to protect watersheds, prevent soil erosion, help maintain soil fertility and ensure a strong flow of irrigation water in rivers and springs. Felling and planting in these areas will be determined by conservation requirements, and will be carried out by the Forest Service. Access to these areas will not be forbidden, but it will not be facilitated either.

(3) Wildlife or nature preserve *(hutan suaka alam)*. Paramount considerations in these zones are those of strict conservation and production. Two subtypes are recognized: (a) General preserve *(suaka margasatwa)* is an area where all kinds of natural vegetation and fauna are considered protected. (b) Special preserve *(cagar alam)*, where particular species of plants or animals are considered threatened and of such

TABLE 2. FOREST FUNCTIONAL AREAS IN BALI PRIOR TO 1970

TYPE	AREA (ha)	REMARKS
Productive forest	29,092	Consisted of all of the following reserves: Prapat Benoa, Prapatagung, Banyuwedang, Candikusuma
Conservation forest		
(a) normal	35,907	Areas include a total of 22,179 hectares of
(b) strict	60,000	nature preserve
Total	124,999	

importance as to require specific protection. Access is not denied to wildlife preserves, but again it is not greatly encouraged.

(4) Tourist or recreational areas *(hutan wisata).* These are forest areas which are meant to serve as attractions to visitors. They are accordingly to be rendered as accessible as conditions will permit. Two subtypes are again recognized: (a) Recreational Gardens *(taman wisata).* These are areas which have been designed as parks or gardens, and natural vegetation communities are largely altered. The Kebun Raya already referred to falls into this category. It is suggested that these areas be chosen because of their scenic qualities. (b) Animal Parks *(taman buru).* These are areas which contain an abundance of wildlife, and where various forms of recreational activity, including hunting, could be envisaged.

In general, the productive zones and the tourist or recreational zones may be considered to be economically functional. The remaining zones are intended to protect certain elements in the local ecology, and are therefore productive indirectly through their beneficial effects on other parts of the economy.

By the late 1970s work had been completed on boundary delimitation in two of the major forest zones. These were the Batukau reserve in the central highlands (Direktorat Jenderal Kehutanan, 1978) and the several contiguous reserves which make up the forest zone in the western portion of the island: Gunung Sangiang, Gunung Bakungan, Prapatagung, Bangyuwedang and Candikusuma (Direktorat Jenderal Kehutanan, 1979).

Figure 2 shows the boundary delimitation adopted for the reserve at Batukau and Table 3 summarizes the areas classified in each type. The Batukau reserve extends across the Bratan caldera. Inside the caldera is a series of three lakes – Danau Tamblingan, Danau Buyan and Danau Bratan. Preservation of water quality in these lakes is a high priority, and is one of the main justifications for establishing a reserve in the caldera. For generations there have been farmers cultivating crops in the caldera, but beginning around 1941, more and more settlers were encouraged to move to the area. Expansion of this settlement, which is now well served by one of the main trans-island highways, led to pressure on the forests, particularly for the provision of firewood. Finally, heightened concern for forest preservation in the Bratan caldera was expressed in the 1970s when it became clear that one of the main species represented in the natural forest at that altitude, the *Podocarpus imbricatus,* was not reproducing satisfactorily.

The Forest Service has chosen to establish recreational forest all along the northern and northeastern parts of the caldera rim, and down on to the floor

TABLE 3. AREAS OF FUNCTIONAL ZONES IN FOREST RESERVES OF BATUKAU AND WESTERN BALI

TYPE OF ZONES	AREAS OF FUNCTIONAL ZONES (ha)	
	Batukau (1978)	Western Bali 1979
Conservation	12,637.3	42,743.5
Tourist-recreational areas	1,054.5	6,970.0
Nature preserves	1,569.0	19,365.0
Arboretum	129.2	–
Productive forest	–	8,050.0
Total	15,390.0	77,128.5

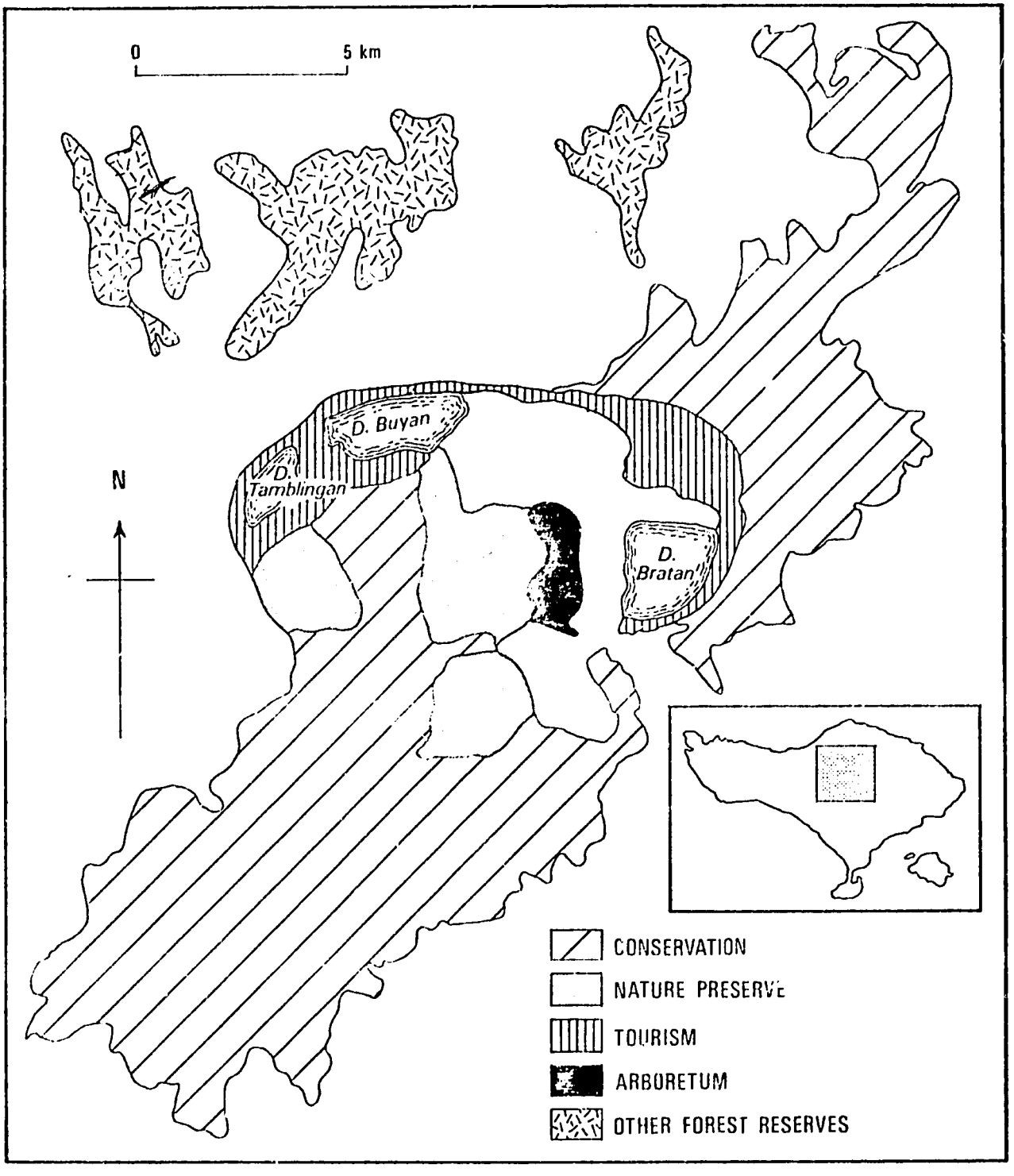

Fig. 2. Forest zoning in the Gunung Batukau Forest Reserve, 1978.

of the caldera. The terrain on the caldera walls is extremely steep and cannot be used for agriculture. In the caldera the arboretum started by the Dutch has been maintained. Much of the remainder of the reserve has been classified as 'conservation forest', with the exception of the summits of three volcanic cones where the more stringent nature preserve, or *cagar alam* classification has been adopted. These are *Podocarpus* zones.

Information concerning the delimitation of functional zones in the western forest reserves is contained in Figure 3 and Table 3. Unlike the previous case, there is little threat to the forest in this part of the island from the encroachment of agricultural settlement. A very large area has therefore been designated as 'conservation', occupying the greater part of the inaccessible reaches of the mountain chain. 'Nature preserves' *(cagar alam)* and 'wildlife preserves' *(suaka margasatwa)* have been established in certain areas towards the west. The uplifted coral limestones of Prapatagung, for example, have given rise to particular soil conditions, and this has been adjudged sufficiently unique to merit the status of a preserve. In Banyuwedang, the savanna areas are also unique for Bali. Since there has been some discussion about the possibility of establishing a tourist resort in the vicinity of Prapatagung, it was thought desirable to delimit some recreational or tourist areas. Understandably most such areas were established along the coastal beaches. It is interesting to note, however, that in addition some tourist areas have been designated in the lower foothills, between the coastal settlement zones and the main bulk of the mountain conservation forest zone. Present tourist patterns do not suggest that such areas would attract very much attention.

Considerable areas of 'productive forest' have been delimited in the western forest reserve. The area is well suited to the growing of certain types of commercial timbers, and some plantation zones have already been established. These include plantations of teak *(Tectona grandis)*, which are as yet still young and *Melaleuca leucadendron*, which is currently being harvested for the production of its highly aromatic oil.

REPLANTING IN BALI *(reboisasi)*

The policy of replanting in the forest reserves, initiated by the Dutch, has been continued by the Indonesian forestry authorities (Direktorat Reboisasi dan Rehabilitasi, 1980a, b). It has been estimated that during the period covered by the three five-year plans, REPELITA I, REPELITA II, and REPELITA III (1969–1984) some 24,000 hectares will have been replanted. Where the data show the regional breakdown (for the first two five-year plans) it is evident that replanting was concentrated in a number of clearly defined areas. East Bali and Karangasem, the areas affected by the 1963 eruptions, had large amounts of replanting. Other important areas of replanting were in the west, in Buleleng and Jembrana, where commercial planting of monsoon forest is being tried. Table 4 shows the total areas under replantation maintenance as of 1979 in the western part of the island, and indicates the areas devoted to a number of selected species.

In the Gunung Batukau reserve some 700 hectares were replanted to *Altingia excelsa, Magnolia Blumei, Michelia champaca, Bischofia javanica, Eugenia polyantha, Crypteronia paniculata* and the exotic *Pinus merkusii*. At Prapat Benoa replanting has followed very closely the kinds of species previously growing in the reserve: 242 hectares have been planted with *Ceriops tagal, (Ceriops candolleana), Rhizophora conjugata, Bruguiera gymnorhiza* and *Calophyllum inophyllum*. It is believed that it will be possible to harvest these trees on the basis of an eight to ten year cycle.

In the western reserve a substantial amount of replanting has been carried out. A plan was prepared in 1958 which envisaged planting 2,000 hectares of *Manilkara kauki* in Prapatagung and 3,000 hectares of *Tectona grandis* in Candikusuma. As Table 4 shows, the eventual pattern departed somewhat from these intentions, but a considerable area was in fact covered.

PLANTING OUTSIDE FOREST RESERVE AREAS

The Forestry Department has been active in encouraging 'spot plantations' *(penghijauan)* in a large number of localities outside the actual re-

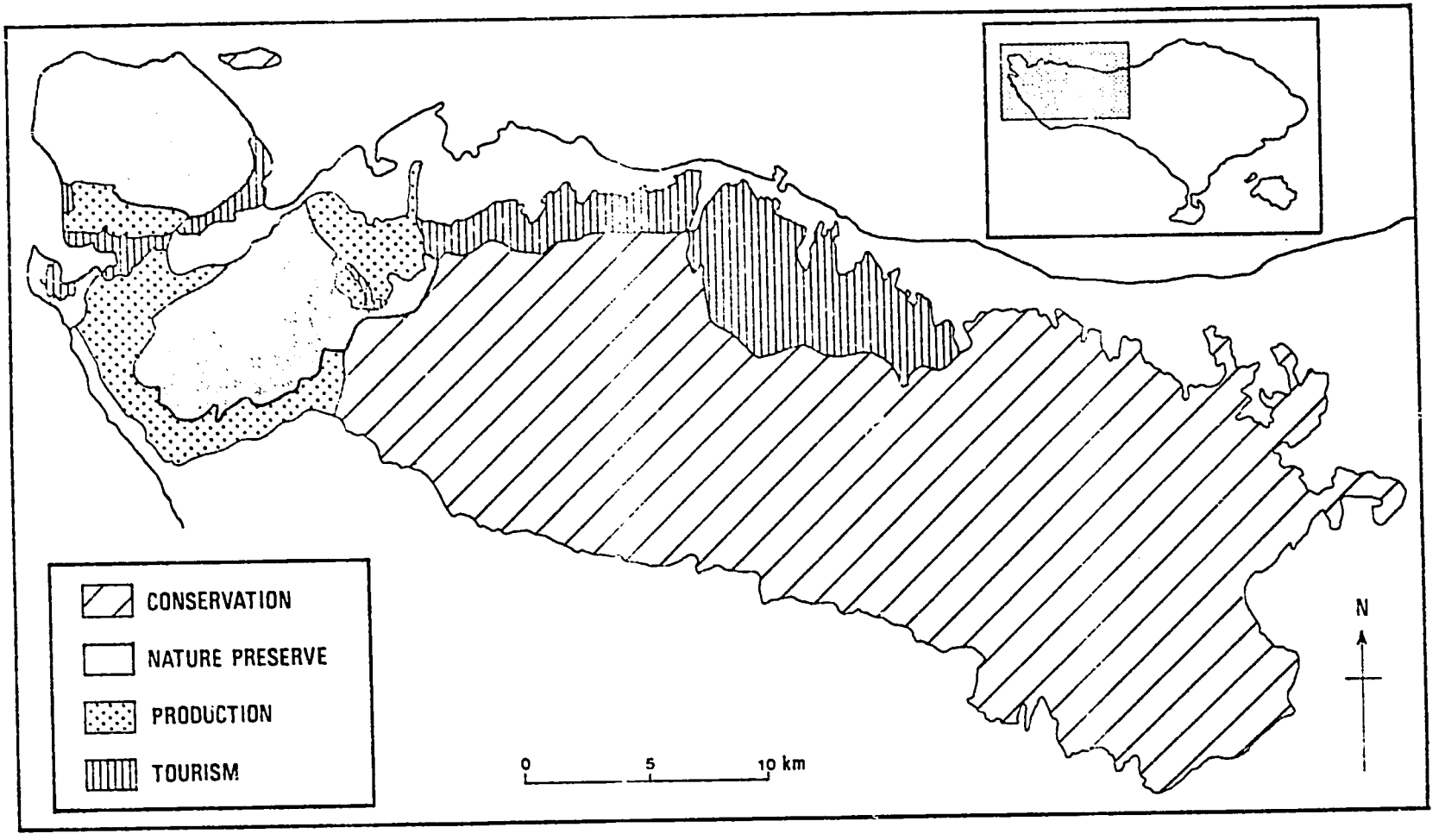

Fig. 3. Forest zoning in the western forest reserves of Bali, 1979 (Gunung Sangiang, Gunung Bakungan, Prapatagung, Banyuwedang, and Candikusuma.

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TABLE 4. REPLANTING AREAS IN WEST BALI, 1979

TREE SPECIES	AREA (ha)
Manilkara kauki	279.2
Tectona grandis	1,224.9
Melalauca leucadendron	872.0
Others*	3,774.4
Total	6,150.5

* Includes *Dalbergia, Acacia, Santalum, Wrightia* and *Zanthoxylum.*

serves. These spot plantations consist of small-scale operations carried out on land belonging to private individuals. The usual justification is that they are needed to protect some particularly vulnerable place and to guard against soil erosion. The Forestry Department provides planting material and supervision; the land and labour are usually contributed by the land owner or by the villagers as a group.

The concept is by no means new in Bali. Traditionally the villagers have been greatly concerned about the beauty of their environment and trees have always played a role in this. Not only are certain types of tree sacred – notably the waringin or banyan – and required to be protected; the forest also in general is respected since it occupies the mountains which are the home of the gods. The Dutch introduced two measures during their administration to reinforce such traditional preoccupations. The first was the 'Koffirooikeur' of February 1936, the second the 'Ravijnsbeschermings verordening van Bali' of December 1939.

The 'Koffirooikeur' was introduced as part of a policy of encouraging the establishment of coffee gardens for cash cultivation on the middle-level slopes of the central mountain ranges. The dadap, or *Erythrina,* was used to provide the necessary shade, and it had the added advantage of being a nitrogen fixing tree. The combination of coffee bushes and shade trees at least partially substituted the pre-existing forest environment. Under this scheme it was hoped to bring the area under coffee to 26,000 hectares.

The 'Ravijnsbeschermings verordening' enabled critical land areas in ravines to be taken off tax registers, and made it possible for the Forestry Department to initiate protective planting. Ownership remained vested with the villagers, but the authorities gained control over its use.

Data on these small scale plantations is difficult to obtain with any degree of accuracy. By 1968 spot plantations were said to cover 3,020 hectares; in addition some 19,000 hectares of land had been designated for ravine protection, though not necessarily planted.

Figure 4 shows the main areas of priority in the early 1970s. Areas of immediate concern lay, for example, along the northern coast of the island, between the existing forest reserve and the coastal strip occupied by the villages. Some the villagers in this area make a habit of burning off vegetation on the slopes in order to provoke some soil erosion and have the soil washed down on to their fields below. Another important area is that around Gunung Agung, a region affected severely by the eruption of 1963. Other areas of extreme urgency include much of the southern peninsula known as Bukit, as well as the nearby island of Penida. It appears that in the future the whole of the eastern part of Bali will be considered a danger zone, as will be the entire limestone area in the south, and the strip of land in Jembrana in the western part of the island lying just to the south of the main forest reserves.

THE ENVIRONMENTAL IMPACT OF FORESTRY POLICY IN BALI

A sound evaluation of the overall effectiveness of forestry policy in terms of its environmental impact is difficult to arrive at. There is very little good data on aspects such as rates of erosion, which would enable us to compare well-forested with poorly-forested catchments. This problem is recognized in the series of studies carried out during the period 1975–81 under the auspices of the Directorate General of Water Resources Development for the purpose of designing a master plan for the management of water in Bali. Although some observations were made to determine erosion rates

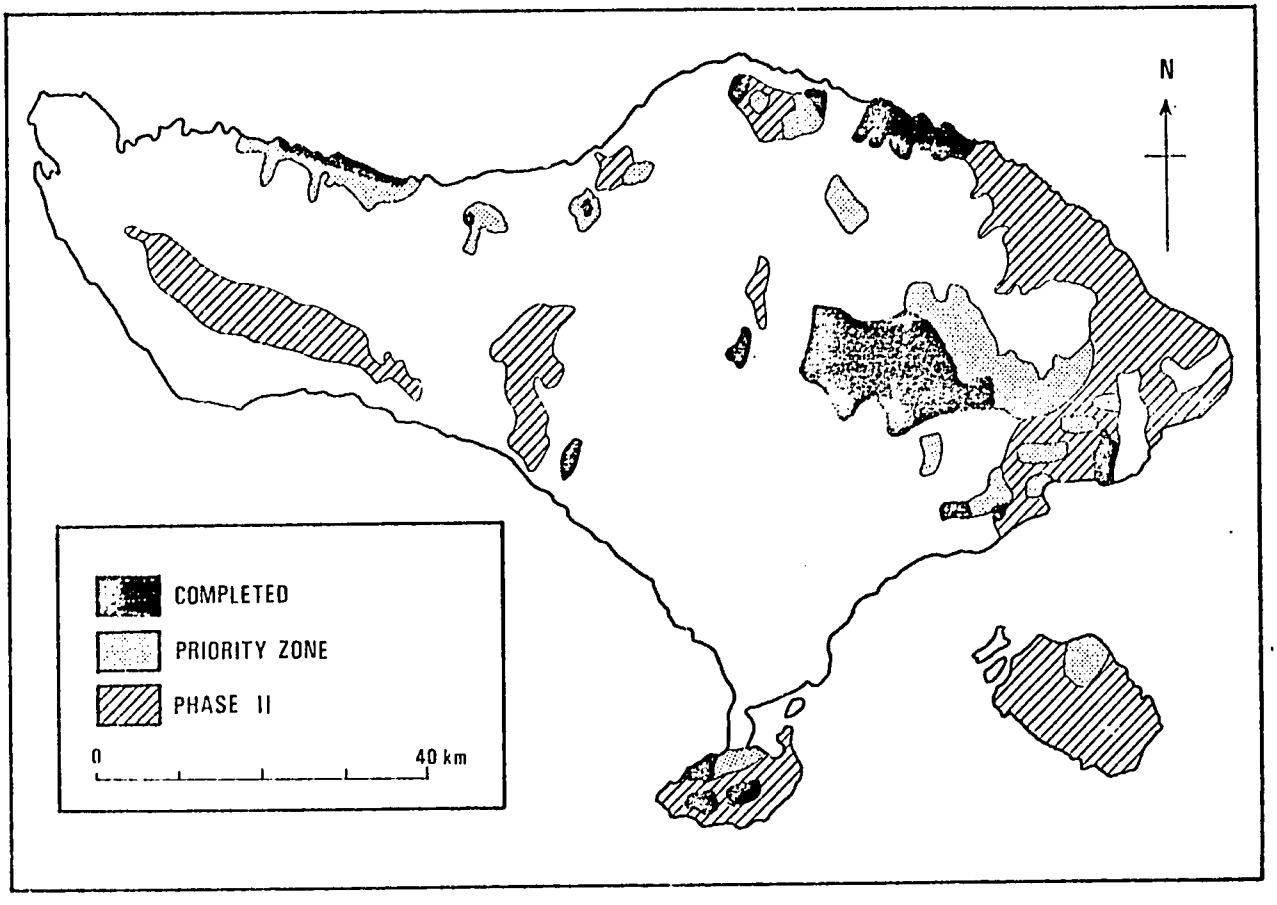

Fig. 4. Priority planting zones as of the early 1970s.

they were rudimentary, and the conclusions which may be drawn from them are very tentative to say the least. We will review some of the findings concerning two aspects of this work: sediment transport by rivers, and overall river basin soil loss.

Some one hundred and sixty rivers have been recognized in Bali, of which only two have catchment areas greater than 200 km^2 in size: Tukad Ayung which flows from north to south just to the west of Ubud, and Tukad Unda draining the south flank of Gunung Agung and reaching the sea close to Klungkung. Twenty four rivers have catchment areas in excess of 50 km^2. Despite the differences in rainfall in different parts of the island, the rivers all tend to exhibit certain features in common. They have steep gradients especially in their upper reaches; their courses are often deeply entrenched except on the lower plains; and their flow regimes are profoundly affected by short, heavy downpours which may occur in any part of their catchments. Those in the eastern part of the island contain areas within their catchments much affected by lahar from Gunung Agung, and consequently, these rivers provide acute problems of water management.

Sediment samples have been collected (Directorate General of Water Resources, 1982) for six streams from different parts of the island (Table 5). Sediment measurements were taken in these rivers for a period of two months in 1978, and estimates made of the total sediment transported on the basis of total flow in the years 1976, 1977, and 1978. The results are shown in Table 5. They have

TABLE 5. CHARACTERISTICS OF SIX PERENNIAL RIVERS SAMPLED FOR SEDIMENT ANALYSIS

Name of River	Location	Catchment Area (km^2)	Length (km)	Vegetation Covering	Annual Suspended Load (m^3)	Suspended Load Per Unit Area ($m^3\ km^{-2}\ yr^{-1}$)
Balian	SW	156	25.3	good	439,681	2,898
Oos	SE	107	45.5	fair	13,067	122
Unda	SE	227	20.0	poor	19,181	93
Daya Sowan	N	107	23.0	good	35,227	423
Sabah	NW	129	28.7	fair	10,717	123
Sangiang Gede	W	86	25.0	good	1,899	43

Source: Directorate General of Water Resources, 1982, table 4/2.

to be regarded with extreme caution, in the light of the unsatisfactory conditions under which the data were obtained.

There is no evident explanation for the high figure associated with the Balian but the sediment yield from Sangiang Gede, the river with the most completely forested catchment, is the lowest. Next lowest was the sediment yield from the Unda, a river of the lahar zone of Gunung Agung. Although rivers in the lahar zone have created considerable problems since 1963 as a result of sediment movement, it is believed that these basins are now somewhat stabilized, partly as a result of remedial measures taken, and partly as a result of the passage of time. Somewhat high figures were recorded for those rivers which had varying but significant proportions of their upper catchments under cultivation. In general these findings offer some testimony in support of the proposition that the forested areas are zones of relatively low erosion rates.

Another piece of evidence concerning the effectiveness of the forest cover in conserving watersheds may be gained from the analysis in the same report of erosion rates. In this instance an attempt was made to estimate the total soil loss from several distinct areas with differing vegetation characteristics. The analysis was carried out in this instance for the watershed of the Unda, and involved estimation of a series of indices: rainfall erosivity index, soil erodibility factor, length factor, slope factor, conservation practice factor, land use factor. Estimates of total erosion were then made for different segments of the watershed, and these are presented in Table 6. It will be noted that these estimates suggest that irrigation agriculture was not liable to cause heavy soil erosion, but dryland agriculture normally does. Generally dryland agriculture is carried on in less suitable areas where irrigation is not possible. Tree crop agriculture and forestry, the latter almost always on very difficult terrain, generated lower rates of soil loss. Bare land had a very high figure for soil loss, as did land covered by former lahar flows.

CONCLUSIONS

Bali's forestry policy at the present time is predominantly conservationist. Although a variety of different uses and functions are envisaged for forest land, the over-riding priority is protection. Other uses are quite readily superseded if the need arises. Management policies reflect this general orientation.

Agricultural and hydrological planning are proceeding on the assumption that forestry policy will continue to serve the needs of watershed control and protection. Continual upgrading of small to medium scale irrigation projects is an important component of agricultural development, and these schemes are invariably dependent on reliable runoff and underground flow of water.

The major problems arise from the fact that the proportion of the island devoted to forest, high though it may be by some standards, is not high

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TABLE 6. EROSION RATES FOR DIFFERENT LAND-USE ELEMENTS IN THE UNDA RIVER CATCHMENT

LAND USE	SLOPE CLASS (%)	AREA (ha)	EROSION RATES	
			tonnes/yr	tonnes/ha/yr
Existing irrigation areas	0 – 5	39	3	0.1
	5 – 8	2,091	423	0.2
	8 – 20	1,568	1,036	0.7
	10 – 30	138	138	1.0
Dryland, annual cropping	5 – 8	2,535	75,911	30.0
	8 – 20	3,260	285,112	87.0
	20 – 30	2,023	859,096	425.0
	30 – 40	811	1,172,972	1,446.0
	over 40	1,009	1,270,549	1,259.0
Dryland, perennial cropping	5 – 8	91	182	2.0
	8 – 20	138	414	3.0
	20 – 30	353	5,648	16.0
Forest	8 – 20	56	168	3.0
	20 – 30	168	2,688	16.0
	30 – 40	–	–	–
	over 40	3,042	317,688	104.0
Bare land	8 – 20	56	38,528	688.0
	20 – 30	869	714,330	822.0
	30 – 40	208	274,294	1,319.0
	over 40	1,718	890,746	518.0
Lahar areas	0 – 5	254	986	4.0
	5 – 8	348	45,585	131.0
	8 – 20	322	207,581	625.0
Summit of Agung	over 40	688	3,099,440	4,505.0

Source: Directorate General of Water Resources 1982, table 5/6.

enough. It would be extremely difficult to increase the amount of land in forest reserves, since to do so would entail displacing farmers from their land. A second problem relates to the disposition of forest lands. The reserves are certainly adequate in the western part of the island, where land still uninhabited was available in the 1920s. But in the central zone (agriculturally the most desirable zone) and in the east (where eruption damage is greatest) there are numerous watersheds without forest protection.

In the light of this the policy of encouraging tree planting outside the reserves is significant. Not only does it enable locally critical points to be identified, it also seeks to involve the villagers in the process of conservation and replanting, thus inculcating attitudes favourable to future conservation measures. Undoubtedly a wide appreciation of the importance of forest zone is the best guarantee that they will continue to be respected.

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