Research Needs and Applications to Reduce Erosion and Sedimentation in Tropical Steeplands (Proceedings of the Fiji Symposium, June 1990): IAHS-AISH Publ. No.192, 1990.

Erosion and sedimentation in Fiji—An overview

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ABSTRACT Soil erosion and sedimentation are major problems in Fiji. The steepland topography and highly erosive rainfall contribute to high natural rates of erosion. Over the past 30-50 years a substantial area of sloping land has been brought into agricultural production. This extension of agriculture and increased logging of rainforests has caused considerable erosion but there is a lack of quantitative information. The effects of erosion include land degradation and decreased productivity, sediment deposition in rivers with subsequent increase in flooding, and damage to coastal ecosystems by transported sediment. Legislation exists for the control of land use and the encouragement of conservation but it has not been widely applied. The land tenure system, increasing demands for cash income and the lack of strong political commitment to conservation contribute to the continuing problems of soil erosion and sedimentation.

INTRODUCTION

Fiji consists of some 320 islands having a total area of about 18,300 km^2 lying between 15 and 22^o S latitude and 177^o W and 175^o E longitude (See Figure 1). Approximately 100 of these islands are permanently inhabited. The usual vision of South Sea islands is one of sparkling beaches, clear water and pristine forests. While some such remain, other areas suffer environmental degradation including soil erosion and sedimentation. In this paper, we present background on the physical features of the Fiji islands, a brief overview of the agriculture systems and an assessment of current erosion including rates of erosion, economic implications, legislation, social altitudes and land management problems.

PHYSICAL FEATURES OF THE FIJI ISLANDS

(a) Climate

The climate of the Fiji Islands is humid tropical. The country can be divided into 2 major rainfall zones. The northern and western lowland areas of the larger islands represent a rain shadow zone (known locally as the 'dry' zone) where rainfall and

FIGURE 1 The Fiji Islands

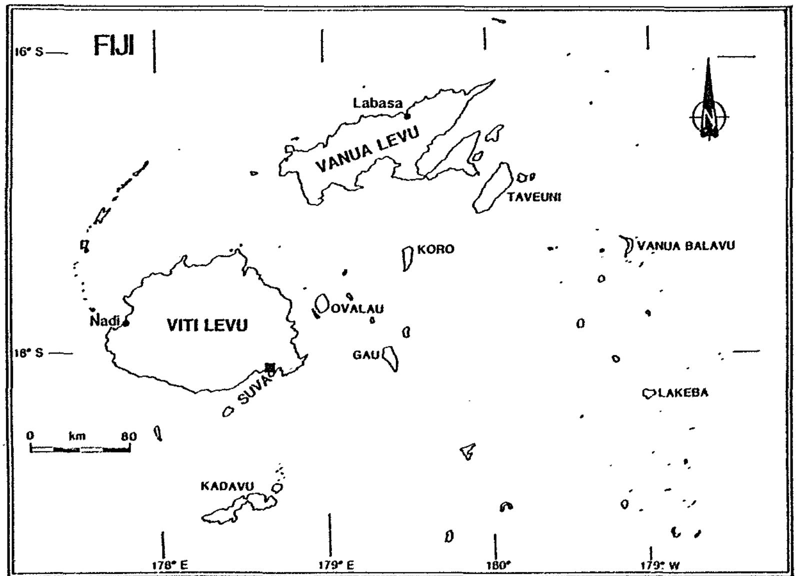

TABLE 1 Climatic data for the Fiji Islands*

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Av. Rainfall (mm)													
Suva	**324**	**315**	**383**	**385**	**254**	**172**	**147**	**140**	**209**	**220**	**266**	**272**	**3087**
Nadi	**293**	**293**	**358**	**185**	**84**	**71**	**48**	**61**	**87**	**95**	**142**	**175**	**1892**
Labasa	**400**	**397**	**422**	**279**	**98**	**72**	**57**	**57**	**87**	**149**	**204**	**223**	**2445**
Max. Rainfall (mm)													
Suva	**641**	**832**	**799**	**960**	**918**	**419**	**408**	**523**	**481**	**900**	**773**	**571**	
Nadi	**598**	**606**	**918**	**406**	**206**	**266**	**190**	**286**	**279**	**342**	**461**	**398**	
Labasa	**835**	**1068**	**846**	**645**	**231**	**250**	**214**	**287**	**250**	**491**	**675**	**564**	
Max. Rainfall in 1 day (mm)													
Suva	**293**	**282**	**196**	**308**	**281**	**188**	**234**	**186**	**214**	**346**	**347**	**195**	
Nadi	**236**	**217**	**242**	**173**	**141**	**103**	**122**	**171**	**125**	**269**	**119**	**272**	
Labasa	**218**	**245**	**180**	**141**	**76**	**89**	**171**	**97**	**55**	**120**	**153**	**99**	
Air Temp (°C)													
Suva	26.8	27.0	26.8	26.1	24.9	24.2	23.3	23.4	23.8	24.5	25.3	26.2	25.2
Nadi	27.1	27.0	26.7	26.2	25.6	24.3	23.5	23.7	24.5	25.2	26.0	26.6	25.5
Labasa	26.7	26.8	26.7	26.2	25.0	24.5	23.6	24.0	24.7	25.0	25.8	26.4	25.5

*Source: Fiji Meteorological Service, Information Sheets 21, 53, 71 humidity are considerably lower than in the south-east areas (the 'wet' zone) which face the prevailing south-east trades. This difference is clearly exhibited by the data for Suva ('wet' zone) Nadi and Labasa ('dry' zone) given in Table 1. On many of the smaller islands the climatic differentiation between windward and leeward sides is much less pronounced.

The most important feature of the rainfall, however, is its intensity. Data on intensity are very limited, and calculation of EI_{30} values is possible for only a few locations. The limited information suggests that EI_{30} values are high ($>$ 500/yr) for the whole of Fiji and that a reasonable estimate can be obtained using the procedure proposed by Roose (1977) for Ivory Coast, which has a similar rainfall regime.

$$EI_{30} = (0.5 \pm 0.05) \times \text{mean annual rainfall (mm)}$$

Further evidence of rainfall intensity is provided by the data for maximum monthly rainfall and maximum rainfall in one day (Table 1). The maximum daily rainfall frequently occurs when tropical cyclones (hurricanes) or other tropical storms pass through the islands. Cyclones affect Fiji on the average once every 1.3 years while tropical storms (locally known as 'Bogiwalu') may occur 2 or 3 times in a normal year. When such storms occur, river flows increase dramatically and sediment transport is visibly enhanced.

(b) Topography

Fiji is dominated by steep, mountainous country deeply incised by rivers and streams. On the four major islands, 67% of Viti Levu, 72% of Vanua Levu, 49% of Taveuni, and 78% of Kadavu is steepland (slopes $>18^{\circ}$) while much of the remaining land is rolling and hilly (slopes $3\text{-}18^{\circ}$). As much of the surface runoff following heavy rain is over steep slopes the erosivity of the water is markedly increased. The steep slopes also lead to frequent landslides following heavy rain (see later).

(c) Soils

The general soil pattern shows a strong correlation with the topographic and climatic pattern. There is a weaker correlation between soil pattern, geology and plant cover. The general pattern of soils can be best described by separating them into three topographic groups and superimposing on this a subdivision based on altitude and climate (Twyford and Wright, 1965).

The topographic separation shows (i) soils developed on the relatively flat areas derived from river or marine deposition, (ii) soils developed on rolling to hilly land, and (iii) soils developed on steep slopes of hills and mountains. The approximate percentages of the land surface covered by the three categories are 15% for flats, 20% for gentle slopes and 65% for steep slopes. The soils can be grouped genetically as follows (classification according to Soil Taxonomy (Soil Survey Staff, 1975)):-

(a) Young sandy soils formed around the coasts of the island (Psamments);
(b) Fertile, deep, agriculturally important alluvial soils occupying the valley bottoms (Fluvents, Inceptisols and Mollisols);
(c) Shallow and moderately deep, dark coloured, nutrient rich soils on rolling and hilly land (Mollisols, Alfisols and Inceptisols);
(d) Sandy and silty moderately deep to deep soils formed from volcanic materials (including ash) containing particles of unweathered parent material (Andepts and Tropepts);
(e) Deep, highly weathered clay-rich soils, often acid and of low base status derived from basic parent materials (Humitropepts, Dystropepts, Humults and Ustults);
(f) Deep, highly weathered oxide-rich clay soils of limited agricultural value (Oxisols and Oxic subgroups of Alfisols and Ultisols);
(g) Deep sandy soils derived from acid parent materials having clay increases in the subsoils, usually strongly weathered and of low base status (Ultisols);
(h) Gleys and peats occupying low-lying areas in valleys or on plateaux (Aquents, Aquepts, Aquolls, Histosols).

Groups (c)-(g) have steepland equivalents or associates.

Wischmeier and Mannering (1969) describe erodibility of a soil as "a complex property dependent both on its infiltration capacity and on its capacity to resist detachment and transport by rainfall and runoff". Erodibility is therefore dependent on properties such as particle size distribution, organic matter content, presence of structure cementing agents such as iron and aluminium oxyhydroxides, bulk density and air-filled pore space.

Erodibility is expected to be low for most Fiji soils because those in groups (d), (e), (f) and (g), which constitute the bulk (66%) of the country's soils, generally have moderately to well developed surface soil structure, and are moderately-well to well drained.

GENERAL AGRICULTURAL PATTERN

While over 60% of Fiji's land area is suited to some form of agricultural activity, only about 16% is suitable for sustained arable farming. The area of land in use has increased by more than 200 per cent over the past 30 years, partly due to marginal land being brought in arable usage. During the same period there has been a small but steady loss of good arable land to non-agricultural uses. As there are now no extensive areas of unused agricultural land, the major drive is, currently, to increase productivity.

Sugar remains the backbone of the agricultural economy with annual production now at 400-500,000 tonnes from approximately 4 million tonnes of cane grown on 95,000 ha. Copra production declined through the 1950's and 1960's but increased slightly in the 1970's. Some 66,000 ha is under coconuts producing about 25,000 tonnes copra/year. Cocoa production is increasing with some 4000 families now involved. Ginger, primarily for export, is grown on hilly land in the wet zone with production expected to reach about 3200 tonnes (for export) by 1990. Tropical fruits (passion-fruit, mangoes, pawpaws, pineapples and citrus) are being produced in increasing quantities but the total area in production is relatively small.

Rice is produced on about 10,000 ha, of which about 550 ha are irrigated. Yields are generally average to low (2-3 tonnes/ha) but a rice intensification programme is now expanding the area under irrigation fourfold, and increasing production such that total grain yield will rise from 30,000 tonnes to 45,000 tonnes by 1990. Maize production is of the order of 3000 tonnes/year but major efforts are being made to expand production as some 10,000 tonnes of maize are imported annually.

Root crops (taro, cassava, yams) are produced in substantial quantities in all areas of the country, in both shifting cultivation and monoculture systems. Much is consumed at source but substantial quantities are transported to the major urban markets on Viti Levu.

Livestock production ensures self-sufficiency in pork and poultry, and 80% self-sufficiency in goat meat. Beef production is increasing slowly and is now at approximately 3,500 tonnes annually. The forestry sector is very active with extensive logging of native forests occurring accompanied by a replanting programme of mahogany and other hardwood species. Planting of exotic pines has occurred over extensive areas of the dry zones of the two major islands and large scale harvesting is now underway. Production is of the order of 100,000 m^3 annually.

THE EROSION SITUATION

Although anecdotal information and casual field observations indicate that extensive soil erosion occurs in Fiji, few quantitative data are available. There is a dearth of measurements from erosion plots and only a limited amount of information from other techniques, e.g., erosion stakes, sediment loads.

The only recent data on erosion plots was obtained by Liedtke and Glatthaar (Liedtke, 1988; Liedtke, 1989; Glatthaar, 1988). Liedtke (1989) measured soil losses corresponding to 22-80 t/ha/yr on slopes of 5-29^{o}, in a sugarcane growing area north of Nadi. In studies in a vegetable/root crop growing area in the 'wet' zone, Liedtke (1988) obtained measurements corresponding to soil losses of 12-2300 t/ha/yr on slopes ranging from 5-25^{o}. The very high value corresponded to a plot having a very long slope ($>$25 m) with bare ground. Glatthaar (1988) using data for the sediment load in the Waimanu river estimated that the average soil loss for the catchment in which the Liedtke plots were located was about 53 t/ha/yr corresponding to a loss of 2-2.5 mm soil per year. These values are particularly high given that the catchment is heavily forested.

Glatthaar further states that one important erosion feature is the instability of the steeper slopes. Landslides are clearly visible on steeper slopes throughout the Fiji group; a major rainstorm in April 1986 caused some 620 landslides in the Waimanu catchment alone corresponding to a soil movement of 92 t/ha/yr or 3.5 mm over the whole catchment.

Hasan (1986) reviewed available data for sediment loads in a number of catchments for both the wet and dry zones and estimated annual soil losses of 24-79 t/ha/yr equivalent to soil losses of 1.6-5.3 mm/yr. These catchments varied in the extent of their agricultural development. Nelson (1987), applying a somewhat extreme extrapolation of the application of the USLE model, determined soil loss values ranging from 10-170 t/ha/yr for 31 land units in the wet and dry zones of Viti Levu. Field observations of soil loss using erosion stakes or profile reference points were reported by Clarke and Morrison (1987). Soil losses of 90-300 t/ha/yr were calculated for areas where forest or indigenous grassland were converted to intensive sugarcane production. Such high erosion rates are not difficult to believe, particularly in the light of measurements on grasslands used for grazing (Limalevu, unpublished data). Using erosion stakes, rates of up to 25 t/ha/yr were recorded on $21-25^{o}$ slopes.

All these measurements and estimations may contain considerable error. The on-site measurements did not include replicated plots, and the estimations all involve untested assumptions. Because the Fiji Ministry of Primary Industries now has only one soil conservation officer with a small research budget, few resources are available to generate further data. The data we now have indicate that the already high rates of erosion that occur naturally on Fiji's steeper lands are considerably increased by human action.

ECONOMIC IMPLICATIONS

Given the difficulties in obtaining accurate measurements of the physical extent of soil erosion, it is not surprising that there have been only a few attempts to carry out the more abstract measurements of the relationship between soil loss and economic loss in Fiji. Qualitative observations point to erosion damage and lowered plant productivity on sizeable proportions of many individual fields, with patches of severely diminished productivity. Sugarcane farmers complain of declining yields, placing blame on the quality of fertilizers imported. As testing of fertilizers indicates no significant change, a more logical explanation of the decline in yields (despite maintaining or increasing fertilizer applications) is the impact of erosion on soil productivity.

A variety of crops suffer erosion-induced production losses; spatially and economically, sugarcane and ginger grown on slopes are the most important. The advance of sugarcane onto slopes over the past thirty years has been the result of an economic imperative to increase national yields and rested in part on the development of new varieties that would produce reasonably well on marginal lands; in contrast, the severe erosion associated recently with ginger, which is almost entirely cultivated on slopes results from agronomic considerations of ensuring good drainage and of practicing quick land rotation to avoid nematode infestation. Subsistence gardens, some of which have been pushed onto steeper slopes by the expansion of cash crops and cattle on the flatter lands, also suffer from erosion, especially where traditional mulching practices are no longer practiced. No quantitative data are available on the extent or severity of soil erosion in subsistence gardens.

Off-site damage from induced erosion is also serious. Notable in Fiji is downstream flooding and sedimentation, which extends in this tropical island country to the mangrove forests, seagrass beds and coral reefs, whose high level of marine productivity is threatened by the land-based activities that cause erosion. Here again, quantitative estimations of loss are not available. The situation is complicated by the decrease in mangrove ecosystems (by reclamation and deforestation), a change that also lessens reef productivity. Anecdotal evidence suggests that sedimentation on seagrass beds and reefs is becoming seriously harmful in some areas. There is no doubt that logging-induced erosion in water-supply catchments has, on occasion, damaged the water supplies of Ba and Labasa, two of Fiji's major towns; or that there is the potential for harmful logging-induced sedimentation in the much larger reservoirs of Vaturu and Monasavu, the latter of which is Fiji's large-scale source of hydroelectricity. The costs of such damage are difficult to ascertain. Currently, however, Fiji spends US$2-3 million per year on river dredging and recompense for loss of fishing rights due to 'development' of mangrove areas is about US$1000-1200 per hectare. No payments for damage to seagras or reef areas have been made to date (K. Swamy, personal communication).

LEGISLATION

The Soil Conservation section of the then Department of Agriculture in Fiji was formed in 1949, when a full time Soil Conservation Officer was appointed. In 1953 a Land Conservation and Improvement Ordinance was ratified; the Ordinance made provision for various conservation orders relating to soil-conservation practices in agriculture, to prevention of over-grazing, to protection of vegetation cover, and to the prohibition of the use of land-damaging sledges. The Ordinance also established a Land Conservation Board to promote the wider extension of land conservation practices. While some conservation measures have been effectively instituted, the influence of conservationist laws on many of the daily activities of farmers has been slight, especially since Independence (1970). Priorities have been more on encouraging economic development through expansion of commercial agriculture onto previously unused lands and on bringing Fijian villagers into commercial agriculture, especially sugar production. The Land Conservation Board has focussed mostly on improvement of drainage and the Land Use Section (Ministry of Primary Industries), which contains the Soil Conservation Unit, emphasizes land use planning rather than active erosion control.

Other regulations associated with the complex leasing and tenancy arrangements that exist in Fiji (see below) empower the enforcement of safe land-use practices in principle. However, this authority has been very rarely used in practice.

LAND TENURE AND EROSION

Particularly in question with regard to land-conservation measures in Fiji today is the country's land-tenure system, whereby some 82 per cent of the land is "native land" held under customary, communal tenure by land-owning groups (mataqali) of ethnic Fijians. This land, which is administered by the Native Land Trust Board (NLTB), cannot be sold but some of it can be leased to non-Fijians (and to Fijians as individuals). Plots of land leased under NLTB procedures account for much of the land used in Fiji's system of small-holder sugarcane cultivation, wherein most farms are about 4 ha. The lack of long-term security of tenure, particularly as it applies to the Indo-Fijian majority of cane farmers, is often blamed for the lack of conservation practices in cane fields. Although other factors are involved (e.g., farmers like "clean" fields and so burn the cane trash rather than using it for mulch), the tenure situation is significant and likely to become more so towards the mid-1990s, when many of the leases will fall due for renewal. Tenants (both Indo-Fijian and ethnic Fijian) are apprehensive that they will lose land that they may have held for as long as thirty years; consequently, they are reluctant to carry out improvements or strive for sustained-yield capabilities. The resolution of this lease-renewal issue is a critical political and, by extension, conservation problem for future land-based developments in Fiji.

Although the NLTB holds land in trust, as a lessor its concern has been more to put land into use than to practice land conservation. Consequently, many sugarcane leases have been given for land steeper than 8-11 degrees (the recognized upper limit for "safe" cultivation of sugarcane). Further, although arrangements exist to discontinue leases to farmers who practice bad husbandry, this authority is scarcely ever exercised.

FUTURE ACTION

The recent awakening in Fiji's government circles to the need for integrated watershed management is one sign that qualitative/quantitative facts about soil erosion and sedimentation and the damage they can cause are beginning to be transformed into political facts that motivate countermeasures. It is mostly the dramatic result of deforestation rather than piecemeal erosion from cultivated fields that is behind the concern for watersheds. But the integrated land use planning that must be part of watershed management will have to include agriculture. The newly established Environmental Management Unit will co-ordinate the agencies that must be involved in national land use planning and management. A State of the Environment Report is also in progress, and new environmental legislation is to be established. Associated with these actions will be calls for the further research needed to specify the soil-erosion and sedimentation situation more clearly, particularly:

- measurement of the areal extent and severity of erosion and land degradation
- development of a predictive soil-loss equation to fit Fiji's conditions
- specification of the relationship of soil loss to loss of crop production
- assessment of the impacts of increased sedimentation on coastal ecosystems

CONCLUSION

The landform and climate of Fiji are conducive to high rates of natural soil erosion. Government policies of increasing agricultural production by using more land and of permitting extensive logging have contributed to an increase in human-induced soil erosion but more precise data on the areal extent and intensity of erosion and sedimentation are needed if the economic implications are to be accurately assessed. Such quantification will also help in assessing the impact of land-conservation measures currently under consideration by the Government.

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