Fiji Watersheds at Risk

Watershed Assessment for Healthy Reefs and Fisheries

Final Report to the United States Department of State
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Executive Summary

Critical Watersheds for Reef Conservation

This study has identified several Fijian watersheds which are particularly important to protect and restore forest cover in order to protect healthy ecosystems and fisheries on high conservation value reefs. Although we have assessed the status of all Fijian watersheds, we highlight those watersheds that have a high propensity for major erosion due to their biophysical conditions (for example, soil, rainfall, slope, level of development) and which are adjacent to priority reefs identified as highest priority by Fiji's National Biodiversity Strategy and Action Plan. These critical watersheds that are adjacent to high priority reefs are either still well-forested and require adequate protection and those that are largely modified but need restoration.

The critical watersheds important for reef conservation are primarily located along the northeast coast of Viti Levu (Ra Province), the southeastern coast of Vanua Levu (Bua), and the western and north-central coast of Vanua Levu (Macuata). All watersheds in Fiji should be well-managed in order to sustain local fisheries (freshwater and marine), maintain clean water, and reduce flood damage. However, this particular subset can greatly impact the health of priority reefs for conservation due to their high erosion potential and adjacency to the reefs. For this reason, their natural forests deserve extra effort for protection or restoration.

Other Critical Watersheds

Most of the critical watersheds, whether they are associated with high conservation value reefs or not, are found on Viti Levu and only two are found on Taveuni. The majority of the watersheds that need protection are in southern and central Viti Levu and southern Vanua Levu, while most of the critical watersheds that need reforestation are in northern Viti Levu and northern Vanua Levu in the drier leeward zones.

Estimates of Status for All Fijian Watersheds

We also estimated the status of all watersheds in Fiji, including the outer islands. Watershed status is a composite index based on the inherent biophysical conditions of each watershed (for example, soil type, rainfall, slope, and area), the current level and distribution of forest cover, and the type and degree of development. Some major findings include:

- The largest blocks of natural forest occur in central and southwest Viti Levu, while Taveuni and Kadavu have the most intact watersheds.
- The watersheds with the highest relative erosion prediction (REP) tend to be found in eastern and central Viti Levu and in central Vanua Levu.
- The watersheds with the lowest relative erosion prediction are found in western Viti Levu and in far eastern and western Vanua Levu.
- Development pressures (logging, road construction and creek crossings) tend to be highest in western Viti Levu and Macuata on Vanua Levu and are lowest in central and eastern Viti Levu and most of Vanua Levu, except Macuata.
- The combined threat from both the REP and the development factors is highest in the small coastal watersheds in northern Viti Levu in Ba and Ra provinces and in Namosi district in southern Viti Levu. On Vanua Levu, the combined threat appears greatest in Macuata Province in northern Vanua Levu.

- The most intact watersheds with the lowest relative erosion prediction are found in the extreme northeast tip of Vanua Levu (Udu Point) and on the Natewa Peninsula, and in Sovi Basin on Viti Levu.
- The most intact forested watersheds occur in windward Taveuni. These are among the most intact watersheds in the entire Oceanic Pacific and constitute a regional conservation priority.

Watershed Impacts on Reefs and Fisheries

Altered watersheds primarily degrade reef and freshwater ecosystems through increasing the amount of sediments and nutrients well beyond natural levels. Sediments smother and shade out corals and other invertebrates and higher levels of nutrients cause an imbalance in ecosystems that often results in blooms of algae. Sedimentation and nutrient-loading are known to reduce fish abundance, species diversity, and coral cover in nearshore reef ecosystems. Logging represents one of the major sources of sedimentation and nutrient-loading.

Corals can survive heavy sedimentation events for short periods. Longer-term stress induced by extended periods of low-level sedimentation may be responsible for most damage to reef ecosystems. *For this reason, logging in smaller coastal watersheds, which cover the majority of Fiji's coastlines and are often steep and have low retention capacity for sediments relative to larger watersheds, is likely one of the major contributors to degradation of coastal marine ecosystems and fisheries in Fiji.* Logging roads continue to bleed sediments for over a decade so their input of sediments, particularly in higher rainfall zones, is likely long-term and continuous on adjacent marine and freshwater ecosystems. Burning of grasslands, particularly in higher rainfall zones, also greatly contributes to erosion within watersheds. Erosion mitigation practices such as closing logging roads through revegetation and building erosion berms, particularly on stream crossings, reforestation of streamsides, and stricter adherence to logging code practices intended to prevent logging on slopes and along streams should be implemented in all watersheds. Logging should be entirely prohibited in critical watersheds, particularly those that are adjacent to high conservation value reefs and those that contain high conservation value forests. Watersheds of southern Bua, Macuata, and Ra Province should remain unlogged. Taveuni and Kadavu, both well-forested islands, should also prohibit logging as their broader ecosystems, from the ridgetops to reefs, are largely intact.

We recommend future studies related to watershed impacts focus on the following:

- quantification of river flow and discharge rates in a range of watersheds of different quality on different islands;
- collection of data on slopes, soils, rainfall intensity, rainfall seasonality and land cover on the outer islands;
- assessment of coral reef mortality from riverine sediment and other pollutants;
- assessment and mapping of reef habitats and reef quality;
- quantification of soil erosion impacts from infrastructural developments such as roads, creek crossings and logging;
- analysis of satellite imagery to determine offshore and coastal currents, and to study sediment plumes from watersheds after heavy rainfall events.

CONTENTS

Acknowledgements

We thank the many local communities and individuals in Fiji who allowed us to work on their land and explore their forests and reefs. Their hospitality, generosity, and interest are greatly appreciated. We thank the people of Kubulau and Nabukavesi, in particular, for allowing our team to study their watersheds. The Provincial Offices of Bua, Macuata, Namosi, Rewa, Ra, and Caukadrove also provided support. We thank the Government of Fiji for their technical input, support, and collaboration in this project, particularly the Ministry of Fisheries and Forests and Department of Environment, who maintains an MOU with our organization that allows us to contribute to biodiversity conservation and resource management issues in Fiji. We thank the Forestry Department, the Department of Lands and Survey, the Ministry of Agriculture, Lands, Sugar and Land Resettlement, the Fiji Meteorology Department and SOPAC for sharing spatial data used in this analysis. In particular we thank Asesala Cokanacagi of the Land Resources Unit of the Ministry of Agriculture, Samuela Lagataki and Akosita Lewai of the Forestry Department and Dr Wolf Forstreuter and Elizabeth Whippy of SOPAC for generously sharing critical datasets. We greatly appreciate the contributions of several environmental, water and soil resource management specialists who provided technical reviews of the approach and results. In particular we thank Dr Dick Watling of Environment Consultants Fiji, Maria Elder of the Ministry of Agriculture, Michael Bonte of SOPAC, and Dr John Morrison and Dr Nacanieli Tuivavalagi both formerly of USP. The United States Department of State and the US Embassy to Fiji Islands, Kiribati, Nauru, Tonga and Tuvalu supported this project, for which we are grateful. We thank, in particular, David Lyons, Ted Seay, John Emery, Heidi Hanneman, and Repeka Ufiamorat for their interest and support in this work.

Logging roads cause accelerated soil erosion, especially when designed poorly (WCS).

Fiji Watersheds at Risk: Watershed Assessment for Healthy Reefs and Fisheries

1. Introduction

The relationship between forested watersheds and healthy reefs is widely recognised (Hubbard 1987; Rogers 1990; Hodgson & Dixon 2000; Furnas 2003), but poorly documented and little understood in terms of critical parameters, thresholds, synergistic effects, and habitat- or taxon-specific impacts. There have been no studies in Fiji, and few elsewhere in the world, which attempt to map watershed status and relate them to marine habitat and fisheries status across entire archipelagos. Here we model and map watershed status with respect to estimated impacts on freshwater resources and to downstream reef and marine resources, particularly high priority reefs for biodiversity conservation. Ongoing research (Jenkins in prep., Olson et al. in prep.) is gathering data on the status of freshwater and marine resources in Fiji which will be analyzed in conjunction with the watershed health indices developed here. This project provides the first watershed database available for all Fiji's watersheds that includes secondary watersheds, smaller coastal watersheds, and smaller island watersheds.

Watershed Model
The results of this research essentially serve as map-based "indicators" of watershed health and quality. Using MapInfo GIS tools, we have modelled watershed features to produce a map of current status and predictive impact, given existing land cover and pressures on the land. The model is used here to identify critical watersheds that should be removed from logging or conversion to other land use, because of their particularly important role in protecting terrestrial soil and freshwater resources and downstream marine resources such as coral reefs and local fisheries. We also highlight those critical watersheds that directly impact coral reefs identified as having high conservation value in Fiji's National Biodiversity Strategy and Action Plan (Department of Environment 1999) and WWF's FIME workshop (Suva, 2002).

Erosion & Development
Two main "threats" to watershed status have been analysed in this study. The first and most important threat factor is that from soil erosion. Predicted soil erosion is the erosion that would be predicted by a model based on slope, soil, rainfall and land cover. The model predicts erosion based on current land cover conditions; modifying the land cover will alter the expected soil erosion. Soil erosion contributes both to sedimentation in rivers and coastal ecosystems, as well as nutrient-loading, which is positively correlated to sedimentation load (Birkeland 1997). Both sedimentation and nutrient-loading constitute major threats to coastal reef ecosystems (Hodgson 1993; Hodgson & Dixon 2000; Furnas 2003). The second factor that has been analysed relates to development, or the degree to which the watershed has been impacted by anthropogenic development. In this case logged area, road density and number of creek crossings were used as indicators of infrastructural development. Both soil erosion and nutrient-loading are associated with watershed development.

Since soil runoff is the major pollutant in Fiji's coastal waters, the project has focused on determining the relative predicted soil erosion and runoff for Fiji watersheds. It should be noted that actual erosion rates from Fiji watersheds (in terms of tonnes of soil lost per watershed per annum) have not been determined in this project. Thus, while the model can be used to make *relative* comparisons between watersheds, it cannot be used to quantify *absolute* erosion rates from each watershed. Quantitative predictions of actual erosion rates await calibration of the soil erosion model with data on runoff rates, rainfall intensity, rainfall seasonality, soils, current land cover etc at the watershed level, for a number of watersheds. Similarly, the quantification of the predicted erosion from infrastructural developments such as roads, creek crossings and logging activity will require much more data than are currently available. Our watershed model is preliminary given the scarcity of key datasets for some areas, but it is hoped that it will be refined and improved as more data become available and as research hypotheses become better informed. However, the major trends are sufficiently accurate to rely on this analysis as a planning and management tool.

Logging of Coastal Watersheds

This analyses help identify those coastal watersheds that have the greatest propensity for soil erosion given their inherent biophysical characteristics and degree of development. Modified coastal watersheds are likely to have a significant impact on coral reefs because: a) the majority of coastline is dominated by smaller, coastal watersheds in Fiji; b) coastal watersheds are steep with low capacity for retention of sediments; c) reefs adjacent to small watersheds are adapted to lower sediment levels than those nearer to larger rivers; and d) logging roads promote low level but consistent soil erosion even in low rainfall events and overall sedimentation exposure is worse than acute, but short duration, heavy rainfall landslip events. For these reasons, the extensive logging that is taking place in coastal watersheds is a major concern for Fiji's coastal marine ecosystems and local fisheries. This analysis identifies those coastal watersheds that are particularly prone to causing major sedimentation and nutrient-loading of associated coastal marine ecosystems if logged.

2. Methods

2.1 Watershed Mapping

A total of 333 watersheds were mapped visually using the following GIS layers: a 25m DTM with contour shading, the hydrology network, and 20m relief contours. Watershed boundaries were digitized carefully from topographic maps (Government of Fiji 1982-2002) to follow ridges and other obvious geographical features separating drainage basins (Fig. 1). Major rivers on the larger islands were mapped to sub-catchment (secondary catchment) level. Due to the large number of very small creeks on smaller islands and in many coastal watersheds on the larger islands, creeks were grouped into larger functional catchments containing up to 20 creeks each, using the guideline to lump creeks that flow into the same embayment or along the same section of coastline**.** Islands smaller than 100 ha were not mapped or analyzed. All watersheds were given names based on the available names of streams, creeks, and rivers on topographic maps, or using island names of smaller islands. Some smaller islands were mapped as single watersheds, particularly low islands.

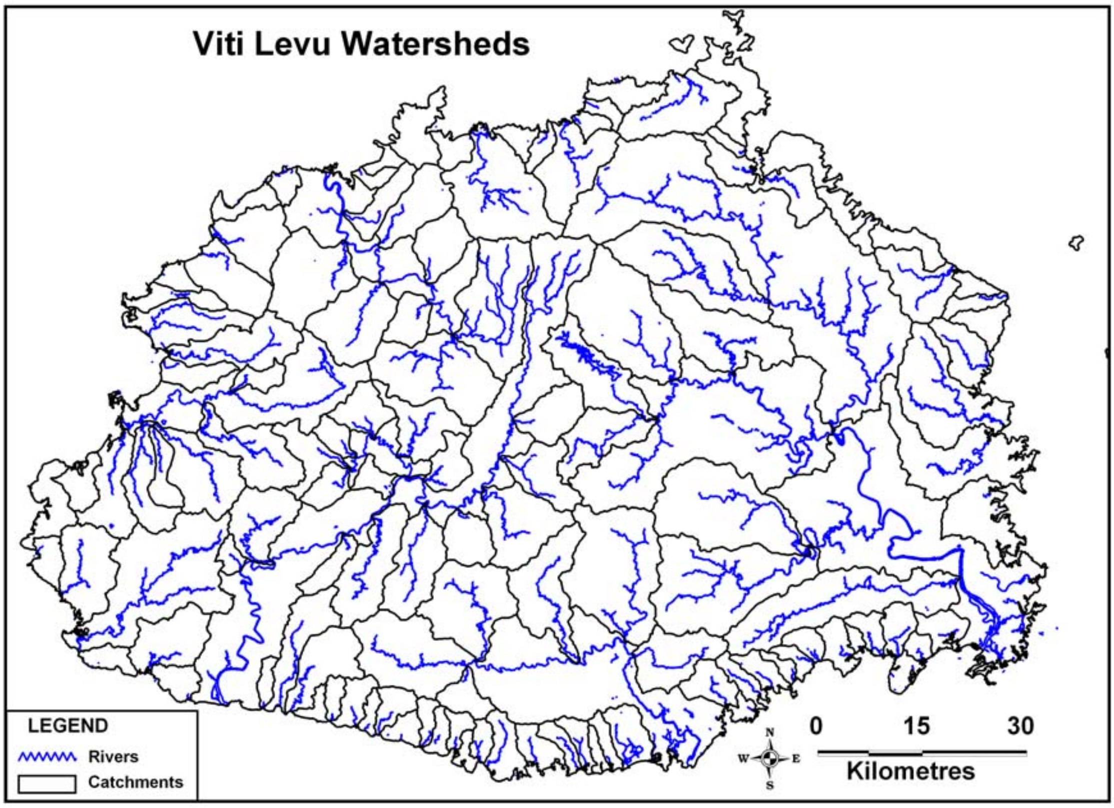

Figure 1. Major watersheds of Viti Levu, Fiji (WCS).

2.2 Relative Erosion Prediction Index

The relative erosion prediction index is a relative measure of the predicted erosion under current land cover, from each watershed. The index can be used to compare watersheds qualitatively but not to determine absolute erosion rates from each watershed. An erosion prediction model has been developed based on five of the most important environmental factors influencing erosion, namely: slope, land cover, total rainfall, rainfall seasonality, and soil erodibility.

The major determinants of soil erosion are rainfall erosivity and soil erodibility (Morrison 1992). Rainfall erosivity itself is a property of rainfall which can be described and quantified as the potential capacity of rain to cause erosion in given circumstances. Soil erodibility is a property of soil which can be defined and quantitatively evaluated as the vulnerability of the soil to erosion in given circumstances (Hudson 1977). Soil erodibility itself is dependant on the intrinsic properties of the soil itself and how the soil is used which itself is dependant on the slope angle, the length of slope, the type of vegetative cover and cultivation practice and the extent of conservation practices, if any.

A mathematical relationship to estimate soil erosion, termed the Universal Soil Loss Equation (USLE), has been developed which combines all these factors (Wischmeier and Smith 1965). However, there are considerable reservations about the applicability of the USLE under Fiji conditions (Morrison 1992). Furthermore, using the USLE to determine potential soil erosion rates throughout Fiji would require substantial data for a large number of factors at significant spatial resolution. Such data are, in most cases, lacking. Consequently, a simpler, modelling equation was developed for this study based on work done for Fiji's forest function map (Watling 1994), and on global work on assessing the impact of watersheds on coral reefs (Bryant *et al.* 1998).

A model of Relative Erosion Prediction (REP) for Fiji watersheds was developed based largely on the methodology used for the determination of forest functions in Fiji (Watling 1994). The Watling model was refined to incorporate land cover information generated by the Fiji Forest Department for the main Fiji islands supplemented with more recent land cover data from other sources. The formula for the REP is as follows:

Relative Erosion Prediction (REP) = slope factor + soil factor + rainfall intensity factor + rainfall seasonality factor + land cover factor

GIS values (relative weightings) were assigned to each factor as follows:

i. Slope

Slope is recognised to have a major influence on soil erosion rates. In the Reefs at Risk erosion model (Bryant *et al* 1998), it is given the biggest weighting, followed by land cover and then precipitation. Similarly, in the Fiji forest function model (Watling 1994), extreme slopes (over 60%) are given an over-riding weighting to override other contributions in the identification of forest that should be protected.

Slope maps were generated from Digital Terrain Models (DTMs). DTMs at 25m resolution for Viti Levu and Vanua Levu were obtained from SOPAC while DTMs for other islands were generated from 20m contour maps.

The slope classes selected for the Fiji forest function map (Watling 1994) were also selected for this project with one minor change. Areas of very low slope (less than 3.5%), were given a GIS value of 0.5 to reflect the fact that there is no significant erosion on such slopes (Table 1).

Table 1. GIS Values for Slope Classes

Slope		**Description**	**GIS Value**
%	X°		
0-3.5	0-2	Very Low	0.5
3.6-30	3-16	Low	1
31-50	17-26	Moderate	2
51-60	27-31	Steep	3
Over 60	Over 32	Extreme	9*

* Over- ride value of 9 is given to extremely steep slopes

ii. Rainfall

There are two important parameters of rainfall that influence erosion. The first is the rainfall intensity, and the second is the rainfall seasonality (Watling 1994). Rainfall intensity relates to the amount of energy imparted by falling rain on the soil, while seasonality is important because the vegetation in areas with severe dry seasons is much reduced and the soil is therefore more vulnerable to any sudden major rainfall event.

There were two sources of data for the rainfall maps. The first source was Fiji's Forestry Department which provided the iso-erodent and rainfall seasonality maps which had originally been produced for the Fiji Forest Function map (Fiji Forestry Department 1994). These maps covered Viti Levu (iso-erodent and seasonality) and Vanua Levu (iso-erodent) only (Fig. 2). The second source of data was the Fiji Meteorology Department which provided rainfall data for a number of the other islands.

Rainfall Intensity

Rainfall intensity quantifies the erosive forces of rainfall and runoff and is given the code R in the USLE. As noted by Watling (1994) iso-erodent maps (measuring the rainfall factor R) have only been prepared in Fiji for the Rewa and Ba watersheds (Nelson 1987). Consequently, a proxy must be chosen to estimate the rainfall intensity. Watling (1994) in the Fiji forest function mapping project used Roose's (1977) formula which was developed in tropical West Africa with a similar rainfall regime to Fiji. Roose's formula relates the rainfall factor (R) with the mean annual rainfall (H):

$$R/H = 0.5$$

Thus, an estimate of R can be obtained quite simply by dividing the annual rainfall in two. A tentative iso-erodent map for Viti Levu and Vanua Levu was generated by the Fiji Forestry Department based on the three iso-erodent classes used in the Watling erosion model (Table 2).

Table 2. GIS Values for Rainfall Intensity

R- Isoerodent Value	Isoerodent Class	GIS Value assigned
< 2000mm	High	1
2001-3200mm	Very high	2
> 3201 mm	Extreme	3

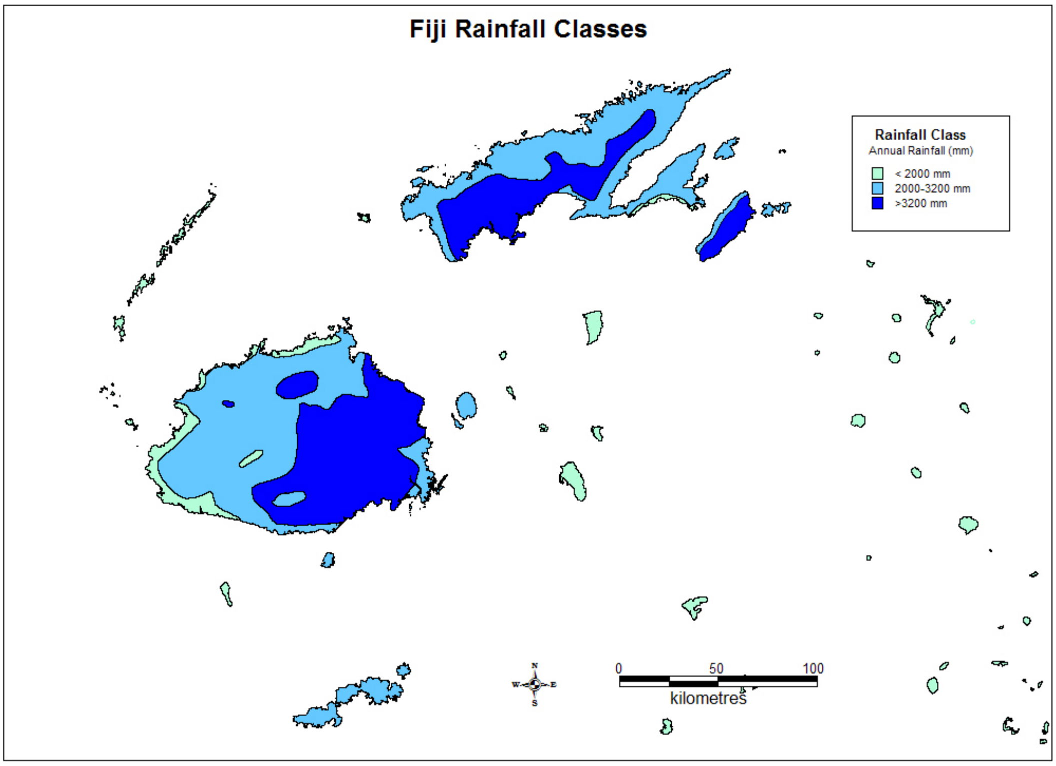

Figure 2. Rainfall classes for the Fiji Islands (courtesy Fiji Department of Forestry and Fiji Meteorological Department).

Rainfall seasonality

Rainfall seasonality is an important contributing factor to soil erosion because heavy rains following an extended dry period, when upper soil horizons are desiccated and vegetation cover may be stressed, are highly erosive. Watling notes that a commonly used index that is significantly correlated with sediment yields in rivers is Fournier's (1960) ratio of p^2/P where p is the highest mean monthly rainfall and P is the mean annual rainfall. The ratio is an index of the concentration of rainfall into a single month and therefore gives a crude measure of rainfall seasonality (Fig. 3). The classes used in the Watling erosion model were used in the analysis (Table 3).

Table 3. GIS Values for Rainfall Seasonality

Seasonality Value (p^2/P)	**Seasonality Class**	**GIS Value assigned**
< 70 mm	Moderate	1
> 70 mm	High	2

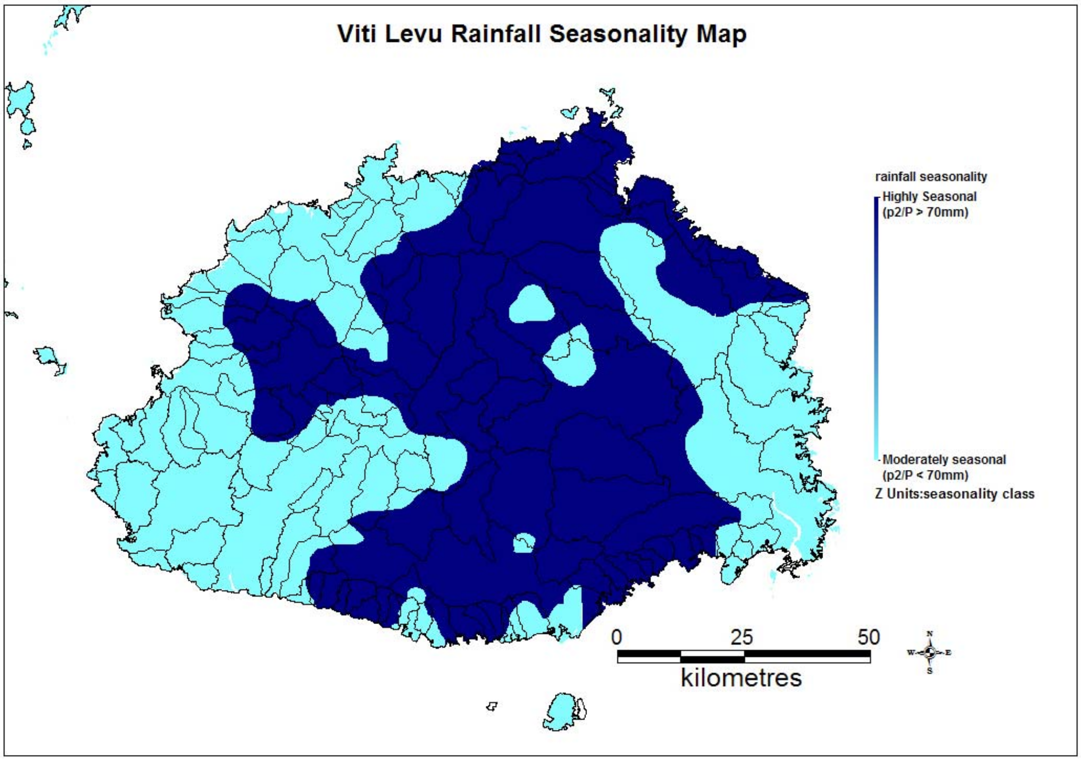

Figure 3. Rainfall seasonality for Viti Levu, Fiji (courtesy Fiji Department of Forestry and Fiji Meteorological Department).

iii. Soil erodibility

Watling's (1994) soil erodibility index was used for the development of the soil erodibility factor (see Table 4). Soil mapping was based on the work of Twyford and Wright (1965). The digital soil map for Viti Levu was obtained from SOPAC, but the Vanua Levu soil map could not be obtained (Fig. 4).

Table 4. GIS values for soil erodibility

Soil Classification	GIS Value assigned
Recent soils- coastal sands	2
Recent soils- alluvium	1
Nigrescent – limestone origin	3
Nigrescent – from other sources	4
Latosolic soils	2
Humic latosols	3
Ferruginous Latosols	4
Red-yellow Podozolic soils	3
Gley soils	2
Organic soils	4
Saline soils- marine marshes	3

Legend for Erodibility Index

Erodibility Index	Rating
1	Low
2	Moderate
3	High
4	Severe

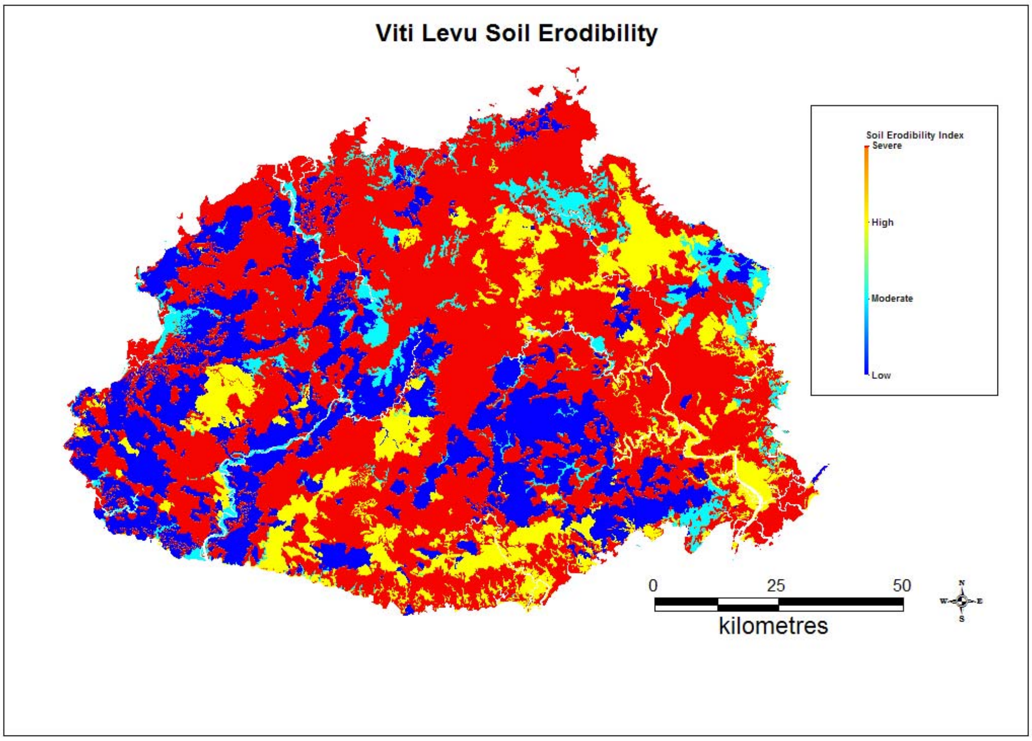

Figure 4. Soil erodibility estimated for Viti Levu, Fiji (courtesy SOPAC).

iv. Land Cover

Land cover has a major influence on erosion levels because vegetation intercepts much of the rainfall and reduces the energy of rainfall on the soil surface and thereby lowers the extent of soil detachment (Morrison 1992). Other influences of vegetation include the binding effect of roots in keeping soil in place and the influence of organic matter in supporting soil microflora and fauna which further promote soil aggregation (Morrison 1992).

The GIS values used for the analysis are based on relative erosion rates developed by the Reefs at Risk project and applied to International Geosphere-Biosphere program (IGBP) land cover classes (Bryant *et al.* 1998). Erosion rates for each land cover class have been reclassified and grouped into a GIS value ranging from 0 to 4 (Table 5).

Table 5. GIS Values for Land Cover Classes

Land Cover Class	Relative Erosion Rate (Bryant et al 1998)	GIS Value assigned
Water bodies	0.5	0
Dense or Medium Dense Forest (multiple use, protection or preserved)	1.0	1
Mangroves	1.0	1
Timber Production Hardwood Forest	1.0	1
Amenity Hardwood Forest	1.0	1
Timber Production Pine Forest	1.5	1
Amenity Pine Forest	1.5	1
Scattered Forest (multiple use, protection or preserved)	4.0 to 8.0	2
Coconut Areas	12.0	3
Sugar Cane	21.0	4
Other non forested areas	-	3

There were two main sources of the land cover maps used in the analysis. For the larger islands including Viti Levu, Vanua Levu, Taveuni, Gau and Koro, the forest function map (Fiji Forestry Department 1994) was used, while for all other islands, the forest cover was digitised from the Lands and Survey 1:50,000 topographic map series (Fig. 5). Finally, a map of sugar cane areas on Viti Levu and Vanua Levu was added to the land cover maps.

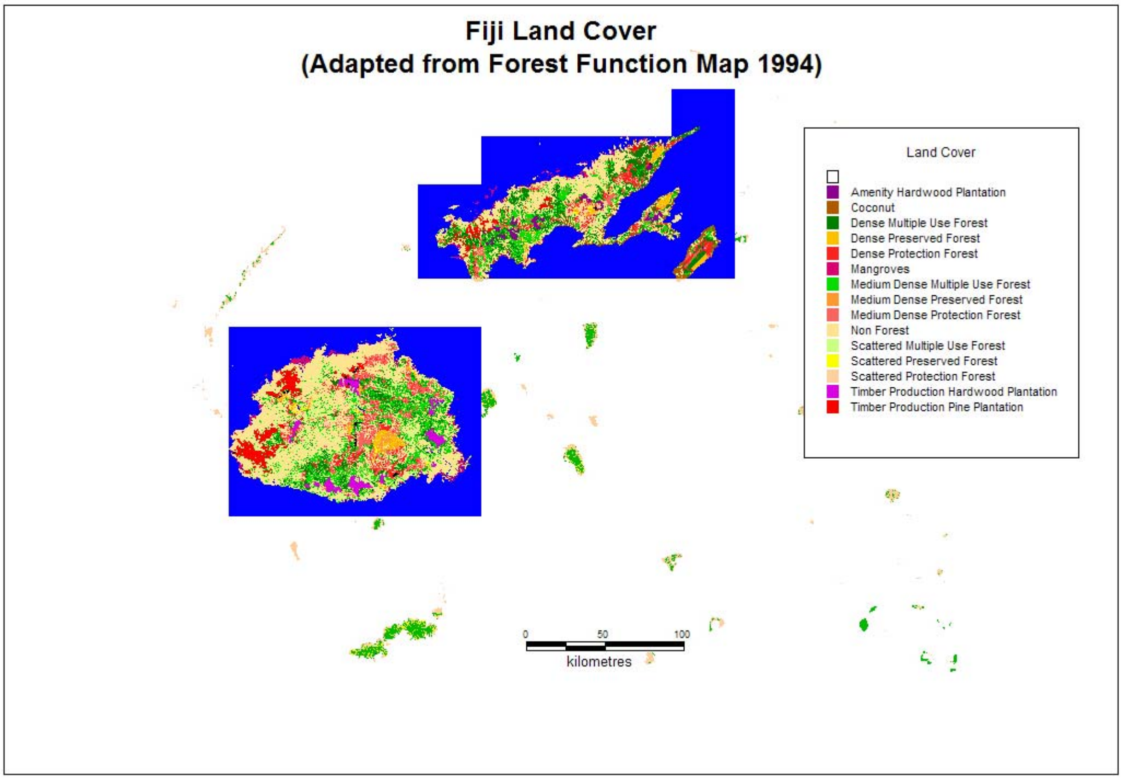

Figure 5. Forest functions for Fiji's major islands and natural forest cover estimated for outer islands (Fiji Forestry Department 1994; WCS in prep.).

2.3 Combination of environmental factors to determine Relative Erosion Prediction

The five environmental factors (slopes, soil erodibility, rainfall seasonality, rainfall intensity and land cover factor) were all added in the relative erosion prediction (REP) model. Note that water bodies were given a GIS over-ride value of 0 to reflect the fact that there is no soil to erode in such bodies.

Modelling was performed using a MapInfo extension called Vertical Mapper. Before the factors could be combined they were all converted to a 100 x 100m (1 ha) pixel raster format and projected to a common projection (Fiji Map Grid). Each watershed was then ranked based on two statistics: the average REP and the total REP for each watershed. A summary of the GIS values assigned to the factors and how watershed status was classified, is given below.

1. Slope	
Very Low	0.5
Low	1
Moderate	2
Steep	3
Extreme	9
2. Rainfall intensity	
High	1
Very High	2
Extreme	3
3. Rainfall seasonality	
Moderate	1
High	2
4. Soil Erodibility	
Low	1
Moderate	2
High	3
Severe	4
5. Land cover	
Water body	0
Forest	1
Scattered forest	2
Coconut plantation	3
Unspecified non-forest	3
Cane land	4

The full model using all five environmental parameters was only run for Viti Levu, due to the lack of GIS data layers available for Vanua Levu and the other islands. A simpler model was run for Vanua Levu and Taveuni using only three of the parameters, namely, slope, rainfall intensity, and land cover. The model was not run for the other islands due to the unavailability of key layers such as slopes and rainfall seasonality data. Data completeness levels for the erosion prediction model are shown in Figure 6.

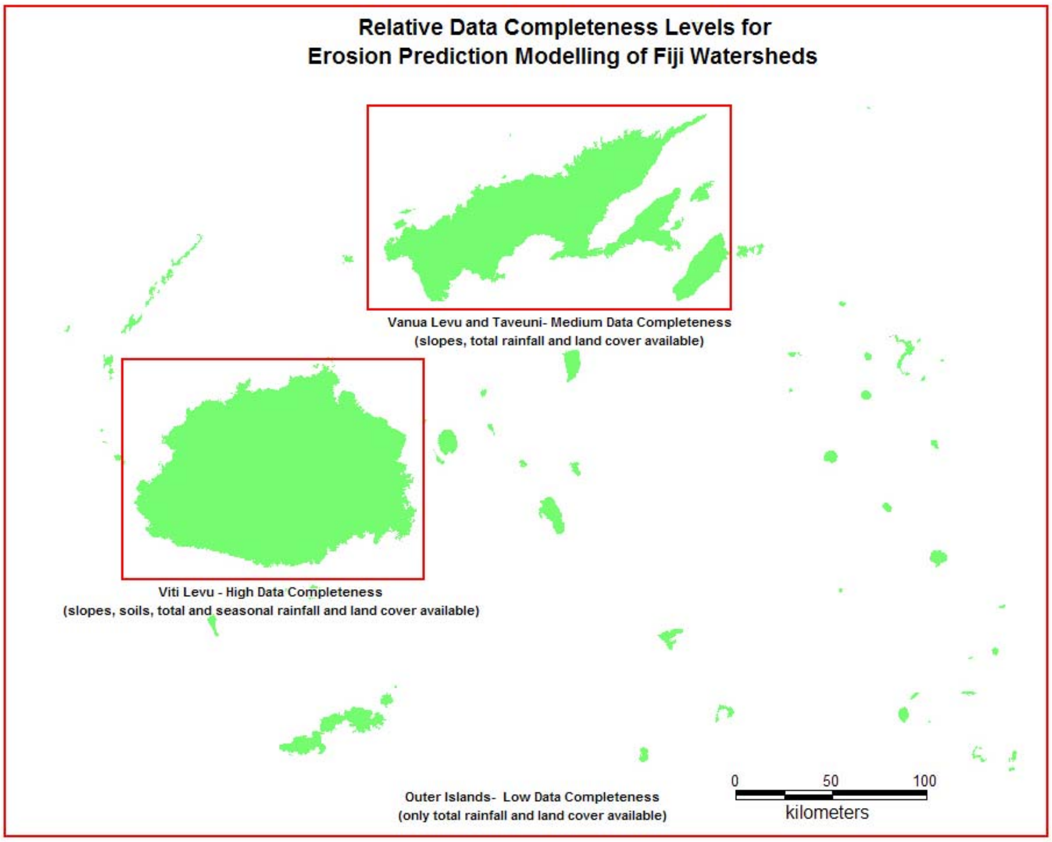

Figure 6. Data completeness levels for the Relative Erosion Prediction (REP) model.

When additively combined in the model, the range of possible REP values for each 1ha pixel for Viti Levu was 0 to 22, while for Vanua Levu and Taveuni it was 0 to 16. The highest REP values are on sugar cane areas on extreme slopes in areas of extreme rainfall erosivity and high rainfall seasonality and on soils with severe erodibility. An REP value of 0 reflects a water body (which were then removed from the analysis), while REP values less than 6 are forested areas on gentle slopes in low rainfall areas with moderate seasonality on soils of low erodibility. In effect, the actual range of REP values that were generated per grid pixel was 3.5 to 21 for Viti Levu and 1.5 to 16 for Vanua Levu. The mean REP per watershed ranged from 6.3 to 12.2 for Viti Levu and 4.1 to 6.9 for Vanua Levu and Taveuni watersheds (Figure 2).

Watersheds can be grouped into three "equal count" REP classes as shown in Table 6.

Table 6. Watershed REP classes

Mean REP value in the Watershed		**REP Class**
Viti Levu	Vanua Levu & Taveuni	
6.3 to 9.5	4.1 to 5	Low
9.5 to 10.3	5 to 5.4	Medium
10.3 to 12.2	5.4 to 6.9	High

2.4 Watershed Development Index

The Watershed Development Index (WDI) relates to watershed development, or the degree to which the watershed has been impacted by infrastructure. In this case, road length per km^2, number of creek crossings per km^2 and the area logged between 1992 and 2004, were used as indicators of infrastructural development and then combined into a composite development index. Each factor is described below:

i. Road density

Roads promote erosion by disrupting the natural flow of water down slopes and rapidly funnelling rainfall events such that increased scouring occurs. In the Fijian context, roads in small watershed may be the principal source of sediment (Nelson 1987). This is particularly true in logging areas because the roads and skid tracks are not sealed and are often poorly designed and constructed on steep slopes with poor drainage (Nelson 1987). Research in the Monasavu Highlands of Viti Levu suggests it takes roughly seven years for revegetation of logging roads to significantly diminish erosion associated with logging activity (Department of Forestry 1995).

A GIS map of Fiji's road network was obtained from the Department of Lands. While the road network is not up to date and does not include all the logging roads—field observations suggests many new logging operations have occurred since this mapping effort—it can still be used to provide a general indication of the density of roads in the watersheds. The road length per square kilometre was used as a proxy indicator of road density and thus sediment load from roads.

ii. Number of creek crossings

Creek crossings are an entry point for sediment washing off roads, to enter creek channels. Furthermore, creek crossings often require large fills in natural drainage channels which can impede water flow. Thus, the number of creek channels per km^2 can be used as another crude indicator of the impact of roads on sediment levels in streams and creeks. A GIS layer of Fiji hydrology was obtained from the Department of Lands and MapInfo was used to count the number of times roads crossed the creeks within each watershed.

iii. Forest cover

The natural vegetation of most of the land area of the Fiji islands is wet to mesic tropical forest cover (Mueller-Dumbois 1998). Thus, the degree to which forests have been removed in a watershed is an indicator of human impact. Furthermore, vegetative cover is an important factor in erosion because of the interception of rainfall by the vegetation, the role of roots in binding soil together and the promotion of healthy soil microflora and fauna which help to bind the soil into larger aggregates thereby reducing soil detachment (Morrison 1992). According to Nelson (1987), the vegetation management factor (for use in the USLE), for closed forest is 1/100 of that for bare ground and 1/75 that for subsistence agriculture.

The forest cover map was generated from the Forest Function map prepared by the Fiji Forestry Department (1994) (Figures 7 and 8). In this case, "forest" was defined as scattered, medium or dense natural or plantation forest. Plantation forest includes both hardwood and softwood plantations. Natural forest includes multiple-use and protection or preserved forest.

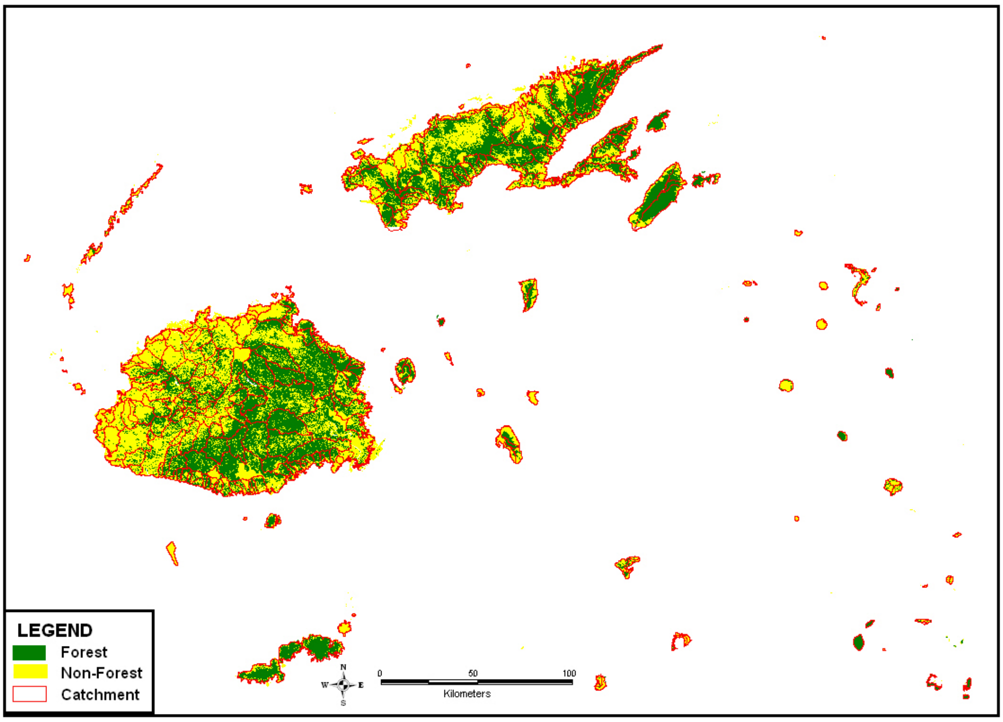

Figure 7. Forest cover and watersheds of Fiji circa 1990's. Pine and mahogany plantations are included.

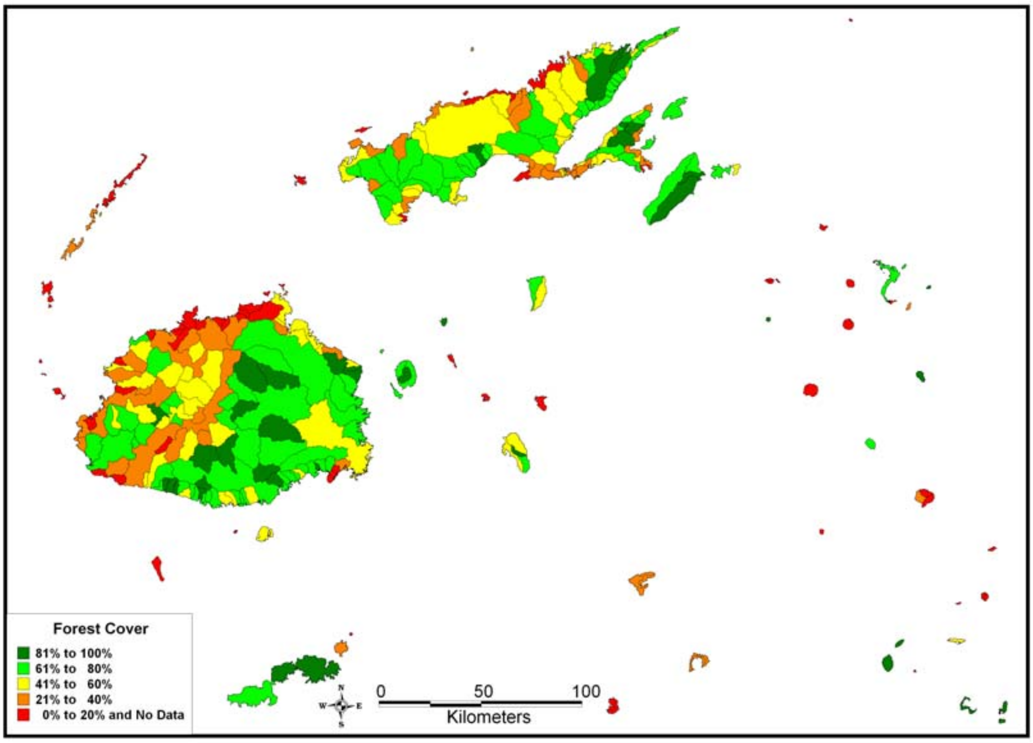

Figure 8. Forest cover as percent of land area in Fiji Watersheds.

iv. Area logged

Logging causes erosion because of the combined effect of removing vegetation and forest humus layers, and the impact of the network of roads, landing areas, and skid trails that must be constructed to remove the timber (Nelson 1987). Road building contributes most to erosions. The area logged as a percentage of the original forest cover can be used as an indicator of the impact of logging within each watershed.

Maps of yearly logging activity on Viti Levu and Vanua Levu were obtained from the Fiji Department of Forestry for the years 1992 to 2004. These maps were combined into a composite map showing the total area logged between the two reference years. This data only documents licensed concessions and not illegal logging which may be extensive in some areas.

2.5 Combination of development factors to determine Watershed Development Index

Threat classes and associated GIS values were assigned to each of the four development factors as shown in Table 7.

Table 7. Watershed Development Index factors

Factor and Rule	DI Class	GIS Value assigned
Road Length (in km) per km^2		
0 to 2	Low	1
3 to 5	Medium	2
6 and above	High	3
Creek Crossings per km^2		
0 to 6	Low	1
7 to 12	Medium	2
13 and above	High	3
1992 Forest Cover (as percent of land area)		
0 to 33%	High	3
34 to 66%	Medium	2
67 to 100%	Low	1
Area Logged 1992- 2004 (as percent of 1992 forest cover)		
0 to 33%	Low	1
34 to 60%	Medium	2
67 to 100%	High	3

The GIS values for each factor where then summed to give a total composite Watershed Development Index (WDI) for each watershed. The watersheds were them classified into three development index categories as follows:

- Watersheds under “high” impact from at least one of the individual development factors were classed as under “high” development overall.
- All other watersheds were classified depending on the sum of the four GIS values assigned to them as follows:

Table 8. Watershed Development Index classes

Sum of GIS values	WDI Class
4 to 5	Low
6 to 7	Medium
8 and above	High

2.6 Combination of REP and WDI into a Composite Threat Index

A composite threat index (CTI) combining REP and WDI was prepared for all watersheds on Viti Levu, Vanua Levu and Taveuni, but not the outer islands due a lack of available data to determine the relative erosion prediction (see Section 2.3). Each watershed was assigned the highest threat category of the two indices. In addition, watersheds that scored two “highs” were reassigned to a “very high” category, as an indication of cumulative threat.

3. Results

A full table of all results for all 333 mapped catchments is shown in Appendix 1.

3.1 Relative Erosion Prediction

The relative erosion prediction (REP) map for each 1 ha grid pixel is shown in Figure 9, while the mean REP per watershed is mapped in Figure 10. Watersheds of the southern and northern coasts of Viti Levu, and the northern watersheds of the Rewa River catchements have high REP values, while the southeastern coast and central watersheds, from north to south of Vanua Levu, have high REP values.

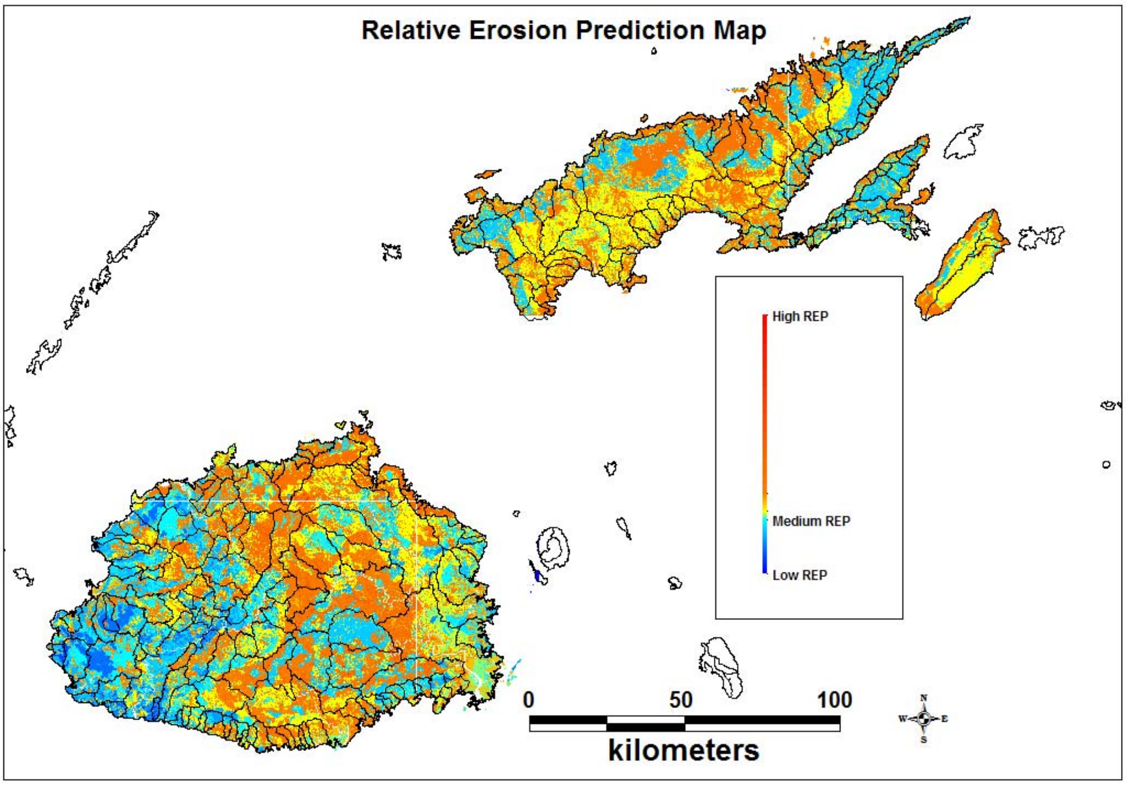

Figure 9. Predicted Relative Erosion levels superimposed on watersheds of major islands.

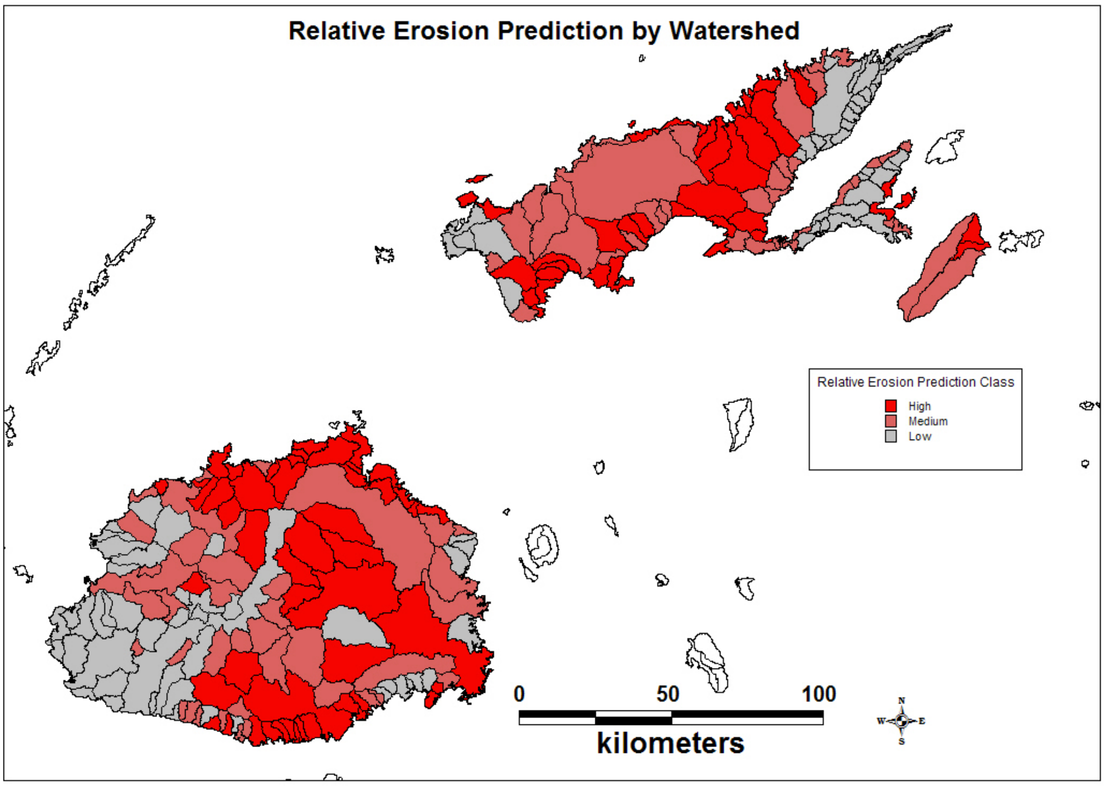

Figure 10. Mean REP in Fiji watersheds.

3.2 Watershed Development Index

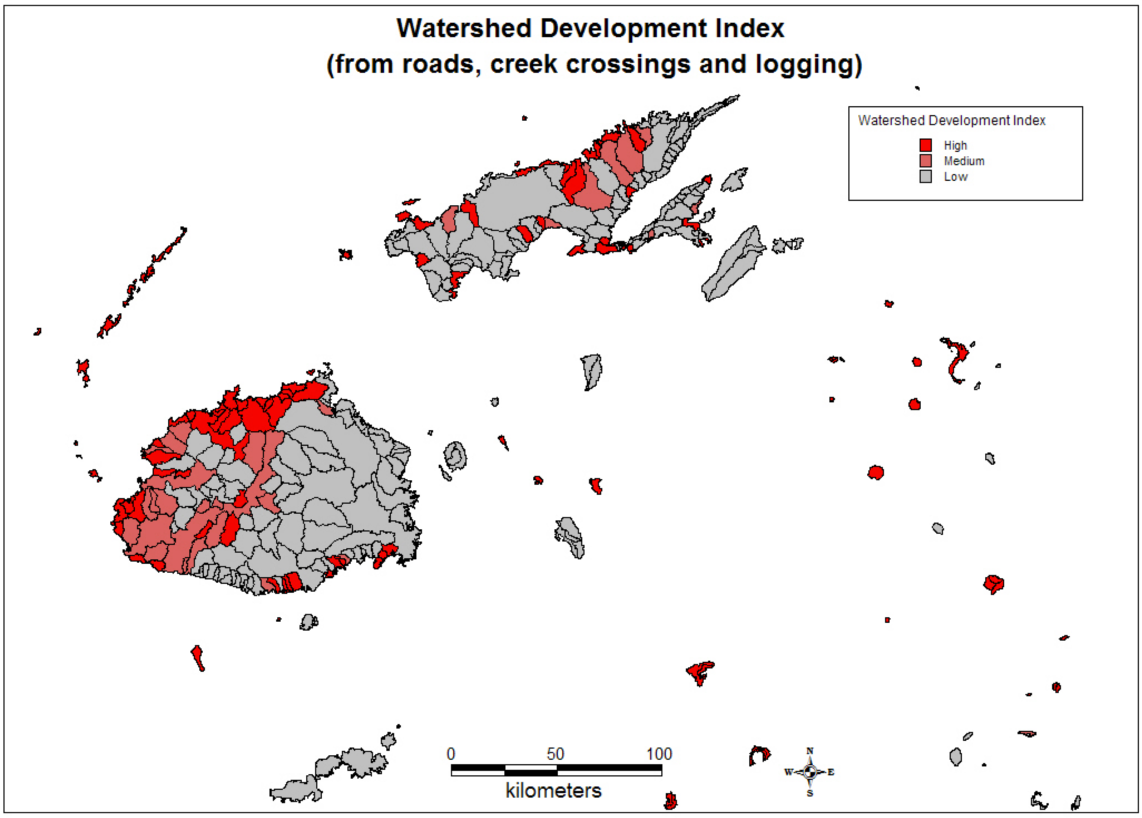

Figure 11. Watershed Development Index for each watershed.

Watershed development is most intense in the western and northern watersheds of Viti Levu and some of the coastal watersheds of southeastern Viti Levu (Figure 11). The watersheds around Labasa and Savusavu, and several in Bua, show the most intense development. Several islands in northern Lau Group and most of the islands in the Yasawas, Mamanucas, and the Yasayasa Moala Group have intensive watershed alteration.

3.3 Composite Threat Index

A summary of composite watershed threat by island is shown in Table 9, while Figure 12 is a map of the Composite Threat Index.

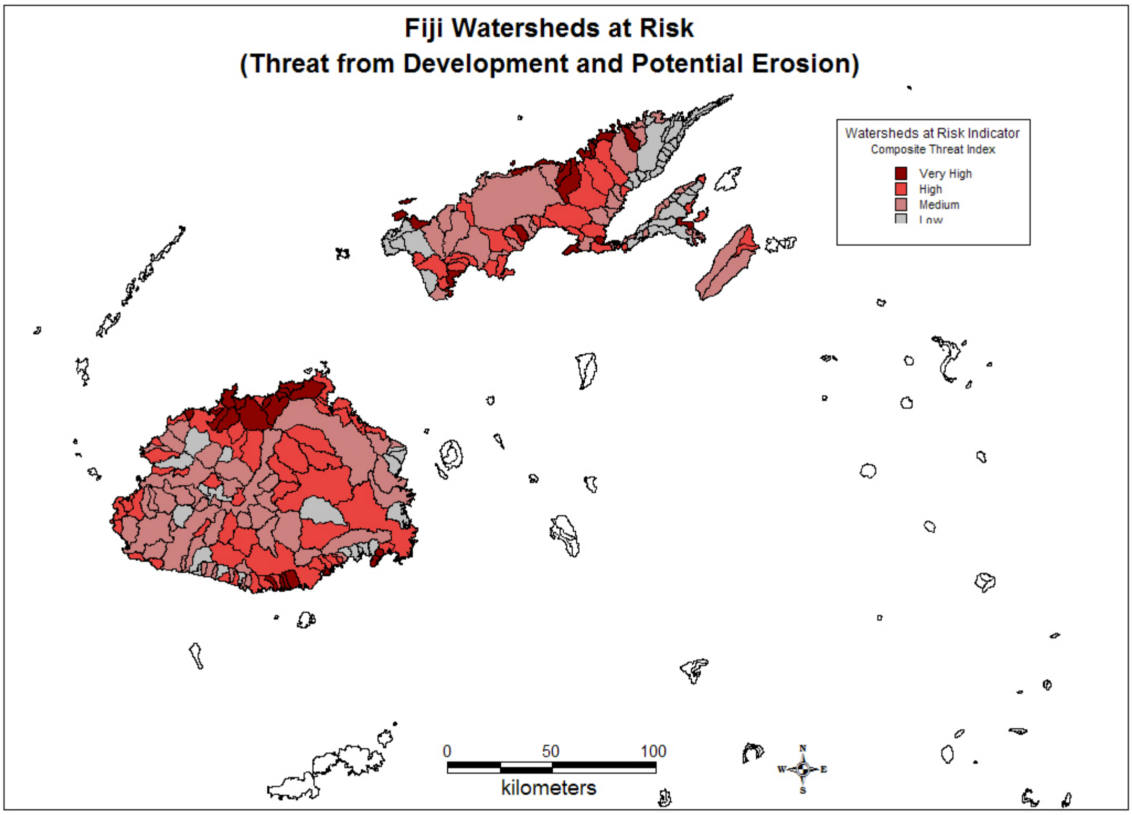

Figure 12. Composite Threat Index by watershed for major islands.

*Table 9. Composite Threat Index by major island**

Island Name	**Number of Watersheds in each Composite Threat Index Class**								
	Low CTI	*% of island*	Medium CTI	*% of island*	High CTI	*% of island*	Very High CTI	*% of island*	**Grand Total**
Taveuni	0	*0*	2	*50*	2	*50*	0	*0*	4
Vanua Levu	36	*33*	31	*28*	25	*23*	18	*16*	110
Viti Levu	20	*15*	43	*33*	48	*37*	20	*15*	131
Grand Total	**56**	***23***	**76**	***31***	**75**	***31***	**38**	***15***	**245**
Percent of all watersheds	*23*	-	*31*	-	*31*	-	*16*	-	*100*

** Outer islands were not mapped due to a lack of relevant data- see Section 2.6*

Two hundred and forty-five watersheds were assessed on Viti Levu, Vanua Levu and Taveuni, including 131 watersheds on Viti Levu, 110 on Vanua Levu and 4 on Taveuni (Table 9). Of these, 56 watersheds (23%) were classified as under low threat, 76 watersheds (31%) as under medium threat, with 75 (31%) under high threat and 38 watersheds (15%) under very high threat. Approximately half of the watersheds under the very high threat category were on each of the two main islands, with none on Taveuni. The most threatened watersheds on the major islands are in northern Viti Levu, the central Coral Coast (southern Viti Levu), and around Labasa on Vanua Levu.

3.4 Results Summary

The watersheds with the highest relative erosion prediction (REP) tend to be found in eastern and central Viti Levu and in central Vanua Levu. The watersheds with the lowest relative erosion prediction are found in western Viti Levu and in far eastern and western Vanua Levu. Development pressures (logging, road construction and creek crossings) tend to be highest in western Viti Levu and Macuata on Vanua Levu and are lowest in central and eastern Viti Levu and most of Vanua Levu, except Macuata. The combined threat from both the REP and the development factors is highest in the small coastal watersheds in northern Viti Levu in Ba and Ra provinces and in Namosi district in southern Viti Levu. On Vanua Levu, the combined threat appears greatest in Macuata Province in northern Vanua Levu. The most intact watersheds with the lowest relative erosion prediction are found in the extreme northeast tip of Vanua Levu (Udu Point) and on the Natewa Peninsula, and in Sovi Basin on Viti Levu.

4. Discussion

Although a summary of watershed status suggests a fairly even spread of watershed quality across the three main Fijian islands, there is marked variation within islands. Further, when the relative size of watersheds is considered, one can see that Taveuni still retains much natural forest cover and some of the most intact watersheds in the entire Oceanic Pacific, Viti Levu still supports several large blocks of forest and larger intact watersheds, and Vanua Levu, with comparably smaller watersheds, has fewer larger blocks of intact natural forest or watersheds than the other two. Kadavu has many intact smaller coastal watersheds.

4.1 Critical Watersheds

Several watersheds have characteristics that make them naturally prone to heavy erosion due to their steep slopes, erodible soils, and intense and highly seasonal rainfall. Such watersheds can either be still relatively intact and covered in dense forest or have already lost most of their forest cover. If forest cover is removed in forested watersheds, particularly heavy soil erosion would be expected. If such watersheds are coastal and adjacent to coral reef and critical marine habitats, it is particularly important to protect them in order to achieve Fiji NBSAP goals. Conversely, if deforested watersheds in areas prone to serious soil erosion are not reforested or managed carefully to conserve soil, they will continue to experience significant soil loss. Both types of watershed can be considered "critical" watersheds: the first are priorities for protection to maintain forest cover; while the second represent priorities for reforestation and other soil conservation measures.

Critical watersheds are thus classified as those:
1) in need of reforestation and soil conservation measures (have less than the national average forest cover of 50%);
2) in need of forest protection (have more than the national average forest cover of 50%);

A map of critical watersheds is shown in Figure 13, while Table 10 summarises the distribution of these watersheds by island. There is an almost even split between critical watersheds that need protection and those that need reforestation on the major islands. Most of the critical watersheds are found on Viti Levu and only two are found on Taveuni. The majority of the watersheds that need protection are in southern Viti Levu and southern Vanua Levu, while most of the critical watersheds that need reforestation are in northern Viti Levu and northern Vanua Levu (see Appendix 1 for the list of watershed names).

Clearly, all watersheds are critical in the sense that the nature of their forest cover and management will greatly influence the abundance and quality of freshwater and coastal marine resources available to local communities. The critical watersheds identified here are those for which a given degree of degradation will result in a proportionally larger input of soil into aquatic ecosystems. For this reason, this particular set of watersheds deserves extra protection and restoration activities. A large number of the critical watersheds are smaller coastal watersheds that are currently being logged.

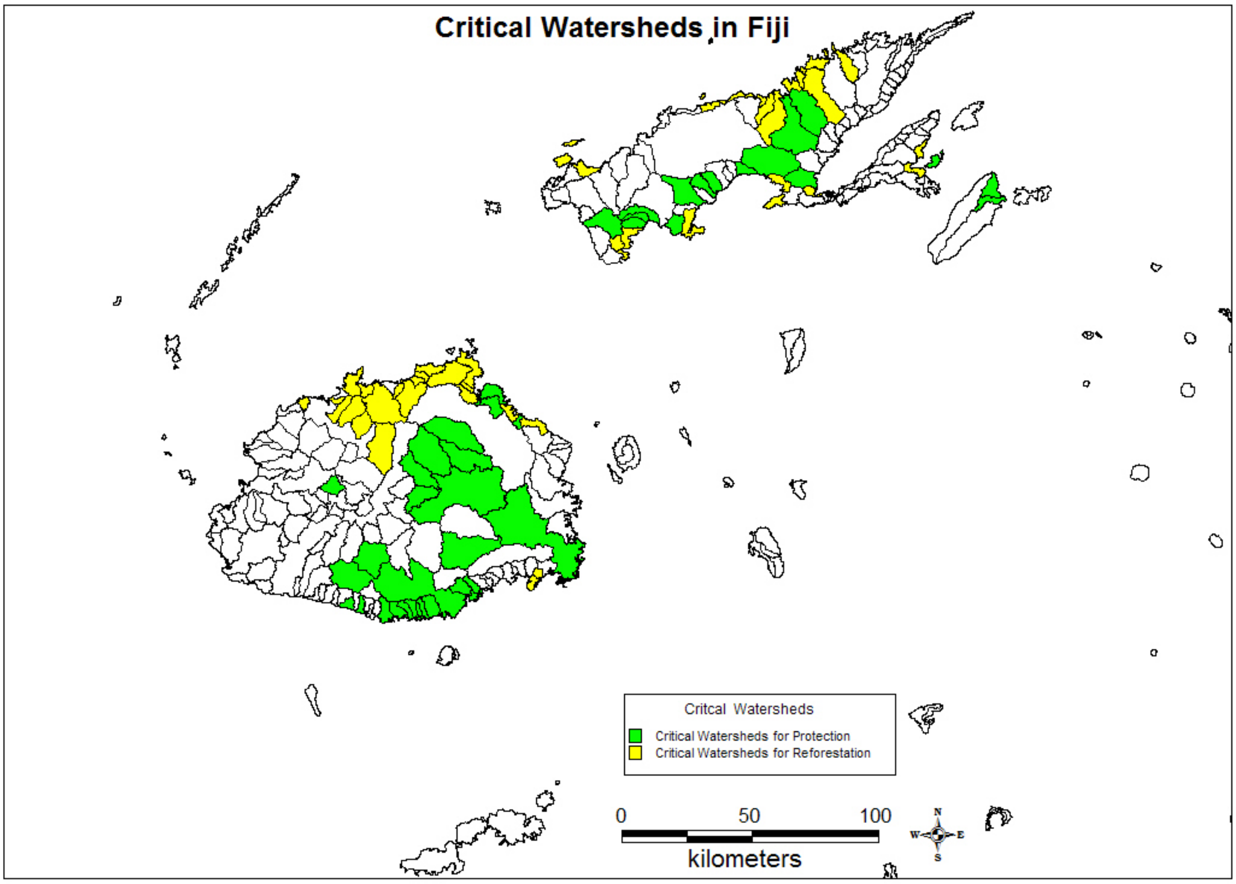

Figure 13. Critical watersheds for Fiji's major islands.

*Table 10. Critical Watersheds by major island**

	No of Critical Watersheds on each island			
Island Name	Critical for reforestation (less than 50% forest)	Critical for protection (more than 50% forest)	Grand Total	Percent of all critical watersheds
Taveuni		2	2	2
Vanua Levu	22	13	35	41
Viti Levu	22	26	48	56
Grand Total	44	41	85	100
Percent of all critical watersheds	52	48	100	-

** Outer islands were not mapped due to a lack of relevant data- see section 2.6.*

4.2 Overlay of Critical Watersheds with High Conservation Value Reefs

Fiji's National Biodiversity Strategy and Action Plan (Dept. Environment 1999) and World Wildlife Fund's Fiji Marine Ecoregion Workshop (Suva 1999) identified several reef areas that are of global significance to biodiversity conservation. These are the Great Sea Reef, the Vatu-i-Ra reefs, Namena Reef, and reefs of the southern Lau islands (Figure 14). These reefs were selected because they are particularly rich in species, have high complexity of reef types, contain unusual reef types, and have particularly intact and resilient reef ecosystems.

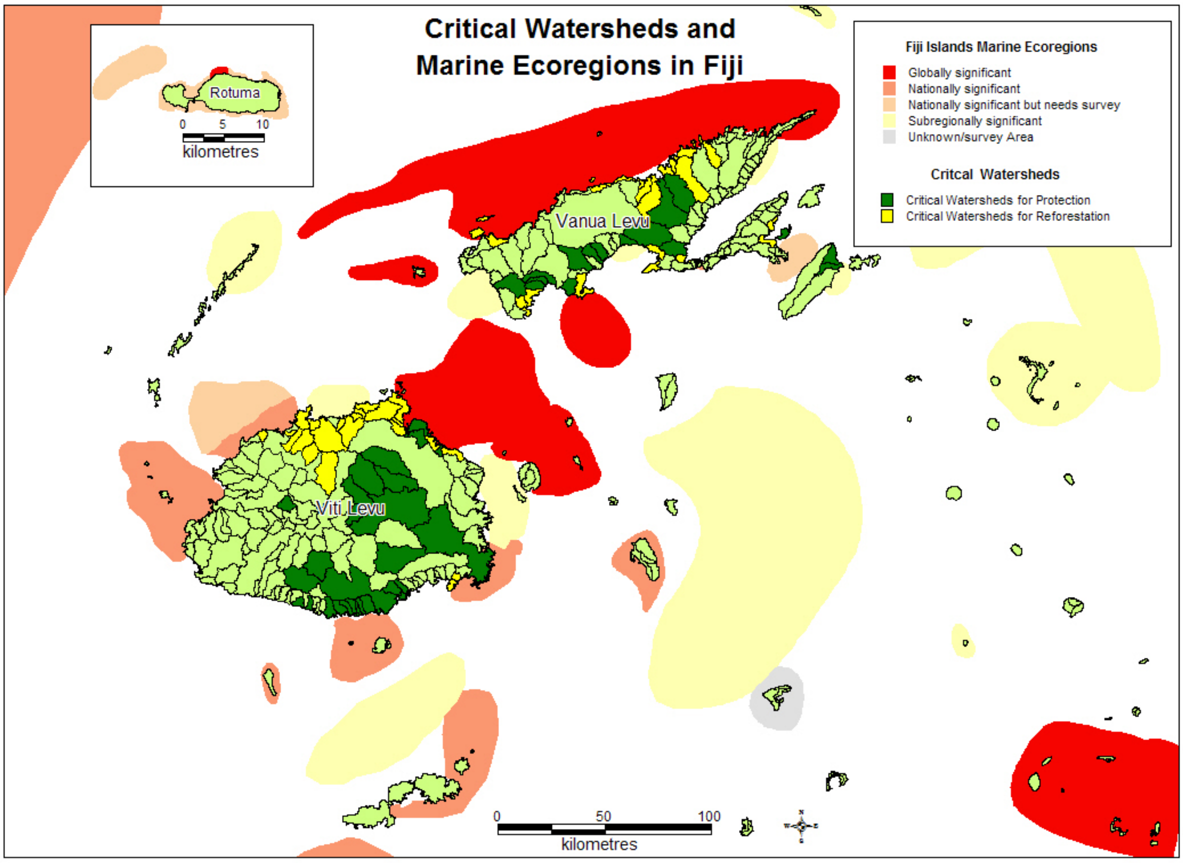

Figure 14. Critical watersheds and marine ecoregions in Fiji. Globally significant reef areas of Fiji are shown in red (WWF FIME Workshop, Suva, 2002).

Those watersheds that are adjacent to these globally significant reefs require protection and restoration in order to help maintain the outstanding features of the marine ecosystems and local fisheries. The critical watersheds important for reef conservation are primarily located along the northeast coast of Viti Levu (Ra Province), the southeastern coast of Vanua Levu (Bua), and the western and north-central coast of Vanua Levu (Macuata) (Figure 14). All watersheds in Fiji should be well-managed in order to sustain local fisheries (freshwater and marine), maintain clean water, and reduce flood damage. However, this particular subset can greatly impact the health of priority reefs for conservation due to their high erosion potential and adjacency to the reefs. For this reason, their natural forests deserve extra effort for protection or restoration.

4.3 Logging in Smaller Coastal Watersheds & Fisheries

We propose that subsistence fisheries for local communities are particularly threatened by logging in smaller coastal watersheds throughout Fiji. Clearly, overfishing has a major influence on the quality and quantity of these fisheries, but nutrient-loading and sedimentation from degraded watersheds has an equal, and perhaps more long-term, impact on coastal ecosystems.

This hypothesis is based on the following argument. The majority of coastal marine ecosystems and local fisheries are directly adjacent to smaller coastal watersheds. Sediment plumes from larger rivers influence only a small portion of Fiji's reefs, and some of these reef communities are adapted to intrusions of freshwater and periodic, high sediment-loads. Reefs adjacent to smaller coastal watersheds are also periodically exposed to high sediment loads, but not to the extent of those near larger rivers. Smaller coastal watersheds are generally steeper and have lower retention capacity for sediments. Sedimentation of coastal lagoons and reefs causes corals to die and have reduced growth and recruitment through smothering, abrasion, shading, and inhibition of settlement of larvae (Birkeland 1997). However, most corals are able to deal with periodic, and short-term heavy sedimentation events. Logging causes persistent high sediment loads, particularly in higher rainfall areas, for up to a decade afterwards. Simply put, coral reefs are not adapted to the long-term stress imposed by persistent sedimentation, even low-level sedimentation, and associated elevation in nutrients that is associated with sedimentation (Furnas 2003). Long-term degradation of reef ecosystems is driven, in large part, by nutrient loading in nearshore areas of the Great Barrier Reef of Australia (Furnas 2003).

Degradation of coral reefs and fisheries from logging has been documented in the Philippines and Costa Rica (Cortes & Risk 1985; Hodgson & Dixon 2000). In Bacuit Bay, Palawan, an eleven-fold increase in sediments associated with logging in coastal watersheds was associated with a 20% decrease in coral cover, a 95% drop in coral species richness, and an 80% decline in fish catch over a ten-year period (Hodgson & Dixon 1988, 2000). After logging ceased, no recovery was seen for at least five years. Major stressing of ecosystems, whether it be through overfishing or impacts associated with watershed degradation, may irreversibly shift ecosystems to different states, perhaps less productive ones from a fisheries perspective.

For these reasons, we believe it is logging in smaller coastal watersheds that is having, along with overfishing, the biggest influence on the decline of nearshore subsistence and domestic fisheries. Clearing of forests for agriculture does cause erosion, but not to the degree caused by road building during logging operations. Fiji, from local landowners to government agencies, should carefully consider the benefits versus the costs of logging smaller coastal watersheds.

4.4 Conservation and Resource Management Implications

This study has established a basic methodology for modelling and mapping predicted soil erosion from Fijian watersheds based on their physical parameters of soil, rainfall, slopes and land cover. We have also elaborated a simple method for mapping the relative impact of development pressures such as logging, roads and creek crossings on watersheds and on combining the erosion model and a map of development pressures into a composite threat index. The study highlights the critical watersheds that are naturally prone to heavy soil erosion due to their steep slopes, erodible soils and intense and highly seasonal rainfall. Many of these critical watersheds are currently under serious threat from logging and other forms of development. Some of the critical watersheds are coastal catchments that have a particularly significant impact on adjacent reefs and fisheries. It is important to identify and map such catchments as they should become priorities for soil conservation and forest protection efforts to enhance Fiji's important coastal and marine resources.

Forests within critical watersheds, particularly those adjacent to globally significant reef ecosystems, should be considered for inclusion into the incipient Protected Forest Network being discussed within government. The location of theses forests should be considered in the ongoing revision of the Forest Function map of Fiji—critical watersheds should be classified under Protection Forests—as well as in the concession and development planning of NLTB, Forestry, and Lands.

Data verification with field data of real erosion rates is necessary to test and calibrate the relative erosion model, the development indices and the overall methodology and assumptions made. GIS datasets of soils and seasonal rainfall for Vanua Levu and the outer islands are needed to improve the erosion model for these areas. Furthermore, more work is required to quantify the impacts of watershed degradation on the adjacent coral reef areas, especially those of high value. Once a map of reef status is available (in prep. Dept. Fisheries, WCS), it will then be possible to relate reef status to watershed status and to identify reefs at particular risk from degraded watersheds, and conversely to identify those watersheds that are of particular importance to adjacent high value reefs.

Research Recommendations

Based on experience working with existing data, we recommend that further studies in the following areas be conducted:

- quantification of river flow and discharge rates in a range of watersheds of different quality on different islands;
- collection of data on slopes, soils, rainfall intensity, rainfall seasonality and land cover on the outer islands;
- assessment of coral reef mortality from riverine sediment and other pollutants;
- assessment and mapping of reef habitats and reef quality;
- quantification of soil erosion impacts from infrastructural developments such as roads, creek crossings and logging;
- analysis of satellite imagery to determine offshore and coastal currents, and to study sediment plumes from watersheds after heavy rainfall events.

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Appendix 1: Watershed Characteristics and Status for the Fijian Archipelago.

Island Name	Catchment Name	Sub Catchment Name	Area (Ha)	Viti Levu REP	Vanua Levu REP	REP Class*	Creek Crossings/ km^2	Rd Length/ km^2	Forest %	Logged Area (% of 92 forest)	WDI Index*	Combined Threat Index*	Critical Index*
Avea	Avea Island		238	-	-	0	1	1.31	63	0	1	0	0
Batiki	Batiki Island		943	-	-	0	3	1.16	0	0	3	0	0
Beqa	Beqa Island		3684	-	-	0	1	0.49	55	0	1	0	0
Bulia	Bulia		168	-	-	0	0	0.00	0	0	3	0	0
Cicia	Cicia		3520	-	-	0	0	0.00	15	0	3	0	0
Cikobia	Cikobia Island		1203	-	-	0	0	1.56	0	0	3	0	0
Cikobia-I-Lau	Cikobia-I-Lau		283	-	-	0	0	0.00	98	0	1	0	0
Gau	Waiboteigau Creek		1562	-	-	0	1	0.87	97	0	1	0	0
Gau	Gau North		5578	-	-	0	2	0.96	52	0	1	0	0
Gau	Gau South East		2712	-	-	0	3	1.07	69	0	1	0	0
Gau	Gau West		3995	-	-	0	2	1.23	59	0	1	0	0
Kabara	Kabara Island		3148	-	-	0	2	0.60	100	0	1	0	0
Kadavu	Kadavu West		17046	-	-	0	3	0.96	68	0	1	0	0
Kadavu	Kadavu Central		8085	-	-	0	2	1.04	84	0	1	0	0
Kadavu	Kadavu East		18193	-	-	0	1	0.43	83	0	1	0	0
Kaibu	Kaibu Island		144	-	-	0	1	0.44	0	0	3	0	0
Kanacea	Kanacea Island		1256	-	-	0	0	0.00	0	0	3	0	0
Kia	Kia		160	-	-	0	1	0.64	27	0	3	0	0
Kioa	Kioa Island		1835	-	5.887	3	0	0.00	77	0	1	3	2
Komo	Komo		166	-	-	0	17	3.74	0	0	3	0	0
Koro	Koro East		5352	-	-	0	3	1.60	53	0	1	0	0
Koro	Koro West		5060	-	-	0	2	1.46	64	0	1	0	0
Kuata	Kuata		142	-	-	0	0	0.00	0	0	3	0	0
Lakeba	Lakeba East		1837	-	-	0	3	2.82	19	0	3	0	0
Lakeba	Lakeba North		1615	-	-	0	2	2.37	11	0	3	0	0
Lakeba	Lakeba West		1949	-	-	0	2	3.18	25	0	3	0	0
Laucala	Laucala		1260	-	-	0	0	0.00	47	0	1	0	0
Mago	Mago Island		2161	-	-	0	0	0.00	0	0	3	0	0

Island Name	Catchment Name	Sub Catchment Name	Area (Ha)	Viti Levu REP	Vanua Levu REP	REP Class*	Creek Crossings/ km^2	Rd Length/ km^2	Forest %	Logged Area (% of 92 forest)	WDI Index*	Combined Threat Index*	Critical Index*
Makogai	Makogai		845	-	-	0	4	1.49	99	0	1	0	0
Malake	Malake		445	10.143	-	0	1	0.41	4	0	3	0	0
Malolo	Malolo		933	-	-	0	3	2.06	0	0	3	0	0
Malolo LaiLai	Malolo Lailai		221	-	-	0	0	2.76	0	0	3	0	0
Mana	Mana		113	-	-	0	0	2.50	0	0	3	0	0
Marabo	Marabo Island		108	-	-	0	0	0.00	0	0	3	0	0
Matacawa Levu	Matacawa Levu		944	-	-	0	1	1.19	26	0	3	0	0
Matuku	Matuku East		1559	-	-	0	2	1.03	4	0	3	0	0
Matuku	Matuku West		1341	-	-	0	2	0.80	8	0	3	0	0
Moala	Moala East		1745	-	-	0	5	1.24	27	0	3	0	0
Moala	Moala West		4683	-	-	0	2	1.00	33	0	3	0	0
Moce	Moce East		567	-	-	0	1	0.35	6	0	3	0	0
Moce	Moce West		505	-	-	0	1	0.43	6	0	3	0	0
Moturiki	Moturiki Island		1125	-	-	0	4	1.68	62	0	1	0	0
Munia	Munia Island		464	-	-	0	0	0.00	39	0	1	0	0
Nacula	Nacula Island		2124	-	-	0	1	0.32	17	0	3	0	0
Naigani	Naigani Island		205	-	-	0	1	0.60	71	0	1	0	0
Nairai	Nairai		2421	-	-	0	3	0.97	0	0	3	0	0
Naitauba	Naitauba		709	-	-	0	0	0.00	0	0	3	0	0
Namuka-i-Lau	Namuka-i-Lau Island		1057	-	-	0	7	1.12	48	0	2	0	0
Nananu- i-Cake	Nananu- i-Cake Island		223	9.947	-	0	0	1.61	23	0	3	0	0
Nananu-i-Ra	Nananu-i-Ra Island		275	10.029	-	0	0	0.00	15	0	3	0	0
Nanuya Levu	Nanuya Levu		138	-	-	0	0	0.00	43	0	1	0	0
Naqelelevu	Naqelelevu Island		144	-	-	0	0	0.00	0	0	3	0	0
Naviti	Naviti		3376	-	-	0	0	0.13	31	0	3	0	0
Nayau	Nayau Island		1817	-	-	0	0	0.00	79	0	1	0	0
Ogea Driki	Ogea Driki Island		528	-	-	0	0	0.89	100	0	1	0	0
Ogea Levu	Ogea Levu Island		1189	-	-	0	0	0.27	100	0	1	0	0
Oneata	Oneata Island		448	-	-	0	0	0.58	14	0	3	0	0
Ono-i-Lau	Ono-i-Lau		640	-	-	0	3	2.35	0	0	3	0	0
Ovalau	Bureta River		3154	-	-	0	1	0.51	87	0	1	0	0

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Ovalau	Ovalau West		2583	-	-	0	3	1.05	73	0	1	0	0
Ovalau	Ovalau East		4517	-	-	0	2	0.99	60	0	1	0	0
Qamea	Qamea		3493	-	-	0	2	0.51	79	0	1	0	0
Rabi	Rabi Island		6627	-	-	0	2	0.74	77	0	1	0	0
Rotuma	Rotuma Island		4367	-	-	0	0	2.22	51	0	2	0	0
Susui	Susui Island		335	-	-	0	0	0.00	17	0	3	0	0
Taveuni	Taveuni North		4139	-	5.780	3	1	0.69	64	0	1	3	2
Taveuni	Waibula River		3085	-	5.531	3	1	0.43	83	0	1	3	2
Taveuni	Taveuni West		18306	-	5.328	2	2	1.16	60	0	1	2	0
Taveuni	Taveuni East		18087	-	5.314	2	0	0.30	84	0	1	2	0
Tavewa	Tavewa		154	-	-	0	2	1.62	0	0	3	0	0
Tavua	Tavua		185	-	-	0	0	0.00	0	0	3	0	0
Totoya	Totoya North		1868	-	-	0	1	0.31	24	0	3	0	0
Totoya	Totoya South		1171	-	-	0	2	1.14	26	0	3	0	0
Tuvuca	Tuvuca Island		1328	-	-	0	0	0.00	100	0	1	0	0
Vanua Levu	Batiri		2491	-	6.032	3	0	0.42	48	2	1	3	1
Vanua Levu	Wainunu River		19831	-	5.326	2	1	1.26	80	13	1	2	0
Vanua Levu	Kilaka		2474	-	5.278	2	0	0.44	80	15	1	2	0
Vanua Levu	Natovatu		3877	-	5.409	3	1	1.17	78	4	1	3	2
Vanua Levu	Natua		1438	-	5.389	2	1	0.80	75	6	1	2	0
Vanua Levu	Waikotoavou Creek		1785	-	5.391	2	0	0.20	80	71	3	3	0
Vanua Levu	Nasekawa River		20116	-	5.850	3	0	0.20	71	0	1	3	2
Vanua Levu	Solove River		4355	-	5.245	2	1	0.37	52	0	1	2	0
Vanua Levu	Koroalau River		6342	-	5.370	2	0	0.23	80	4	1	2	0
Vanua Levu	Dawato River		1625	-	4.622	1	4	0.96	77	0	1	1	0
Vanua Levu	Vatudiriniu		1263	-	4.757	1	0	0.14	64	16	1	1	0
Vanua Levu	Mataniwai River		1156	-	4.983	1	3	1.82	38	17	1	1	0
Vanua Levu	Kasavu River		1181	-	4.553	1	5	2.47	54	0	2	2	0
Vanua Levu	Vidawa Creek		823	-	5.077	2	3	1.13	52	0	1	2	0
Vanua Levu	Buca River		7674	-	4.394	1	2	1.52	84	1	1	1	0
Vanua Levu	Qaloqalo River		845	-	5.031	2	5	1.32	43	0	1	2	0

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Vanua Levu	Lumiboso		4703	-	4.478	1	1	0.25	82	7	1	1	0
Vanua Levu	Nasagale		1279	-	4.407	1	1	0.73	79	0	1	1	0
Vanua Levu	Viani		703	-	4.434	1	0	0.11	13	0	3	3	0
Vanua Levu	Votua River		12459	-	5.163	2	1	1.83	71	6	1	2	0
Vanua Levu	Sarowaqa River		15674	-	5.288	2	1	1.59	74	11	1	2	0
Vanua Levu	Dama River		9599	-	5.543	3	1	0.62	65	2	1	3	2
Vanua Levu	Tabia River		7651	-	5.317	2	2	1.82	47	12	1	2	0
Vanua Levu	Wailevu		11493	-	6.071	3	3	3.97	22	34	3	4	1
Vanua Levu	Qawa River		15205	-	5.648	3	2	1.96	54	33	1	3	2
Vanua Levu	Labasa River		20728	-	5.660	3	2	2.51	61	9	2	3	2
Vanua Levu	Qaloyago River		4116	-	5.771	3	3	3.32	26	66	3	4	1
Vanua Levu	Dreketi River		85053	-	5.342	2	1	1.95	57	26	1	2	0
Vanua Levu	Yanucari Creek		1635	-	6.428	3	2	1.55	10	0	3	4	1
Vanua Levu	Ravuka		1582	-	4.674	1	4	1.88	65	0	1	1	0
Vanua Levu	Wainikoro River		17199	-	5.323	2	5	2.47	57	53	2	2	0
Vanua Levu	Bourewa River		2136	-	4.176	1	1	0.50	88	8	1	1	0
Vanua Levu	Nakura River		1305	-	4.401	1	6	1.83	80	0	1	1	0
Vanua Levu	Tivo		1117	-	4.499	1	4	0.90	76	3	1	1	0
Vanua Levu	Nabouono		2006	-	5.845	3	1	0.81	15	38	3	4	1
Vanua Levu	Bucalevu		980	-	6.530	3	3	4.05	5	0	3	4	1
Vanua Levu	Nasinu		1083	-	4.925	1	2	0.68	54	7	1	1	0
Vanua Levu	Tawake		2118	-	4.812	1	2	0.81	60	0	1	1	0
Vanua Levu	Saqali		2136	-	4.763	1	3	0.90	61	0	1	1	0
Vanua Levu	Natewa		1979	-	5.458	3	1	0.60	23	0	3	4	1
Vanua Levu	Nabalebale		704	-	5.306	2	1	0.48	35	0	1	2	0
Vanua Levu	Naqaiqai		1682	-	5.116	2	0	0.33	34	0	1	2	0
Vanua Levu	Valesavu		2175	-	4.650	1	2	0.93	67	0	1	1	0
Vanua Levu	Nawaido		926	-	6.864	3	2	1.60	6	0	3	4	1
Vanua Levu	Wairiki		6272	-	4.863	1	2	0.96	71	37	1	1	0
Vanua Levu	Yanawai River		10500	-	5.406	3	1	1.15	79	26	1	3	2
Vanua Levu	Dogoru River		2542	-	5.377	2	0	0.99	77	3	1	2	0

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Vanua Levu	Macuata-i-Wai		307	-	5.834	3	0	0.10	9	0	3	4	1
Vanua Levu	Yaqaga		955	-	5.892	3	1	0.57	12	0	3	4	1
Vanua Levu	Vanuakumi		1797	-	4.755	1	6	1.77	62	0	1	1	0
Vanua Levu	Lakeba		2010	-	4.680	1	2	0.58	65	1	1	1	0
Vanua Levu	Natuvu		1215	-	4.604	1	3	0.91	68	6	1	1	0
Vanua Levu	Navetau		1212	-	4.627	1	2	0.35	65	0	1	1	0
Vanua Levu	Nasoni River		3081	-	4.724	1	3	1.06	72	23	1	1	0
Vanua Levu	Nakarabo		1731	-	5.147	2	2	0.83	41	100	3	3	0
Vanua Levu	Korotasere		2838	-	5.031	2	1	0.36	68	12	1	2	0
Vanua Levu	Koronatoga		2501	-	5.005	2	2	0.70	54	15	1	2	0
Vanua Levu	Mariko River		7076	-	5.658	3	0	0.23	50	0	1	3	2
Vanua Levu	Nailoilo		665	-	5.087	2	0	0.24	44	22	1	2	0
Vanua Levu	Dreketi Creek		1493	-	4.815	1	3	0.69	71	0	1	1	0
Vanua Levu	Wainivatu		2236	-	5.260	2	3	0.93	42	5	1	2	0
Vanua Levu	Naqaravutu		1271	-	5.062	2	2	0.50	61	0	1	2	0
Vanua Levu	Nanuca		3892	-	4.286	1	3	1.22	53	21	1	1	0
Vanua Levu	Tacilevu		2144	-	4.605	1	2	0.90	35	0	1	1	0
Vanua Levu	Nukubalavu		2319	-	5.694	3	2	2.04	13	0	3	4	1
Vanua Levu	Nakelikoso River		3721	-	5.294	2	1	1.00	39	0	1	2	0
Vanua Levu	Nadamole		3111	-	5.511	3	0	0.76	39	0	1	3	1
Vanua Levu	Codreudreu		2809	-	5.559	3	1	0.43	59	42	2	3	2
Vanua Levu	Natuvu		4879	-	5.326	2	0	0.58	82	3	1	2	0
Vanua Levu	Raviravi		5377	-	6.019	3	0	0.59	44	14	1	3	1
Vanua Levu	Nakabuta		4138	-	5.457	3	0	0.57	72	6	1	3	2
Vanua Levu	Nalomate River		4835	-	5.600	3	0	0.29	68	0	1	3	2
Vanua Levu	Korolevu River		3238	-	5.905	3	0	0.20	53	0	1	3	2
Vanua Levu	Nasavu		3452	-	6.310	3	0	0.53	33	0	3	4	1
Vanua Levu	Nabau		3725	-	5.378	2	1	0.34	48	1	1	2	0
Vanua Levu	Luvuluvu		13088	-	4.625	1	2	1.22	80	13	1	1	0
Vanua Levu	Vatubogi		3449	-	4.600	1	2	1.00	67	0	1	1	0
Vanua Levu	Vaganai		5458	-	4.947	1	1	0.74	52	3	1	1	0

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Vanua Levu	Aileya Creek		5721	-	5.574	3	1	0.94	24	26	3	4	1
Vanua Levu	Nakalavo		7125	-	5.209	2	1	3.46	36	4	2	2	0
Vanua Levu	Draunivuga		5797	-	5.225	2	0	1.69	51	94	3	3	0
Vanua Levu	Raviravi		4535	-	5.362	2	1	1.45	35	1	1	2	0
Vanua Levu	Sasa		1878	-	6.085	3	2	1.54	7	0	3	4	1
Vanua Levu	Qaranisisi		4861	-	5.089	2	4	2.08	60	6	2	2	0
Vanua Levu	Nabubou		2757	-	5.153	2	3	0.99	43	0	1	2	0
Vanua Levu	Vunivia River		5683	-	4.198	1	2	0.83	88	2	1	1	0
Vanua Levu	Nadawa Bay		1880	-	4.451	1	0	0.13	59	9	1	1	0
Vanua Levu	Narara		3283	-	4.524	1	1	0.37	73	17	1	1	0
Vanua Levu	Delaimaravu		3688	-	5.400	2	2	1.18	28	0	3	3	0
Vanua Levu	Vunisavisavi		5257	-	4.342	1	1	0.58	65	0	1	1	0
Vanua Levu	Loa		2380	-	5.413	3	5	1.66	30	0	3	4	1
Vanua Levu	Qaranibali		708	-	4.856	1	2	0.76	64	0	1	1	0
Vanua Levu	Dama		983	-	5.342	2	4	1.38	34	0	1	2	0
Vanua Levu	Salia		1240	-	5.207	2	2	0.68	55	0	1	2	0
Vanua Levu	Kubulau		1060	-	5.395	2	2	0.78	26	0	3	3	0
Vanua Levu	Vunivutu		4067	-	5.980	3	4	2.01	14	50	3	4	1
Vanua Levu	Naboutini		779	-	4.904	1	4	0.79	54	0	1	1	0
Vanua Levu	Udu		1115	-	4.613	1	1	0.62	62	0	1	1	0
Vanua Levu	Dromuninuku		1202	-	5.269	2	4	1.42	29	12	3	3	0
Vanua Levu	Taveti		3457	-	4.901	1	1	0.94	55	0	1	1	0
Vanua Levu	Lagalaga River		6105	-	5.789	3	7	3.76	31	0	3	4	1
Vanua Levu	Nakanakana		1771	-	5.511	3	5	1.62	34	42	2	3	1
Vanua Levu	Malau		2476	-	5.990	3	1	0.79	16	2	3	4	1
Vanua Levu	Nakawaka River		2091	-	5.886	3	0	0.36	53	0	1	3	2
Vanua Levu	Qelewara		2499	-	5.051	2	4	1.65	44	0	1	2	0
Vanua Levu	Bucaisau River		15085	-	5.694	3	2	1.38	44	45	2	3	1
Vanua Levu	Drekeniwai River		4935	-	4.705	1	2	1.20	64	7	1	1	0
Vanua Levu	Nasavu River		21876	-	4.451	1	2	0.76	92	22	1	1	0
Vanua Levu	Nasavu		3721	-	5.409	3	0	1.13	75	86	3	4	2

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Vanua Levu	Vunivau		2724	-	5.336	2	6	3.29	28	0	3	3	0
Vanua Vatu	Vanuavatu Island		403	-	-	0	0	0.26	0	0	3	0	0
Vanuabalavu	Vanuabalavu East		5617	-	-	0	1	0.69	20	0	3	0	0
Vatoa	Vatoa		394	-	-	0	0	1.23	0	0	3	0	0
Vatulele	Vatulele Island		3053	-	-	0	0	1.00	0	0	3	0	0
Vatuvara	Vatuvara		340	-	-	0	0	0.00	100	0	1	0	0
Viti Levu	Nubulotulotu Creek		1579	10.085	-	2	2	1.17	64	0	1	2	0
Viti Levu	Muanidele Creek		2587	8.247	-	1	2	1.23	74	12	1	1	0
Viti Levu	Qaraniqio		4226	10.552	-	3	1	1.66	58	100	3	4	2
Viti Levu	Korovisilou		3900	10.423	-	3	2	1.00	65	11	1	3	2
Viti Levu	Samabula		1260	10.337	-	3	2	5.50	4	0	3	4	1
Viti Levu	Tamavua		2906	8.606	-	1	1	2.16	68	0	1	1	0
Viti Levu	Lami		2154	9.353	-	1	0	1.26	75	0	1	1	0
Viti Levu	Waivudawa		695	8.952	-	1	3	1.54	85	18	1	1	0
Viti Levu	Naikorokoro		1922	9.394	-	1	1	0.40	75	48	1	1	0
Viti Levu	Naboro		1042	9.595	-	2	3	1.90	69	71	3	3	0
Viti Levu	Wainadoi		2441	10.103	-	2	3	1.64	69	72	3	3	0
Viti Levu	Yako		3075	8.688	-	1	15	6.05	6	0	3	3	0
Viti Levu	Marika Creek		3133	8.252	-	1	4	4.56	1	0	3	3	0
Viti Levu	Vuda		7604	9.291	-	1	2	2.25	33	0	3	3	0
Viti Levu	Lawaki		2986	8.581	-	1	1	3.04	45	0	2	2	0
Viti Levu	Musuniwai Creek		1670	7.949	-	1	1	5.22	3	0	3	3	0
Viti Levu	Vitogo Creek		7577	10.119	-	2	2	2.21	35	0	2	2	0
Viti Levu	Teidamu Creek		7248	7.859	-	1	3	3.12	55	0	2	2	0
Viti Levu	Tavarau		2553	10.224	-	2	5	3.25	20	49	3	3	0
Viti Levu	Nakavika		1646	11.146	-	3	6	3.91	10	0	3	4	1
Viti Levu	Yaqara River		9682	11.516	-	3	2	1.10	24	0	3	4	1
Viti Levu	Nasivi River		16693	10.754	-	3	4	3.03	26	15	3	4	1
Viti Levu	Waisai Creek		1607	11.101	-	3	1	0.99	1	0	3	4	1
Viti Levu	Rabulu		1793	10.236	-	2	3	1.86	1	0	3	3	0
Viti Levu	Togovere		1353	10.894	-	3	2	1.06	2	0	3	4	1

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Viti Levu	Penang River		10224	11.176	-	3	3	1.58	18	0	3	4	1
Viti Levu	Nasililivatu Creek		954	11.218	-	3	1	0.47	47	0	1	3	1
Viti Levu	Rukuruku Creek		4501	10.969	-	3	2	1.10	55	0	1	3	2
Viti Levu	Naqele		1189	11.815	-	3	0	0.05	54	0	1	3	2
Viti Levu	Naimasi Creek		1875	8.950	-	1	1	0.58	83	1	1	1	0
Viti Levu	Namatakula		1493	9.624	-	2	2	0.96	67	29	1	2	0
Viti Levu	Nawaqadamu Creek		1479	9.641	-	2	1	1.31	84	0	1	2	0
Viti Levu	Namada		1218	8.313	-	1	4	2.25	68	0	1	1	0
Viti Levu	Vusu		1356	6.345	-	1	1	2.24	41	0	2	2	0
Viti Levu	Qilai		2248	10.708	-	3	3	1.41	71	54	1	3	2
Viti Levu	Mau		1080	11.305	-	3	5	1.82	64	79	3	4	2
Viti Levu	Taunovo		1618	10.337	-	3	1	1.37	68	100	3	4	2
Viti Levu	Wainiyabia		1095	10.373	-	3	2	0.91	76	96	3	4	2
Viti Levu	Drodrowa Creek		1150	9.979	-	2	3	1.20	62	0	1	2	0
Viti Levu	Naboutini		1506	9.363	-	1	2	0.99	88	18	1	1	0
Viti Levu	Navutulevu		1579	10.426	-	3	2	1.06	68	0	1	3	2
Viti Levu	Vatukulelima		1221	9.581	-	2	3	1.87	83	0	1	2	0
Viti Levu	Valase		2696	9.531	-	2	2	2.01	81	6	1	2	0
Viti Levu	Sanasana		2248	7.529	-	1	8	5.55	9	0	3	3	0
Viti Levu	Tamuqali Creek		1123	11.167	-	3	4	4.38	0	0	3	4	1
Viti Levu	Natunuku		1206	10.122	-	2	3	2.81	5	0	3	3	0
Viti Levu	Vatutavui		5295	10.569	-	3	2	2.21	10	0	3	4	1
Viti Levu	Wainacibayawa Creek		2276	10.582	-	3	6	4.84	8	0	3	4	1
Viti Levu	Drauniivi		1340	10.874	-	3	3	1.18	9	0	3	4	1
Viti Levu	Barotu		3279	11.462	-	3	4	2.02	37	0	2	3	1
Viti Levu	Navuniivi		4638	11.137	-	3	1	0.64	56	0	1	3	2
Viti Levu	Namarai		2473	12.216	-	3	2	0.77	41	2	1	3	1
Viti Levu	Nasinu		3317	11.629	-	3	2	1.13	34	0	1	3	1
Viti Levu	Natovi		2871	9.424	-	1	2	0.82	86	4	1	1	0
Viti Levu	Sawakasa		5128	9.439	-	1	1	0.73	80	24	1	1	0
Viti Levu	Vatuwaqa		1782	10.395	-	3	2	7.61	4	0	3	4	1

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Viti Levu	Togalevu		1439	9.461	-	1	4	2.04	58	36	2	2	0
Viti Levu	Rukurukulevu		2614	7.384	-	1	5	3.45	17	0	3	3	0
Viti Levu	Momi		4910	8.273	-	1	14	5.53	21	0	3	3	0
Viti Levu	Tau		2539	7.005	-	1	12	5.22	34	0	3	3	0
Viti Levu	Qerekuro		1576	9.686	-	2	3	1.71	54	0	1	2	0
Viti Levu	Ellington		6272	11.542	-	3	4	1.80	45	0	1	3	1
Viti Levu	Vunidogoloa		3445	10.548	-	3	4	1.61	1	0	3	4	1
Viti Levu	Nawai Creek		7178	8.237	-	1	10	5.07	25	0	3	3	0
Viti Levu	Rewa	Wainavombo	20043	9.063	-	1	0	0.02	87	0	1	1	0
Viti Levu	Rewa	Wainidina	22527	10.353	-	3	1	0.45	70	16	1	3	2
Viti Levu	Rewa	Lawaki	17322	10.317	-	3	3	1.69	75	1	1	3	2
Viti Levu	Dawasamu River		7874	9.930	-	2	0	0.30	87	7	1	2	0
Viti Levu	Waibula River		15002	10.045	-	2	2	1.61	65	32	1	2	0
Viti Levu	Navunimono		15042	9.727	-	2	1	1.61	67	22	1	2	0
Viti Levu	Rewa	Wainibuka	74567	10.282	-	2	2	1.27	64	2	1	2	0
Viti Levu	Rewa	Wailoa	19193	10.580	-	3	2	0.73	84	9	1	3	2
Viti Levu	Rewa	Wainivondi	9942	11.393	-	3	1	1.05	72	45	1	3	2
Viti Levu	Rewa	Wainisavulevu	7533	11.023	-	3	0	0.10	86	0	1	3	2
Viti Levu	Sigatoka	Narewa	1443	9.803	-	2	2	1.06	62	0	1	2	0
Viti Levu	Sigatoka	Nangalitala	7630	8.726	-	1	2	0.91	75	0	1	1	0
Viti Levu	Sigatoka	Yalavou	9888	9.303	-	1	2	1.52	34	64	2	2	0
Viti Levu	Sigatoka	Sarava	2818	10.290	-	2	2	1.56	16	0	3	3	0
Viti Levu	Sigatoka	Nasikawa	8977	10.062	-	2	0	0.34	58	100	3	3	0
Viti Levu	Sigatoka	Lato	4634	9.908	-	2	1	0.24	38	0	1	2	0
Viti Levu	Sigatoka	Nasa	9975	9.679	-	2	0	0.17	59	0	1	2	0
Viti Levu	Sigatoka	Solikana	5457	10.143	-	2	0	0.03	67	22	1	2	0
Viti Levu	Sigatoka	Wainivau	6186	10.080	-	2	0	0.00	61	63	2	2	0
Viti Levu	Sigatoka	Tuwalu	3639	8.370	-	1	0	0.70	33	100	3	3	0
Viti levu	Sigatoka	Damu	2884	9.368	-	1	1	0.60	55	42	2	2	0
Viti Levu	Sigatoka	Wailulu	4410	9.986	-	2	2	1.18	85	47	1	2	0
Viti Levu	Sigatoka	Mbusa	6942	9.631	-	2	1	0.93	56	7	1	2	0

Island Name	Catchment Name	Sub Catchment Name	Area (Ha)	Viti Levu REP	Vanua Levu REP	REP Class*	Creek Crossings/ km^2	Rd Length/ km^2	Forest %	Logged Area (% of 92 forest)	WDI Index*	Combined Threat Index*	Critical Index*
Viti Levu	Sigatoka	Narogilevu	4185	10.633	-	3	1	1.07	63	18	1	3	2
Viti Levu	Sigatoka	Nadevo	2103	8.885	-	1	0	0.81	77	35	1	1	0
Viti Levu	Sigatoka	Namada	5276	9.200	-	1	1	1.01	56	27	1	1	0
Viti Levu	Sigatoka		61119	9.160	-	1	2	1.55	38	37	2	2	0
Viti Levu	Sigatoka	Saweta	2011	8.860	-	1	1	0.86	40	34	2	2	0
Viti Levu	Navua	Wainokoroiluvo	20873	10.136	-	2	0	0.19	77	8	1	2	0
Viti Levu	Navua	Wainamoli	12813	10.554	-	3	0	0.00	85	5	1	3	2
Viti Levu	Navua	Volasa	3126	9.661	-	2	3	1.74	96	6	1	2	0
Viti Levu	Nadi	Namosi	9279	9.914	-	2	2	1.40	47	1	1	2	0
Viti Levu	Nadi	Nagado	2081	9.604	-	2	2	2.04	33	0	3	3	0
Viti Levu	Nadi		22673	9.757	-	2	2	2.13	36	10	2	2	0
Viti Levu	Ba	Nadrau	11764	9.306	-	1	1	1.58	70	2	1	1	0
Viti Levu	Ba	Wavuniyasa	3704	9.251	-	1	1	0.89	42	0	1	1	0
Viti Levu	Ba	Veisara	3905	10.486	-	3	3	4.15	8	0	3	4	1
Viti Levu	Ba	Navisa	6875	10.327	-	3	3	2.61	24	5	3	4	1
Viti Levu	Ba	Nainamau	5480	11.120	-	3	1	0.84	42	0	1	3	1
Viti Levu	Ba	Savatu	15446	11.441	-	3	2	0.94	43	41	2	3	1
Viti Levu	Ba		21756	9.847	-	2	2	2.35	29	7	3	3	0
Viti Levu	Navua	Veinuqa	10863	10.133	-	2	0	0.00	85	0	1	2	0
Viti Levu	Sabeto		9127	9.138	-	1	2	1.59	49	2	1	1	0
Viti Levu	Naimasimasi		8142	9.488	-	1	1	1.76	60	31	1	1	0
Viti Levu	Rewa	Waisomo	13572	10.587	-	3	1	0.29	90	1	1	3	2
Viti Levu	Rewa	Wainimala	47953	10.739	-	3	1	0.49	71	3	1	3	2
Viti Levu	Navua	Wainikovu	7885	10.263	-	2	1	0.56	91	49	1	2	0
Viti Levu	Lobau		3584	10.865	-	3	3	1.60	89	63	1	3	2
Viti Levu	Navua		51848	10.423	-	3	1	1.07	80	49	1	3	2
Viti Levu	Veisari		2814	9.476	-	1	2	1.05	77	40	1	1	0
Viti Levu	Rewa	Waimanu	19851	10.130	-	2	1	0.71	75	5	1	2	0
Viti Levu	Nasinu		2945	10.211	-	2	3	4.51	21	0	3	3	0
Viti Levu	Rewa		53585	10.543	-	3	1	1.59	51	15	1	3	2
Viti Levu	Yarawa		2926	11.159	-	3	4	1.55	59	55	2	3	2

Island Name	Catchment Name	Sub Catchment Name	Area (Ha)	Viti Levu REP	Vanua Levu REP	REP Class*	Creek Crossings/ km^2	Rd Length/ km^2	Forest %	Logged Area (% of 92 forest)	WDI Index*	Combined Threat Index*	Critical Index*
Viti Levu	Sigasigalaca		2036	10.761	-	3	1	0.80	76	34	1	3	2
Viti Levu	Waivunu		1917	11.460	-	3	2	1.02	53	69	3	4	2
Viti Levu	Navola		1910	10.901	-	3	2	1.42	51	33	1	3	2
Viti Levu	Tamanua		7424	9.133	-	1	1	0.80	78	0	1	1	0
Viti Levu	Sovi		7138	9.041	-	1	2	2.23	57	35	2	2	0
Viti Levu	Voua Creek		7692	8.572	-	1	3	2.95	39	0	2	2	0
Viti Levu	Tuva River		24990	8.336	-	1	4	2.66	62	0	2	2	0
Viti Levu	Kubuna		9209	7.965	-	1	5	3.52	61	0	2	2	0
Viti Levu	Nadi	Nawaka	9805	8.286	-	1	5	2.34	64	0	2	2	0
Viti Levu	Nadi	Masi	3147	7.601	-	1	10	3.96	49	0	2	2	0
Viti Levu	Nadi	Malakua	5911	8.452	-	1	8	4.27	40	1	2	2	0
Viti Levu	Ba	Wasali	10217	10.130	-	2	1	1.30	41	28	1	2	0
Viti Levu	Ba	Nakara	15611	9.521	-	2	1	0.79	51	9	1	2	0
Viwa	Viwa Island		457	-	-	0	0	1.61	0	0	3	0	0
Vuaqava	Vuaqava Island		843	-	-	0	0	0.00	100	0	1	0	0
Vulaga	Vulaga Island		1622	-	-	0	0	0.33	100	0	1	0	0
Vurosewa	Vurosewa Island		3017	-	-	0	1	0.32	35	0	1	0	0
Wakaya	Wakaya		893	-	-	0	4	2.33	0	0	3	0	0
Waya	Waya		2196	-	-	0	0	0.17	0	0	3	0	0
Wayasewa	Wayasewa		636	-	-	0	0	0.00	0	0	3	0	0
Yacata	Yacata North		262	-	-	0	0	0.00	0	0	3	0	0
Yacata	Yacata South		561	-	-	0	1	0.31	0	0	3	0	0
Yadua taba	Yadua taba		1450	-	-	0	0	0.20	7	0	3	0	0
Yanuca	Yanuca		183	-	-	0	0	0.31	0	0	3	0	0
Yaqeta	Yaqeta		719	-	-	0	0	0.12	28	0	3	0	0
Yasawa	Yasawa Island		3093	-	-	0	4	1.71	10	0	3	0	0

See text for explanation of indices; "- " = no data