Land-based activities and impacts on coral reefs and the marine environment of the Pacific Islands

Robert John Morrison  
*University of Wollongong, johnm@uow.edu.au*

N. S. Tuivavalagi  
*National University of Samoa*

Follow this and additional works at: [https://ro.uow.edu.au/scipapers](https://ro.uow.edu.au/scipapers)

Part of the Life Sciences Commons, Physical Sciences and Mathematics Commons, and the Social and Behavioral Sciences Commons

**Recommended Citation**


Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au
Land-based activities and impacts on coral reefs and the marine environment of the Pacific Islands

Abstract
This paper recognizes the fact some of the problems encountered in the coral reefs and marine environment of the Pacific are actually due to land-based activities. This message needs to be clearly brought to the attention of farmers and others who work the land - as well as to fishermen and others whose activities focus on coral reefs and the marine environment.

The paper discusses the Pacific environment and some relevant key issues. The paper goes on to discuss land-based activities that harm the coral reef environment - with some emphasis on agricultural activities and soil erosion; however, the impacts of other land-based activities are also discussed. Strategies for reducing the harmful effects of land-based activities are then discussed with reference to worldviews, various strategies, integrated approach and technical considerations.

The paper recognizes the Vetiver System as an appropriate mechanism for combating the effect of soil erosion and discusses this system to some detail before ending with some conclusions and recommendations. However, the main message of this paper is that there is an urgent need to clarify the impacts of the various land-based activities on coral reefs and the marine environment, and to devise ways of minimizing or eliminating the negative effects of land-based activities.

Disciplines
Life Sciences | Physical Sciences and Mathematics | Social and Behavioral Sciences

Publication Details

This conference paper is available at Research Online: https://ro.uow.edu.au/scipapers/394
Land-Based Activities and Impacts on Coral Reefs and the Marine Environment of the Pacific Islands

N. S. Tuivavalagi\textsuperscript{1} and R. J. Morrison\textsuperscript{2}

\textsuperscript{1}Research Fellow, Institute of Samoan Studies, National University of Samoa, P.O. Box 5768, Apia, Samoa  Email: filia@samoa.ws
\textsuperscript{2}School of Earth and Environmental Sciences, University of Wollongong, NSW 2522, Australia  Email: johnm@uow.edu.au

INTRODUCTION

This paper recognizes the fact some of the problems encountered in the coral reefs and marine environment of the Pacific are actually due to land-based activities. This message needs to be clearly brought to the attention of farmers and others who work the land — as well as to fishermen and others whose activities focus on coral reefs and the marine environment.

The paper discusses the Pacific environment and some relevant key issues. The paper goes on to discuss land-based activities that harm the coral reef environment – with some emphasis on agricultural activities and soil erosion; however, the impacts of other land-based activities are also discussed. Strategies for reducing the harmful effects of land-based activities are then discussed with reference to worldviews, various strategies, integrated approach and technical considerations.

The paper recognizes the Vetiver System as an appropriate mechanism for combating the effect of soil erosion and discusses this system to some detail – before ending with some conclusions and recommendations. However, the main message of this paper is that there is an urgent need to clarify the impacts of the various land-based activities on coral reefs and the marine environment, and to devise ways of minimizing or eliminating the negative effects of land-based activities.

THE PACIFIC ENVIRONMENT AND KEY ISSUES

There are a number of factors that contribute to the fact that the problems caused by land-based activities on the marine environment and coral reefs are critical in the Pacific islands. These factors include the small size of the majority of the islands which greatly reduces their buffering capacity and thereby greatly increases their vulnerability. In these small islands, the percentage of land area close to the sea is very high and is effectively 100% in most cases. As Power (2002) puts it, “...due to their size, most island states are entirely coastal entities”. This makes the impact of land-based activities on the marine environment and coral reefs more direct and immediate.

In the Pacific islands, there have been records of chemical dumping and poor regulation of land-based activities (Morrison and Brodie, 1985). In addition, there have been inadequate facilities to deal with waste (Morrison and Munro, 1999). These are related to the fact that most of the islands are economically weak and have given lower priority to the installation of the appropriate facilities required. Especially through the South Pacific Regional Environment Programme (SPREP), there have been a number of important initiatives and projects such as the introduction to the Pacific islands (via a Samoan project) of the Fukuoka Method of disposing and recycling rubbish, the International Waters Project to conserve and sustainably manage coastal and ocean water resources in the Pacific islands (SPREP, 2003:13-15), etc. However, the task at hand is a massive and complex one requiring a continual effort and collaboration of all stakeholders.
In the high volcanic and continental islands there is an additional problem due to erosion (Morrison, 1999). Some of the soils are quite erodible while some of the rains are highly erosive giving rise, in the absence of proper management, to high levels of soil loss and erosion. There is also the problem of rapidly increasing populations that is putting pressure on natural resources and the capacity of governments and communities to deal with problems relating to the unsustainable use of natural resources.

As population increases, more islanders have to share the resources obtainable from the sea and coral reefs. Increases in populations may result in a significant increase in pollutants entering the aquatic environment. For example, increasing populations have forced people on some islands to cultivate fragile soils on steep slopes, causing more soil erosion. As shown in Table 1, the population density in some island countries are as high as 300 people/km² or more – with Nauru having the highest of 577 people/km². However, in all Pacific islands, irrespective of population density, there are hotspots – pockets where people tend to concentrate, e.g., urban areas, and there are also areas that are vulnerable for one reason or another, e.g., areas with erodible soil or steepland.

Chemicals from land based activities can enter the aquatic environment via overland flow or via percolation downward through the soil. Percolation of chemicals in the Pacific is relatively easy for a variety of reasons. In the low coral islands, the soils are mostly sandy and hold only limited quantities of chemical ions – as sands, compared to clays, have extremely small surface areas per kg and practically no charge by which chemical species could be drawn to and held by the soil/sand particles. In the high volcanic and/or continental islands of the Pacific, the kind of clay present (oxyhydroxides) is highly weathered and also has very little charge compared to the clays (layer silicates) generally found in temperate countries. To make matters worse, these oxyhydroxide clays form good soil structures that allow easier percolation of rainwater (with any dissolved pollutant) to the underground water system.

There is also a dangerous trend in the Pacific islands with regard to the worldview of the local peoples. In pre-missionary days, people had an animistic worldview where nature including natural resources was greatly revered and some animals and plants (totems) were considered as gods and actually worshipped. In those days, when a temporary taboo was placed on fishing or harvesting of marine resources, there was no need to police or enforce the law as people greatly feared the consequences of displeasing the gods.

The missionaries came with the concept that there is only one God – the God of Love. Converts were released from their fear of the various gods they used to believe to control nature and thereby lose their respectful fear of nature itself. In Samoa for example, Meleisea (1987) referring to the Reverend John Williams’ diary reported how this missionary required new converts to eat their gods during village feasts. This represents a very drastic change in worldview that had serious environmental consequences.

Unfortunately, a more disastrous global influence is emerging – that of consumerism. This is of course part of a worldwide trend but will have a far more disastrous effect in the Pacific islands because of the small size of the islands, their economies and their capacity to cope with rapid economic changes. Crocombe (2001:231-2) referred to consumerism as the religion of commerce and one of the most barbaric ethical systems with the following four main commandments: (a) Yourself over others; (b) consumption over production; (c) waste over conservation; and (d) impulse gratification over long term consequences.

Below is a list of the key regional issues facing the Pacific islands with regard to sustainable development of their coastal and ocean environments as identified by Power (2002) who mentioned that these issues have been highlighted in a number of recent documents (Council of Regional Organizations
of the Pacific (CROP) 2001a, 2001b and SPREP 2000):

- Implementation of management regimes and conventions relevant to the Pacific islands;
- Sustainable management of living resources (fisheries);
- Sustainable management of non-living resources (minerals);
- Pollution prevention and waste management;
- Marine biodiversity and natural resource conservation and management;
- Coastal degradation;
- Marine scientific research;
- Defense, surveillance, monitoring and enforcement;
- Sustainable tourism;
- Training, education, and public awareness;
- Shipping;
- Appropriate technology transfer;
- Climate change and sea-level rise;
- Natural and environmental disasters;
- Intellectual property rights/ownership and access to genetic resources;
- Globalization; and
- Vulnerability.

Table 1. Population, Land Area, Population Density and Sea Area of the Pacific Island Countries

<table>
<thead>
<tr>
<th>Country (or SUB-REGION)</th>
<th>Population (Est. mid-2003)</th>
<th>Land Area (km²)</th>
<th>Population Density (people/km²)</th>
<th>Sea Area (x 1,000 km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MELANESIA</td>
<td>7,337,900</td>
<td>539,732</td>
<td>14</td>
<td>8,170</td>
</tr>
<tr>
<td>Fiji</td>
<td>831,600</td>
<td>18,333</td>
<td>45</td>
<td>1,290</td>
</tr>
<tr>
<td>New Caledonia</td>
<td>235,200</td>
<td>18,576</td>
<td>13</td>
<td>1,740</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>5,617,000</td>
<td>462,243</td>
<td>12</td>
<td>3,120</td>
</tr>
<tr>
<td>Solomon Islands</td>
<td>450,000</td>
<td>28,370</td>
<td>16</td>
<td>1,340</td>
</tr>
<tr>
<td>Vanuatu</td>
<td>204,100</td>
<td>12,190</td>
<td>17</td>
<td>680</td>
</tr>
<tr>
<td>MELANESIA</td>
<td>525,000</td>
<td>3,214</td>
<td>162</td>
<td>11,649</td>
</tr>
<tr>
<td>Federated States of Micronesia</td>
<td>112,600</td>
<td>701</td>
<td>161</td>
<td>2,978</td>
</tr>
<tr>
<td>Guam</td>
<td>162,300</td>
<td>541</td>
<td>300</td>
<td>218</td>
</tr>
<tr>
<td>Kiribati</td>
<td>88,100</td>
<td>811</td>
<td>109</td>
<td>3,550</td>
</tr>
<tr>
<td>Marshall Islands</td>
<td>54,000</td>
<td>181</td>
<td>298</td>
<td>2,131</td>
</tr>
<tr>
<td>Nauru</td>
<td>12,100</td>
<td>21</td>
<td>577</td>
<td>320</td>
</tr>
<tr>
<td>North. Mariana Islands</td>
<td>75,400</td>
<td>471</td>
<td>160</td>
<td>1,823</td>
</tr>
<tr>
<td>Palau</td>
<td>20,300</td>
<td>488</td>
<td>42</td>
<td>629</td>
</tr>
<tr>
<td>POLYNESIA</td>
<td>637,900</td>
<td>8,133</td>
<td>78</td>
<td>10,750</td>
</tr>
<tr>
<td>American Samoa</td>
<td>61,400</td>
<td>200</td>
<td>307</td>
<td>390</td>
</tr>
<tr>
<td>Cook Islands</td>
<td>17,800</td>
<td>237</td>
<td>75</td>
<td>1,830</td>
</tr>
<tr>
<td>French Polynesia</td>
<td>250,000</td>
<td>3,521</td>
<td>71</td>
<td>5,030</td>
</tr>
<tr>
<td>Niue</td>
<td>1,650</td>
<td>259</td>
<td>6</td>
<td>390</td>
</tr>
<tr>
<td>Pitcair</td>
<td>50</td>
<td>39</td>
<td>1</td>
<td>800</td>
</tr>
<tr>
<td>Samoa</td>
<td>178,800</td>
<td>2,935</td>
<td>61</td>
<td>120</td>
</tr>
<tr>
<td>Tokelau</td>
<td>1,500</td>
<td>12</td>
<td>125</td>
<td>290</td>
</tr>
<tr>
<td>Tonga</td>
<td>101,700</td>
<td>649</td>
<td>157</td>
<td>700</td>
</tr>
<tr>
<td>Tuvalu</td>
<td>10,200</td>
<td>26</td>
<td>392</td>
<td>900</td>
</tr>
<tr>
<td>Wallis &amp; Futuna</td>
<td>14,800</td>
<td>255</td>
<td>58</td>
<td>300</td>
</tr>
<tr>
<td>PACIFIC ISLANDS (Total)</td>
<td>8,500,800</td>
<td>551,079</td>
<td>15</td>
<td>30,569</td>
</tr>
</tbody>
</table>

Source: Based on "SPC (2004), and "King (1991).
However, with regard to waste management in the South Pacific, some of the priority needs (according to Morrison and Munro (1999)) are to:

- Give waste management a higher priority in national planning;
- Develop national integrated waste management policies;
- Improve implementation of waste management strategies;
- Provide sustainable funding for these activities;
- Collect improved data on sources, pathways and impacts of wastes;
- Improve landfill management planning and operations;
- Conduct technical and economic analysis of operations to recycle metals;
- Review incinerator performance in the South Pacific;
- Provide suitable long-term storage of hazardous material while disposal mechanisms are being determined;
- Develop practices that lead to the incorporation of septic sludge into agricultural and forestry projects;
- Investigate the use of treated wastewater (effluent) on land;
- Expand training for skilled personnel to work in the waste management industry in the South Pacific; and
- Pool information on waste management in the region.

LAND-BASED ACTIVITIES THAT HARM THE CORAL REEF ENVIRONMENT

The Various Land-Based Activities

Any land-based activity that pollutes the aquatic environment has the potential to cause harm in the marine environment and coral reefs. Wastes can be classified in various ways, e.g., MNRE (undated) classified waste into four main groups namely: municipal waste, industrial waste, hazardous waste and special (or hospital) waste. However, SPREP (2003:5-6) recognized three types of wastes contributing to the pollution of the marine environment: (a) solid waste, (b) sewage and (c) other land-based sources of pollution. In particular, this paper recognizes soil particles as an important pollutant that is released into the aquatic system via various land-based activities.

Land-based activities that produce waste that can harm the coral reef environment include:

- Agriculture;
- Forestry;
- Tourism;
- Energy development;
- Mining and minerals processing;
- Construction activities; and
- Development or extension of residential and industrial areas.

Some of the solid waste get into the marine environment via rubbish dumping into a river or stream, or directly into the sea in coastal areas. Also, wastes from livestock farms are washed into drainage systems then into natural waterways and finally into the sea. However, in view of the small size of most of the islands, the source of pollution is usually close to the sea.
Table 2. Average Biodegradation Rate of Some Rubbish that Commonly Ends Up in the Marine Environment

<table>
<thead>
<tr>
<th>Rubbish Item</th>
<th>Time Required to Break Down</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monofilament line</td>
<td>600 years</td>
</tr>
<tr>
<td>Polystyrene cups &amp; pellets (used in packing material)</td>
<td>500 years</td>
</tr>
<tr>
<td>Plastic six-pack packaging rings</td>
<td>450 years</td>
</tr>
<tr>
<td>Aluminium cans</td>
<td>90 years</td>
</tr>
<tr>
<td>Tin cans</td>
<td>75 years</td>
</tr>
<tr>
<td>Orange peel</td>
<td>½ year</td>
</tr>
</tbody>
</table>

Source: Based on Chapman (2003)

Chemicals are introduced into the water system mainly via agriculture, forestry, industrial discharges, mining and other activities. Naidu and Morrison (1989) have described industries likely to produce undesirable effluents in the Pacific islands, i.e., (a) brewery and distillation, (b) cane sugar manufacture, (c) metal finishing, (d) tanning, (e) food manufacturing and processing, and (f) cement. In agriculture, chemicals are used mainly as fertilizers and pesticides; in forestry they are used mainly for timber treatment; and in mining, chemicals are used in the process of extracting the mineral from the ore. Like solid waste, chemical pollutants have been a major concern for those depending on the streams and rivers as they have caused death by poisoning of fish. These pollutants can also cause harm to organisms in the marine environment. Chemicals used in fertilizers, together with natural or organic fertilizers, contribute to nutrient pollution which leads to algal blooms in the aquatic environment and reduces availability of oxygen in the water which could have a serious negative effect on the fish population. This, in turn, may influence fish and other life forms in the marine environment.

It has been pointed out in Morrison and Munro (1999) that once a contaminant enters the hydrological cycle, it can be rapidly transported within the cycle leading to contamination of sediments, rivers, lagoons, mangroves and reefs. Furthermore, untreated, industrial wastewater can have very large negative effects on the environment, e.g., the Vailema Brewery at Vaitele, Samoa, has been shown to discharge 720 kg BOD per day (equivalent to the discharge from a residential area with 10,500 domestic residents) into a local stream and hence into the sea (ADB/GWS, 1996).

Agricultural Activities and Soil Erosion in the Pacific Islands

Soil pollution in agriculture has been described by Tuivavalagi (1996), Willett and Bowmer (1989), and by Morrison et al. (1996a). Soil particles are introduced into the water system via various types of land-based activities, particularly via the process of soil erosion. Soil erosion by water or rainfall is an important issue in the high volcanic and continental islands of the Pacific — mainly as a result of activities in the agriculture, road-construction and forestry sectors. However, soil erosion may also be caused by any activity where earthwork is involved as in preparation of land for intensive agriculture or subdivision, preparation of sites for housing, construction of playgrounds for rugby, soccer, golf and other sports played in the Pacific. In many cases, soil particles are carriers for nutrients and chemical pollutants.

Some of the main pollution problems related to agricultural activities in the Pacific, as listed in Tuivavalagi (1996), are as follows:

- Poor siting of agricultural activities in relation to the environment (e.g., poultry farm upwind from a boarding school);
- Direct discharge from farms (e.g., cattle farms and piggeries) into water course;
- Excessive use of pesticide;
- Existence of large amounts of outdated and unknown pesticides;
- Improper facilities for storing unwanted and excess pesticides;
- Lack of appropriate data on pesticides (e.g., types, how much used, effects on crops, toxicity, etc.);
- Lack of community awareness; and
- Inadequate information on agricultural activities and their impact on the environment.

According to ESCAP (2000), while traditional Pacific island agricultural systems were highly sustainable, modern commercial agriculture is the most pervasive and environmentally destructive human activity in the Pacific island sub-region, resulting in, among others, the pollution of the surface and groundwater with agricultural chemicals; pollution of the wetlands and the marine environment with silt and agricultural chemicals; and the reduction of biodiversity;

In many Pacific islands, agricultural activities contribute greatly to erosion and soil loss that occur. Practically all erosion in the Pacific is due to water rather than wind and the factors contributing to the total amount of soil loss is given by the Universal Soil Loss Equation (which is discussed in many introductory soil science or fertility textbooks, e.g., Brady, 1990) as:

\[ A = R \times K \times L \times S \times P \times C; \]

where A is the amount of soil loss, R the rainfall factor, K the soil factor, "LxSxP" the land management factor (where L is the slope length, S the slope steepness and P the erosion-control practice), and C the crop management factor. Once we know the factors responsible for soil loss, we can then devise technologies to reduce the amount of soil loss by reducing the value and importance of the land management and crop management factors. With regard to the K factor, it is important to realize that soils in the Pacific vary greatly and some are far more erodible and need to be treated with greater care. With regard to the R factor, we should realize that rain in many areas of the Pacific are very erosive and that it is rainfall which triggers the whole process of erosion and it is important that we try as far as possible to keep the soil covered from the effect of raindrops and rainwater. In fact if we have space for only three words to advice farmers (and other land users) on how to reduce soil loss, the advice would be: "keep soil covered".

As discussed in Tuivavalagi et al. (2002), the three main causes of soil erosion and land degradation in the Pacific islands are: (a) natural hazards, e.g., cyclones; (b) direct causes, e.g., poor land and crop management practices, deforestation, etc.; and (c) underlying causes, e.g., population increase, land shortage, land tenure, poverty, economic pressure, etc. With regard to underlying causes, Tuivavalagi (2003a) has also pointed out the importance of worldviews, concepts, attitudes and awareness. All these potential causes of soil erosion and land degradation should be considered in designing a framework, using an integrated and multidisciplinary approach, to tackle the problem.

A number of projects have been initiated in the Pacific islands to measure soil loss via erosion in agricultural areas, e.g., the PACIFICLAND Project of the International Board for Soil Research and Management (IBSRAM) – as described in IBSRAM (1995). Soil loss from agricultural areas in Fiji vary widely; in sugarcane areas, the amount of reported losses have been 36.7 t/ha/yr (Morrison, 1981), 68.8 and 77.8 t/ha/yr (Liedtke, 1989); in ginger areas, the reported losses have been 21.9 t/ha/yr (Liedtke, 1988), 85.7 t/ha/yr (Morrison, 1981), and 1-300 t/ha/yr (Watling and Chape, 1992); in areas grown in taro the reported losses have been 56.0 t/ha/yr (Liedtke, 1988); and 12-300 t/ha/yr in vegetable/ root crop growing area (Watling and Chape, 1992).

Despite these soil losses, there are technologies available to reduce or eliminate the problem, however, there is need for local verification trials or fine-tunings so the technology is relevant or appropriate.
Such technologies belong to two major groups, i.e., biological (or vegetative) and physical (or mechanical). The biological ones include keeping soil covered with organic matter, use of hedgerows, use of vetiver grass, contour planting, agroforestry, mulching, etc.; while the physical ones include minimum tillage, settling ponds, bench terraces, netting to cover exposed soil, silt traps, etc.

Soil loss in agricultural areas in the Pacific has been reduced by growing hedgerows of plants along contours to prevent soil from eroding down the slope. In Fiji, during 1992-97, such hedgerows reduced soil loss by 87% when pineapple was the contour plant and by 98% when vetiver grass was used as the row crop (Nakalevu, et al., 2003). In Samoa, during 1999, soil loss was reduced by 76% where erythrina was grown along contours (Hunter et al., 1999).

Coral Reefs and the Marine Environment and Impacts of Products of Land-Based Activities

King (1991) described the marine environment as consisting of: (a) the beaches and seagrass, (b) mangroves, (c) coral reefs and lagoons, (d) the open sea and (e) the food webs that link the various components. The land-based activities that impact the marine environment are those that introduce (a) solid waste, (b) chemicals and (c) soil particles into the water system. As pointed out by Chapman (2003), the ocean has long been seen as limitless and able to absorb anything that is discharged into it. However, this view is now changing in many parts of the Pacific for two main reasons – the first has to do with the increase in population while the second has to do with the increasing use of materials that take much longer to break down (see Table 2). The worst of such materials is plastic which, according to Chapman (2003), may be lying around our beaches and reefs for many hundreds of years and, because of its light weight, can be carried hundreds and even thousands of miles by ocean currents and winds.

Chapman (2003) also noted that garbage and oil can kill fish, sea turtles, dugongs, corals, invertebrates and other marine species, as detailed below:

- Sea turtles often mistake plastic bags and balloons for jellyfish which is one of their favorite foods. When they do, they die a slow and painful death because their digestive track becomes blocked;
- Marine animals such as whales and dolphins get curious with garbage items such as bait box straps and six-pack packaging and become tangled up or strangled to death as a result of playing with them;
- Other marine animals can end up with plastic beverage rings around their necks and slowly strangle to death;
- Fish, turtles, and other marine animals can get entangled in derelict fishing gear such as gill nets – which can continue “fishing” many years after being lost or discarded;
- Marine animals that encounter nets and other fishing gear can drown, lose their ability to catch food and be more susceptible to disease and predators;
- Oil can destroy seagrass beds, mangroves, corals, crustaceans (crabs and lobsters), mollusks (giant clams and trochus), and other reef organisms by smothering them and cutting off light and oxygen necessary for their survival.

In Samoa, persistent organic pollutants (POPs) have been found in marine sediments and shellfish (MNRE, 2003). Chemical pollutants can travel through the food chain and their concentration can build up to toxic levels in marine fishes.

Suspended sediment reduces photosynthetic activity in the marine environment which could affect the fish and other marine animals that depend on these sea-plants. In addition, old sediments on the
seafloor may be reworked and resuspended. Deposited particles can actually smother the sea-plants and also affect coral growth. According to SPREP (1993), corals have a number of characteristics which make them sensitive to sediment as explained below:

- Corals use their tentacles to feed on plankton and sediment interferes with feeding;
- Corals are permanently attached and cannot avoid sediment exposure;
- Free-floating coral larvae will only settle and attach to clean, sediment-free surfaces;
- Corals also have algae growing as part of their structure and the algae aid coral growth by their photosynthesis; this process is reduced in turbid, sediment-laden water.

Some corals are more sensitive to sediment exposure than others. Deposition can smother corals and long term exposure to sediments can kill all or part of the colony. Even where exposure does not kill the coral directly, it will reduce coral growth as energy is diverted from feeding to clearing sediment. Sediment exposure may also result in coral bleaching (the loss of the algae) which, in turn, has many effects, including slower growth and less deposition of the coral skeleton. A sedimentation rate of 50-100 mg of sediment per square cm per day will cause less species diversity and percent coral cover (SPREP, 1993).

Effluents from land-based activities discharged into the aquatic environment is a cause for concern as it may cause:

- Algal blooms (due to excessive nutrients) and subsequent water quality problems;
- Direct toxicity to marine organisms (due to metals, hydrocarbons, or pesticides);
- Significant bio-accumulation in food chains leading to indirect toxicity problems for fish and other life forms;
- Health problems to water users (e.g., bacteria, viruses);
- Significant changes in the redox conditions of the waters (changes in BOD, COD, and level of dissolved oxygen);
- Serious damage to marine and coastal ecosystems (due to the influence of sedimentation); and
- Damage to engineering facilities (e.g., pipelines, piers, dams) caused by changes in pH and redox conditions (Carpenter and Maragos, 1989:226).

In addition, Carpenter and Maragos (1989:254-5) have pointed out that the dynamics of coral reefs may be affected by the following:

- Excessive terrigenous or marine sedimentation that buries corals and other bottom-dwelling reef organisms and inhibits larval settlement;
- Excessive dilution of seawater from freshwater runoff;
- Circulation from winds, tidal fluctuations, and wave-driven currents;
- Eutrophication and nutrient enrichment that allow algae or other benthic organisms (sea urchins, sponges, etc.) to compete against and displace reef corals and coralline algae;
- Reduction of sunlight and consequent decreased primary productivity of reef corals and other producers on the reef;
- Frequency and magnitude of earthquakes, lava flows, and subsidence;
- Exposure to catastrophic storms and large waves;
- The capacity of landward ecosystems (mangroves, seagrasses, coastal forests) to trap sediments and control runoff of eroded soils;
- Shoreline and offshore dredging and filling that bury or remove coral communities or change currents and circulation;
- Prolonged exposure to air (lowered sea level) and high temperatures; and
- Prolonged exposure to reduced dissolved oxygen levels.
There are some basic principles that apply across islands, but it should be noted that no two islands are the same. This points to the need to understand the basic parameters of each island, including its marine environment and coral reefs, which in turn influence the impact of land-based activities.

STRATEGIES FOR REDUCING HARMFUL EFFECT OF LAND-BASED ACTIVITIES

Worldviews

Many are aware of the environmentally friendly worldview of the animistic Pacific islanders and, in one way or another, have tried to revive an environment where nature is revered. While this may look like a good idea from an environmental standpoint, it will be disastrous in other aspects. As Crocombe (2001:208) pointed out, it is indeed a good development that we have moved away from the old religious systems which included practices such as cannibalism, human sacrifices, strangling wives at the death of the husband, killing infants born to "inappropriate" parents, burying the very ill while still alive, etc.

According to Crocombe (2001:231), an expert on the sociocultural and economic life in the Pacific islands, one of the greatest needs in the Pacific today is "to evolve a new ethical system, or systems, better adapted to the present and coming context". We argue that such a system exists in the Biblical worldview which provides a solid foundation for sustainable development (Evans et al., 2003; Miller and Guthrie, 2001). This system would be quite appropriate for the Pacific islands where 95% of the population is considered Christian (Johnstone et al., 2001). However, up to the present time, the focus of the church has been mainly on the salvation of souls, and, with regard to activities on the physical dimension, there is minimal emphasis on the teaching and propagation of the Biblical worldview with regard to the environment and other topical issues. This weakness in the current approach of the church should be addressed quickly as the islanders search for a model for sustainable development and before consumerism has even greater environmental impacts in the Pacific islands.

Tuivavalagi has talked and written on the need to consider religion, the church and particularly the Biblical worldview in the developmental processes in the Pacific islands (e.g., Tuivavalagi 1999, 2003a, 2003b). This is not a simply theoretical proposition as Ball (2003) has described how Biblical principles were used through the existing church framework to control pollution by a "land-user community" which was having serious detrimental effects on the fish catches of the downstream, "sea-user community". Such an approach should be seriously considered in the Pacific where some farming communities are not very concerned about the environmental effect of their farming practices (e.g., Taulealea, 1997:36) and where churches and church organizations exist and the majority of the people are religious and Christian in particular. There is a need to develop collaboration with Christian Ministries or Movements that specialize in teaching the Biblical Worldview in relation to agriculture, fisheries and the environment, e.g., the Discipling Nations Alliance (http://www.disciplenations.org). Such organizations are becoming more active and 2004 meetings/training workshops that the authors are aware of included one in Kenya (January) and others planned for the USA (April), Thailand (June) and Samoa (November).

Traditional religion, science and engineering in many Pacific island communities in pre-missionary days reflect a holistic worldview which saw a connection among all creations. The PABITRA (Pacific-Asia Biodiversity TRAnsect) Network, for example, is based on an ancient Hawaiian system of land management (Ahupua'a Resource Management System (Shea et al., 2001:39)) which sees land, from the mountain to the sea, holistically. PABITRA has been active in the field in Hawaii, Fiji and Samoa and
members are considering field activities in other countries particularly Palau or another country in Micronesia, Cook Islands and the Solomon Islands. Further details on PABITRA, are available at their website at http://www.botany.hawaii.edu/pabitra/. For various reasons, including the emphasis in modern times on specialization and compartmentalization rather than holistic thinking, people are becoming less aware of the link between the land and the sea. Such a link obviously exists and it is critical that scientists and others involved in coral reef research, monitoring and management should also have a good understanding of the land - including current and planned land-based activities and the current and potential impact of these activities on the coral reefs and marine environment.

Other Strategies and an Integrated Approach

The most powerful way to influence the behaviour of Pacific islanders is through their belief system - which is intimately related to their view of the world. However, the approach should be integrated and multidisciplinary in the sense that other tested strategies should be applied simultaneously, by all stakeholders, as part of a coordinated framework. Such an integrated approach has been previously discussed, e.g., by FAO and UNEP (1999), FAO (2000) and Tuivavalagi, et al. (2002).

Another powerful way to influence the behaviour of Pacific islanders is through education. For this reason, the formal and informal education systems should be involved such that both the young, starting with those entering primary schools, and the school leavers in the communities are educated.

Yet another powerful way of influencing the behaviour of Pacific islanders is through the introduction of laws, rules and regulations. These could be imposed by the government, church structure or the traditional social leadership. In Samoa, for example, Peteru (1993) has described current and planned legislations to: (a) increase harvestable stocks of fish and other marine resources; (b) conserve and protect marine breeding and feeding areas; and (c) integrate the sustainable development of marine resources with environmental planning and assessment. With regard to village-imposed regulations, coastal villages in Samoa have been made aware of the importance of sustainable development and have, themselves, introduced rules and regulations through the village fono (council) to control fishing activities.

We should also be aware that, apart from the obvious or direct causes of negative impacts on coral reefs and the marine environment, there are also indirect or underlying causes which might be not so obvious, e.g., a high population growth rate. These less obvious causes should also be taken into consideration when designing a strategy to minimize the negative impacts of land based activities.

Crocombe (2001:591-626) has pointed the strengths and weaknesses in the current regional approach, however, wherever appropriate, the Pacific islands should consider using a regional approach to develop strategic responses to environmental issues. The advantages of such an approach, as pointed out by Power (2002) include the:

- Sharing of high investment or establishment costs for capital intensive activities;
- Alleviation of capacity- or capability-constraints in small populations needing specialist skills or advice;
- Attaining of economies of scale in the provision of centralized training services;
- Formulation of better policies or activities that have “spill-over” or “mutually-reinforcing” impacts creating their own economies of scale; and
- Greater potential for providing a stronger voice in global forums.
Technical Consideration

Scientists, including those operating in the Pacific islands, have often placed too much emphasis on technical considerations while these can often be of much less importance, particularly in the Pacific island context. Just because someone comes up with a method of how to reduce wastes entering the water system does not mean that everyone will start using the new invention – as people have other consideration including their belief system, cultural acceptance, cost involved and other factors. This is an additional argument that supports the multidisciplinary approach whereby the natural scientists work collaboratively with social scientists, members of the local communities and other stakeholders. Nevertheless, as this is a meeting of natural scientists, some emphasis must be placed on technical consideration.

With regard to technical considerations, some of the steps to be undertaken include:

(a) Consider the problems in the marine and coral reef environment and identify those that may be due to land-based activities; Monitor these problems;
(b) Consider the various land based activities and identify those that may be contributing pollutants to the water system; Monitor these activities and their level of effluents;
(c) Identify, develop or fine-tune technologies to reduce pollutants entering the water system; Monitor effect of these technologies;
(d) To avoid wasting resources on "re-inventing the keel", we should make a thorough review of the literature and relevant unpublished documents – including action plans for pollution control by national governments and (sub)regional bodies, e.g., Samoa’s biodiversity strategy and action plan (Schuster et al., 2001), SPREP’s action plan for managing the environment of the Pacific islands region (SPREP, 2000) and others.

MNRE (undated) has mentioned four simple methods for minimizing waste, namely: (a) reuse, (b) recycle, (c) compost and (d) recover. It is more effective to deal with the pollutants before they enter the aquatic environment; however, in line with the comprehensive and integrated approach, consideration should also be given to addressing pollutants that have entered the aquatic environment. For example, it is known that mangroves can play an important role in trapping sediments and thereby protect the fringing coral reefs and marine environment from excessive sedimentation. Protection of mangroves and other strategies should be considered.

Soil erosion is a serious global problem and such erosion due to rainfall is a serious problem in the high volcanic and/or continental islands of the Pacific. There are two main methods of dealing with such soil loss – the mechanical method or the natural or vegetative method. After years of research and field observations and millions of dollars worth of construction works, data gathered from various parts of the world confirm that the natural or vegetative method is more effective (Tuivavalagi et al., 2002). The Vetiver System, an effective way of controlling soil loss and protecting water quality, has been gaining popularity worldwide. It is quite appropriate for the Pacific islands and is discussed further in the next section. However, experience in Samoa and Fiji (Nakalevu et al., 2003) show that the technologies employed have to blend long-term conservation with shorter-term cash benefits. For this reason possible ways of using vetiver grass as a source of income should be explored; however, it is possible to use this grass as a thatch and as a raw material for making baskets and many other handicraft items – as explained by Howlette (1996:40) and the Vetiver Network website.
THE VETIVER SYSTEM FOR REDUCING SOIL LOSS FROM LAND-BASED ACTIVITIES

**Figure 1.** Geographical location of areas where the Vetiver System has been introduced around the world. Source: The Vetiver Network Website, www.vetiver.org (courtesy of D. Rachmeler, President & Coordinator).

The Vetiver System is recent (less than 10 years old) but during this short lifespan, it has been introduced into over 100 countries (Rachmeler, 2004). The system has been described by TVN (2004a) as a low cost, and extremely effective system for soil and water conservation and infrastructure stabilization, pollution control, and waste water treatment. The system uses vetiver grass, *Vetiveria zizanioides*, for all its bioengineering and conservation applications.

The vetiver grass, *Vetiveria zizanioides*, is unique and TVN (2004a) reports that it can be used in the tropics, semi tropics and even in areas outside the semi tropics where there are hot summers, and winters that do not include permanently frozen soil conditions. The roots of the grass improve the shear strength of soil by 30 and 40% and engineers liken it to a "Living Soil Nail" (TVN, 2004a). For this reason, apart from being used for soil conservation, the grass is now considered important for the stabilization of road and railroad embankments, river banks, canals, bridge abutments, landslide prevention, as well as for water quality improvement, waste management and other uses.

Howlett (1996:40) has described the most important concerns by governments and farmers, regarding the introduction of vetiver: (a) that it might escape and become invasive; (b) that it might be a host for certain pests and/or diseases; and (c) it does not generate any income. However, as pointed out by TVN (2004b), vetiver does not escape (as it does not produce fertile seeds and has a non-spreading root system) and does not have any serious pest or disease.

Chomchalow and Chapman (2004) have mentioned that "[t]he present campaign on planting of vetiver in agricultural and non-agricultural areas for soil and water conservation has met with some problems in that the growers are not willing to plant vetiver as there is no direct income derived from the planting." However, in their paper, Chomchalow and Chapman (2004) added that, in addition to being used to perform specific functions in soil and water conservation, environmental protection, etc., vetiver plant
has also a few other uses, e.g. as forage for livestock, ornamentals, and miscellaneous other uses. Harvested vetiver leaves, culms and roots are utilized after some degree of processing in various ways, e.g. as input of agriculture-related activities (mulch, compost, nursery block/planting medium, animal feed stuff, mushroom cultivation, botanical pesticides, and allelopathy), handicraft and art works, medicinal applications, fragrance, input of construction-related activities (roof thatch, hut, mud brick, vetiver-clay composite storage bin, veneer/fiber board, artificial pozzalans, ash for concrete work, and straw bale), containers (pottery, melamine utensils, water containers), bouquet, energy sources (ethanol, green fuel), industrial products (pulp and paper, panel), and miscellaneous other utilization. For vetiver grass to be successfully introduced into the Pacific islands, it is important that appropriate potential uses should be explored.

Vetiver thrives over a wide range of ecological conditions but was once thought to be confined to wetlands (TVN, 2004b). The grass grows in highly acidic soils (pH<4) and alkaline soils (pH=11) and its roots can grow to depths of 3-4 m. The grass is easy and cheap to establish, and needs minimum maintenance while each clump of vetiver is so dense that, if configured correctly, it will act as a near perfect natural water filter.

Figure 2. (a) Vetiver grass in nature; (b) Vetiver grass filtering water & soil particles coming down the slope; and (c) rows of vetiver grass, holding the soil together. Source: The Vetiver Network Website, www.vetiver.org (courtesy of D. Rachmeler, President & Coordinator).

Vetiver grass could be planted as a contour hedge where it will act as a continuous filtering system, slowing down rainfall runoff, reducing rilling and gullying, and collecting soil sediments at the hedge face (TVN, 2004b). This reduces the loss of soil and nutrients while soil moisture and groundwater may be improved significantly — while natural terraces and ground leveling develops behind the hedge (see Figure 2b). Another feature of the grass is that it takes up minimal space and is virtually non competitive with adjacent crops.

Grimhaw (2003) describes how vetiver has developed as world technology over four phases of application: (1) soil and water conservation in poor rural areas; (2) infrastructure stabilization; (3) rehabilitation of difficult and often polluted sites; and lastly (4) water quality enhancement and site rehabilitation in relation to industry and intensive commercial agriculture.
TVN (2004c) gives details of the proceedings of the third international Vetiver Conference that was recently held in Guangzhou, China. The papers presented have been organized in the website into 8 sections including: (1) vetiver and water (21 papers); (2) stabilization and erosion control (20 papers); (3) land rehabilitation and phytoremediation (27 papers); and five other sections.

Lotter (2004) has provided an update on vetiver research. In addition, recent studies in Fiji showed that the introduction of contour hedgerows of vetiver and pineapple results in 95% reduction in soil loss compared to soil losses recorded in farmers plots without the hedgerows (Nakalevu et al., 2003). Vetiver grass has a long history in Fiji where it has been promoted as early as 1946 (Nakalevu et al., 2003) but then became a forgotten plant for some time before its recent "rediscovery". Those wishing to consider using the Vetiver System should contact The Vetiver Network at http://www.vetiver.org for detail.

CONCLUSIONS AND RECOMMENDATIONS

Damage to the coral reefs and marine environment may be caused by land-based activities. The approach to solving this problem should be integrated and multidisciplinary involving all stakeholders in a coordinated framework of activities that also include the monitoring of the situation and activities (current and planned) in the coral reefs, marine environment and particularly on land. The potential influence of the church and a regional approach should also be considered.

ACKNOWLEDGEMENTS

The authors appreciate comments by Mr. Bill Cable, the POPs Project Coordinator, MNRE, Apia, Samoa who read an early manuscript of the paper.

REFERENCES


Liedtke, H. 1988. Soil erosion on the fields of indigenous Fijians in the area of Suva (Fiji). In: Liedtke, H. and Glatthar, D. Report about two research projects in the Republic of Fiji, Sponsored by the German Research Foundation. Geographical Institute, Ruhr University, Bochum. pp. 1-51


Rachmeler, D. 2004. Personal communication by email on 19 January 2004 with Dale Rachmeler, President and Coordinator of The Vetiver Network.


