Implications of Climate Change and Sea Level Rise for Western Samoa

Report of a Preparatory Mission

by
Robert Chase
and
Joeli Veitayaki

Funded by the United Nations Environmental Project (UNEP),
in support of the government of Western Samoa.

Apia, Western Samoa
December 1992

Foreword

The first Intergovernmental Meeting on Climate Change and Sea Level Rise for the South Pacific Region was held in Majuro, Marshall Islands, in 1989. It was organised by the South Pacific Commission (SPC) and South Pacific Regional Environment Programme (SPREP) to create a public awareness on the future implications of these issues to the governments. Subsequently, necessary actions are being undertaken to address these issues in order to develop appropriate policies.

In this meeting, SPREP member governments gave the mandate to SPREP to coordinate and act as clearing house on all climate change and sea level activities for the region.

The United Nation Environment Programme (UNEP) then provided financial assistance through SPREP (use of SPREP Climate Change Task Team Group) to undertake preparatory missions to Tonga, Kiribati, Tuvalu, Cook Islands, Guam, Palau, Federated States of Micronesia, Western Samoa and Tokelau to discuss the study with the governments, and to prepare reports before undertaking in-depth studies on the impacts of climate change.

The main task of this mission to **Western Samoa** was to prepare a report in close consultation with the government officials, identifying areas for in-depth study into the potential impacts of expected climate and sea level changes on the natural environment and the socio-economic structures and activities of **Western Samoa**. In addition, it identified suitable and available response options to avoid or mitigate the impacts of climatic changes.

It is anticipated that the **Western Samoan** government will have the opportunity to closely examine these recommendations in the report, and to advise SPREP and other organisations accordingly.

Vili A. Fuavao
Director

Contents

Acknowledgements

The authors wish to thank the United Nations Environmental Project (UNEP) for making this study possible through its funding, the Government of Western Samoa and the South Pacific Regional Environmental Programme (SPREP) for authorising the study. We also thank Mr. Pati Liu of the Division of Environment and Conservation who, during a time when his country was focused on rebuilding after Cyclone Val, was able to arrange the meetings and interviews with the appropriate government and community representatives. Likewise, the time and effort on the part of those interviewed is gratefully acknowledged. Finally, our sincere thanks go to both Mr. Liu Matese Elisara and Dr. Roger Cornforth of the Division of Environment and Conservation for their input before, during and after the actual mission.

While the contents of this report are derived directly from the literature made available to the authors and from the input of those interviewed, the authors take the responsibility for any errors herein. We have tried to make this an accurate portrayal of the situation that exists in Western Samoa. We hope that it will be useful to the Government and people of Western Samoa, SPREP and to others who read it.

Executive Summary

The two person Task Team submitting this report was sent by the South Pacific Regional Environment Programme (SPREP) to Western Samoa in late January, 1992. Its instruction was to prepare, in close consultation with national counterparts identified by the host Government, a proposal for in-depth studies of the potential impact of expected climate changes on the natural environment and the socio-economic structures and activities of Western Samoa.

The Task Team conducted in-depth interviews and follow-up discussions with 21 people in Western Samoa and four people internationally who were identified by the host country co-rdinator as those representing the appropriate Government departments and other interests within the country.

The Task Team found a country in the process of recovering from its second major cyclone in two years. The level of awareness of and concern about the possible detrimental effects of climate change among those interviewed was highly variable. However, all showed concern for the effects of cyclones and particularly for the possibility of increasing frequency and severity of cyclones due to global warming.

The Task Team assessed that Western Samoa's awareness of the potential problems due to climatic change is lacking in many important sectors but is increasing steadily with the broad-based environmental awareness programme being produced by the Division of Environment and Conservation (DEC) within the Department of Land, Survey and Environment (DLSE). Although limited in staff and in its breadth of expertise, the DEC enjoys strong support of the DLSE, the Tourist Bureau, the Prime Minister's Office, an environmentally-based NGO and individuals throughout the Government service and among the general population.

Several environmental studies, workshops and legislative activities have been undertaken or are planned which will greatly aid Western Samoa in its effort to monitor and prepare for the effects of climate change. Lists of those activities which have been accomplished and those in process are given in the report. Areas where additional efforts are recommended include the need for:

A. More specific information on:

- the potential magnitude of climate change in Western Samoa,
- potential damage to reef and land ecology as a result of this change, and
- possible strategies to minimise the negative effects of climate change on the people and ecology of the country.

B. a workable system for "sustainable" land-use planning which takes into consideration legitimate environmental concerns and minimises political intervention. This may include the use of public hearings, reliable Environmental Impact Assessments for all large projects and a "DEC sign-off" requirement for all proposed construction projects submitted to the Prime Minister's Office. These suggestions are in addition to the systems already developed to assure environmentally sound input.

While financial and staff constraints limit the ability of the DEC to work to resolve the problems described above, both they and the Western Samoan government are hampered by two primary factors beyond their control at this time. These were the subjects of this report's recommendations for in-depth studies:

- Lack of reliable information on actual climatic changes and specific effects that Western Samoa will experience. This is a world-wide problem and must be approached both locally and regionally. Locally, two specific recommendations are to:

  (a) upgrade the Meteorological Observatory; and,

  (b) develop and implement a comprehensive study on the reef system to compliment existing and future studies of land-based ecosystems in Western Samoa.

  A third regional recommendation is to identify an individual to interpret local and South Pacific Regional weather and climate data, using the latest international knowledge on climate monitoring. The goal is to provide the South Pacific Region and individual Pacific Island countries with reliable and understandable information on the possible effects of climate change. This should provide the additional information needed by the Western Samoan Government to make rational decisions in preparing the country for the effects of climate change.

- Lack of a National land-use plan (which must include coastal waters) and a system which will enforce its use. Although much is yet to be accomplished, great progress is being made to assure that environmental factors are being considered in Government planning. Part of the long-term plan must include the inter-governmental systems required to ensure that sustainable development will become a reality in Western Samoa. The first steps to assuring that the required plan will be developed are:

  (a) a general acceptance within the appropriate Government Departments of the importance for a long-term land-use plan, and

  (b) a basic understanding within those departments of all the mechanisms required to produce such a plan.

An awareness of the potential effects of climate change and the importance of including the latest knowledge of these effects in any long-term plans must be stressed. The fourth specific in- depth study recommended, therefore, is a high-level workshop on long-term coastal-zone management which should provide a suitable information base among the appropriate government representatives to begin the processes required to produce this long-term plan.

The authors believe that the recommended in-depth studies, coupled with existing and on-going changes in government policy toward the environment, will result in a general awareness of the potential impacts of climate change and will result in effective methods of response to any detrimental effects of climate change.

1. Introduction

1.1 Purpose of the Study

Scientists have hypothesised that, due to "greenhouse gases" being emitted into the atmosphere through human activities, the climate on Earth may change at an accelerated rate in the near future. The potential for serious environmental, social, physical, political and economic difficulties from this change has become a common subject throughout the Pacific during recent years. A list of recent publications on the causes of and possible effects from this climate change can be found in Annex 1.

As a consequence of the increased interest in these potential problems and the possibilities of mitigating their impact with appropriate preparation, The South Pacific Regional Environmental Programme (SPREP) has requested the Association of South Pacific Environmental Institutions (ASPEI) to engaged eight Task Teams to conduct preparatory missions to Cook Islands, FSM, Guam, Marshall Islands, Tokelau, Tonga, Tuvalu, and Western Samoa. These studies are designed to parallel the work done earlier in the Maldive Islands (Pernetta and Sestini 1989) and Kiribati (Sullivan and Gibson 1991). The results from these studies will be discussed during the Second Intergovernmental Climate Change and Sea Level Rise Conference which will be held in March/April, 1992. These reports will also be used to plan subsequent assistance to these countries in formulating and implementing suitable response options to the impacts of climatic change.

1.2 Terms of Reference

The Terms of Reference, as given to the Task Team, are shown in Annex 1.

Although the Terms of Reference focus on potential impact from sea level and temperature rise, maintaining this narrow focus has been difficult in Western Samoa for several reasons.

Higher temperatures and sea level rise are a longer-term problem in most people's minds. In addition, they may not have too great an effect on Western Samoa. Hulm (1989) listed Western Samoa, along with Vanuatu, Wallis and Futuna, Easter Island and PNG, as the Pacific Island countries least affected by sea level rise, although he describes them as sustaining "impacts locally severe to catastrophic, requiring forward planning on a local and sub- regional level". In a more recent study, Pernetta (1990) placed Western Samoa 26th out of 26 South Pacific countries in terms of susceptibility to the effects of increased temperatures and sea level rise.

However, as Wyrtki (1990) points out, there are many other effects associated with global warming. These may affect Western Samoa more than some of the other island states. For example, within two years Samoa has experienced two devastating cyclones which were originally considered 100-year storms (Figures 1 and 2). The latter cost the country an estimated $662m WST (National Disaster Council, 1991). Clearly, while the timing of these two cyclones may not be related to climate change, the potential for increased frequency of cyclones appears to be more of a concern among the Western Samoan people than are the other possible results of climate change.

This also suggests that Pernetta's methodology should be developed further. While he considered selected long-term effects of climate change (eg. sea level), other long-term effects (eg. changes in wind patterns or ocean currents), extreme events of short duration (increasing strength and frequency of cyclones, longer dry periods) and all other potentially disruptive factors must be included in any complete analysis of the destructive potential of climate change. If this is done, Western Samoa may rank higher among the countries most susceptible to the effects of climate change.

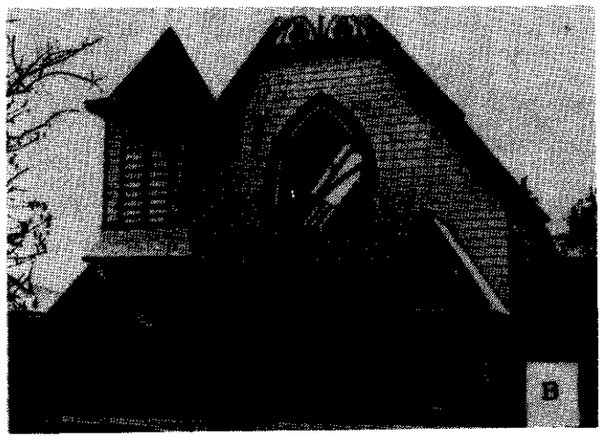
1.3 Programme of the Visit

The mission was preceded by two preparatory meetings in November and December between the senior author, members of the Division of Environment and Conservation (DEC) and, in one meeting, the Supervisor of Western Samoa's Meteorological Observatory. A proposed introduction and outline for the final report was developed from these meetings for presentation during the actual mission.

To ensure the most effective use of limited time during the mission itself, the acting Assistant Director of DEC invited all appropriate government representatives to a seminar on the first morning. At that seminar, an overview of the concerns about climate change was given and the purpose of the present study and the information needed for its preparation (the report outline) were discussed. Subsequent meetings were held with the representatives from the individual Government departments and the participating NGO as listed in Annex 3. A draft report was prepared and distributed in the later stages of the mission. It was discussed with each of the representatives and the final version completed in Wellington following the mission.

Mr. Veitayaki, in compliance with the requirements of the Terms of Reference, recorded a radio interview on the current state of knowledge concerning the greenhouse effect and its possible consequences for Pacific Island countries. This was broadcast after his departure.

Figure 1: Damage to infrastructure in Western Samoa during Cyclone Val.



A. Schools lost their roofs or collapsed
B. Church windows collapsed, roofs were removed
C. Damage to homes was extensive
D. Boats and this barge were sunk
E. Roads near the ocean were undermined by waves

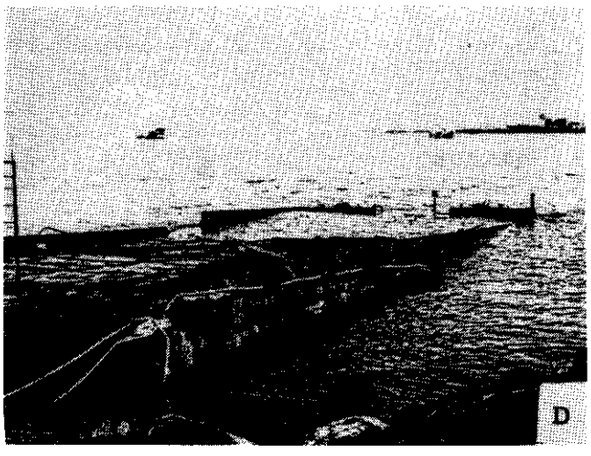
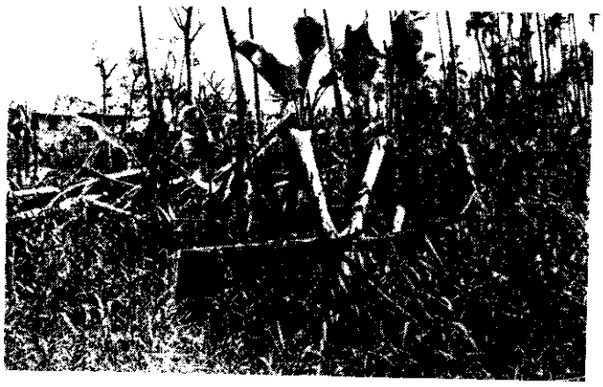


Figure 2: Damage to agriculture in Western Samoa during Cyclone Val. Note that all these crops will require 9 months to five years to recover.



A. Banana
B. Coconut
C. Papaw
D. Cocoa
E. Breadfruit
F. Taro

2. Western Samoa: Background

Western Samoa is comprised of volcanic islands located in the South Pacific Ocean. There are two large and two small inhabited islands and twelve small uninhabited islands and islets. Over two-thirds of the population lives on Upolu, the second largest island in the group, where the capital city, Apia, is located (Figure 3 and Table 1).

Table 1."Thumbnail sketch" of Western Samoa.

Location: 13-17° S. latitude
171-173° W. longitude
Max. tides: 1.2 m (diurnal)

Factor*	Total	Rank
Land area (km^2)	2,935	6
Sea area (km^2)	120,000	15
Est. population	157,158	5
Coastline (km)	403	6 (of 9)
Pop. density (km^{-1})	53	11
No. islands	8	15
No. islets	8	17
Max. altitude (m)	1,854	5
Mean altitude (m)	796	4 (of 17)

* Adapted from Pernetta, 1990.

A comprehensive description of the physical, environmental, social, economic, political and marine issues in Western Samoa has been prepared by the DEC (1991) as their National Report for the United Nations Conference on Environment and Development.

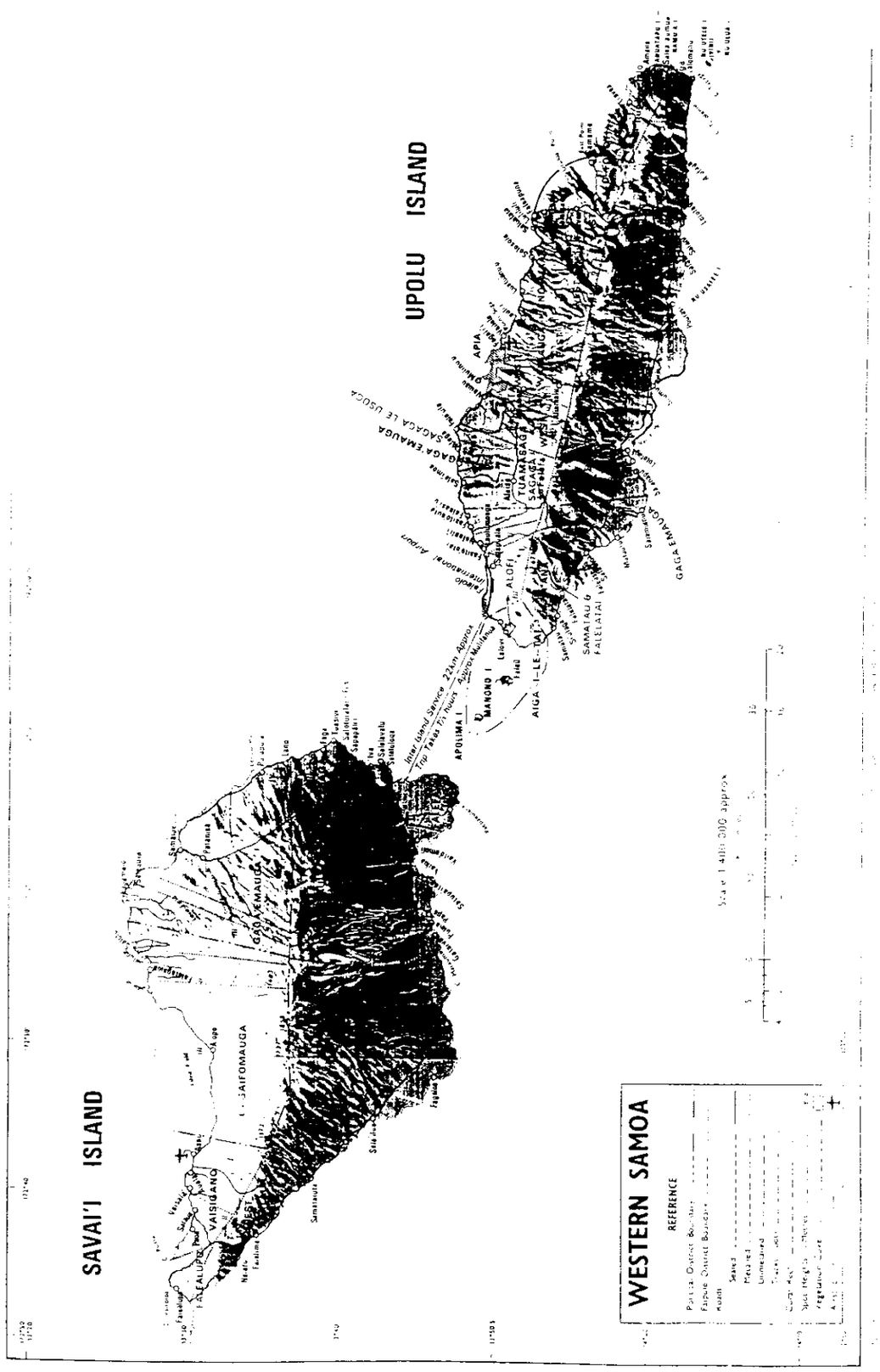
2.1 Geology

The islands of Western Samoa are young, built from basaltic volcanoes lying east of the northern end of the Tonga trench. A few of the volcanoes are still active (lava from the most recent eruption in 1905 covered an area of 150 km^2). Erosion is still rapid in the soft and steep basaltic flanks, resulting in deep, steep-sided valleys. On both main islands there is an almost flat to gently undulating coastal plain followed by rolling slopes before the steeper sloping foothills are encountered. On both islands, upland plateaus provide rolling land at 650 m and 1300 m elevations on Upolu and Savai'i, respectively (Wright 1963). These may have considerable agricultural potential. The highest points on the two islands are 1113 m and 1854 m, respectively.

2.2 Climate

Wright (1963) begins his book on the soils of Western Samoa with a comprehensive discussion of the country's weather. Much of the discussion below is taken from this review and from Burgess (undated).

Figure 3: Map of Western Samoa



2.2.1 Seasons

Western Samoa has two generally recognised seasons, the "dry" season during the cooler part of the year (April-October) and the "wet" season during the hotter part of the year (November-March).

Western Samoa is located near the southern edge of the intertropical convergence zone. The southeast trades blow for 82% of the dry season and 54% of the wet season (Figure 4). According to Wright (1963), the fact that the island chain lies parallel to these trade winds results in the absence of the strong "windward" and "leeward" effect found in most other Pacific islands. During the wet season, the trade winds are periodically displaced by the eastern extension of the Australasian low-pressure area and by hurricane systems generated near Kiribati and Tuvalu. These have their greatest impact on the weather on the north-western and western sides of both main islands. Tropical storms, including cyclones, usually occur from December to March.

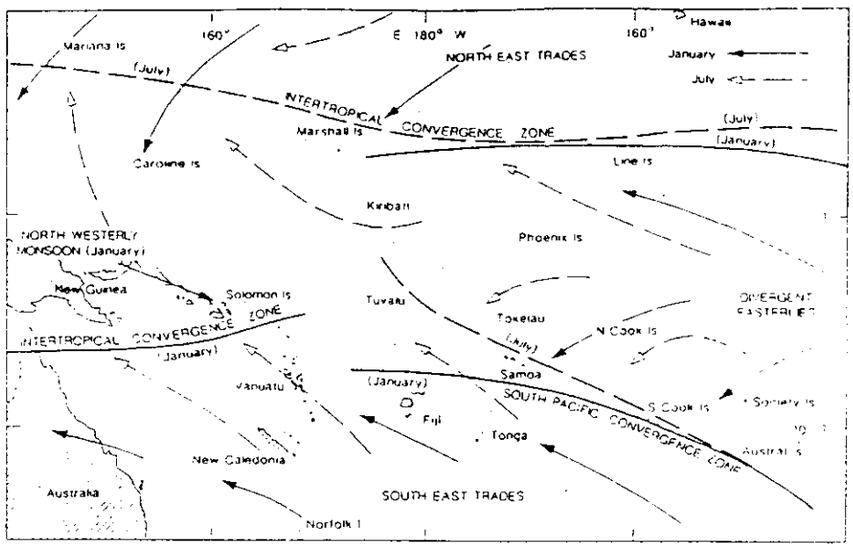
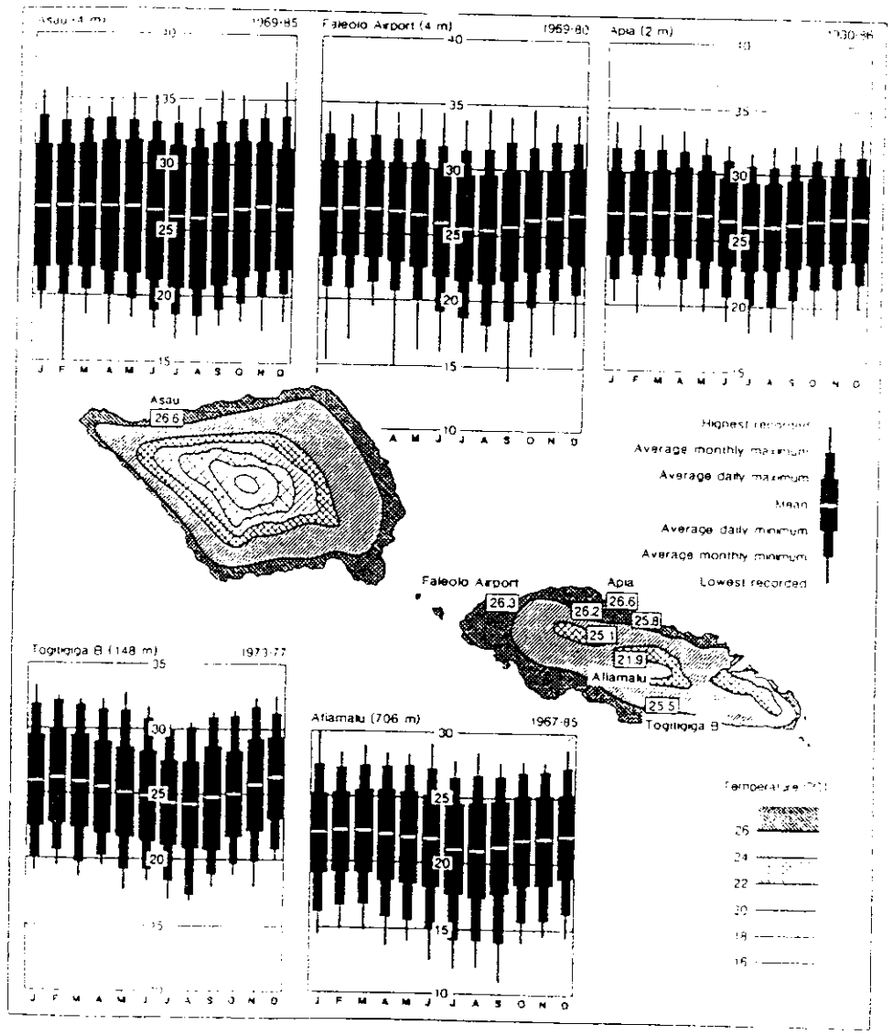


Figure 4: Typical Southern hemisphere summer (January) and winter (July) circulation of the South-west Pacific.
(Burgess, undated)

2.2.2 Temperature

Increased cloud cover and rainfall during the wet season help mitigate the potentially hotter weather when the sun is in the southern hemisphere. This, along with the moderating influence of the ocean, results in the small difference in average temperature between the tw seasons. Therefore, the annual temperature variation in Western Samoa is only 1-2°C, averaging 26-27°C at sea level and 22°C at 700m (Figure 5). The range of mean daily temperatures is 6-8°C in January, and 7-9°C in July in most places (the maximum range is at Asau: 9°C in January, and 11°C in July) (Burgess, undated).

Figure 5: Mean daily temperature (°C) over Western Samoa, 1951-80, and the monthly temperature at selected stations.
(Burgess, undated)



2.2.3 Rainfall

Rain occurs in all seasons and in all parts of the islands. Annual rainfall is variable according to location and altitude (Table 2). Although not as pronounces as most other Pacific islands of its size for reasons discussed above, the main islands are large enough to create orographic effects resulting in a higher rainfall in all months along the southern (windward) lowlands (average approximately 3000 - 5200 mm/yr) and a rain shadow along northern (leeward) shores during the "dry" season, averaging as little as 2100 mm/yr (Figure 6). Rainfall increases with elevation to an average monthly rainfall of over 700 mm in January, alone, in the highest elevations on both Savai'i and Upolu. Paine (1989) reports that mean annual rainfall above 1,200 m on Savai'i exceeds 7000 mm while Carter (1984) reports averages of 5000-7000 mm in the windward south and south-east shores. Mean seasonal variation is negligible on the southern coasts of both islands and is greatest on the northern coasts of both islands and in the highlands of Upolu. An extensive analysis of Western Samoa's long-term weather data is available in Burgess (undated).

The volcanic nature of Samoa and the evolution of its soils results in extremely high infiltration rates. Of the rain that falls on the islands, one study (Stednick 1990) suggests that 29% infiltrates into the groundwater, 23% is lost to evapo- transpiration and 48% enters the stream systems. In addition, after a few hours of dry weather, the first 5-10 mm of rain that falls on these porous soils seldom produce any runoff into the streams (K. Doig, personal communication).

Table 2: Normal monthly and annual rainfall, mm (1951-80).
(Burgess, undated)

Station	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Year*
North-west Savaii													
Falealupo	392	231	306	159	88	69	62	90	63	177	206	248	2091
Asau	459	355	373	219	85	71	43	92	55	154	197	407	2510
Asau Forest	518	427	486	472	133	100	86	111	75	226	497	386	3517
North-east Savaii													
Fagamalo	521	376	428	279	238	224	164	167	189	321	317	454	3678
Tuasivi	294	229	290	216	191	137	152	149	176	274	319	299	2726
South-west Savai'i													
Salailua	316	300	237	247	173	166	146	220	234	394	374	274	3081
South-east Savai'i													
Palauli	279	206	236	206	252	230	220	265	318	403	379	288	3282
Satupaitea	262	193	221	193	236	216	206	249	298	378	356	270	3078
North-west Upolu													
Faleolo	322	266	268	172	158	109	83	157	122	220	204	272	2353
Apia	410	319	376	237	166	151	122	122	163	252	275	370	2963
Nafanua	479	374	449	227	157	183	115	128	145	270	261	450	3238
Moamoa	519	370	485	275	203	137	118	146	159	274	279	474	3439
Alafua	495	410	462	269	196	150	119	145	148	247	269	424	3334
Avele Farm	457	454	465	209	223	169	116	118	161	283	333	425	3413
Alaoa	585	462	474	299	236	175	136	152	158	309	284	463	3733
Upolu Highlands													
Afiamalu	720	626	674	400	300	273	204	245	265	450	537	581	5275
North-east Upolu													
Laulii	568	427	428	244	206	228	123	177	192	320	381	415	3709
Piula	386	367	344	230	248	182	218	217	216	324	323	381	3436
Lemafa	561	401	325	294	287	325	310	348	439	621	581	523	5221
South-west Upolu													
Falelatai	246	286	371	287	278	173	131	151	143	282	294	268	2910
Sataoa	294	250	336	366	240	211	206	286	341	348	362	205	3445
South-east Upolu													
Lotofaga	314	280	276	267	286	273	253	304	417	424	389	382	3912
Vaipu	469	454	548	407	444	305	341	381	364	343	519	508	5321

Samoan soils are geologically young and can be extremely rocky. This and their coarse textural properties permit water to infiltrate rapidly and are therefore considered "droughty" for agricultural purposes. As a result, crops often begin to show water stress a few days after it stops raining. Although agriculture is not well developed in Western Samoa, it is certain that, due to these factors, irrigation will be more common as commercial agriculture expands.

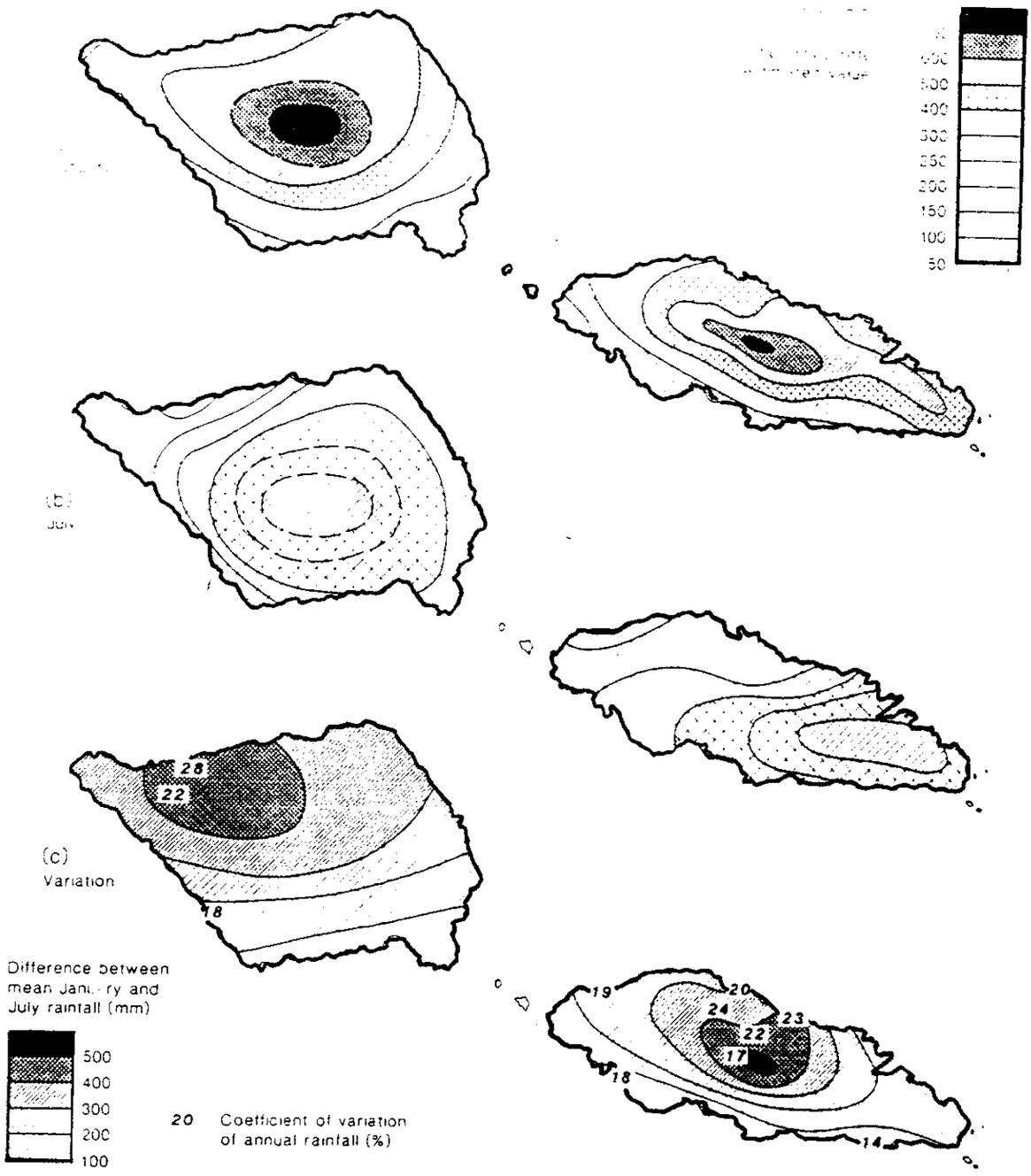


Figure 6: Mean annual rainfall (mm) for (a) January, (b) July and (c) the difference between January and July rainfall over Western Samoa.

Surface water from rainfall is depended upon for power generation and domestic use. Municipal water is frequently deficient in quality and quantity in the urban areas and chronically in short supply in many rural areas. This is partially due to limited catchment areas, frequent dry periods, under-built supply systems, loss of water into the jointed basalt which form the stream beds, old and leaking pipes and a general disregard for water conservation among the populace. Eroded materials accumulate in existing water storage sites and decreases water quality in the untreated systems. Five of the twelve main catchment areas were identified as having problems due to land clearing, flooding and water diversion for hydro-electric production (Stednick, 1990). These problems result in frequent shortages in municipal water supply and power rationing, particularly during the dry season.

A large hydro-electric scheme at Afulilo is being developed. This will provide considerable water storage but only by flooding prime wetlands if rainfall is sufficient. The water, once used for power generation, will be diverted into Fagaloa Bay.

2.3 Marine Ecosystem

2.3.1 Near Shore

Due to the volcanic activity of the Pliocene Age and the subsequent rise in sea level, the reefs and lagoons of Western Samoa are limited in size as compared with other South Pacific islands and there are few offshore reefs and shoals. The main islands are surrounded by barrier reefs of varying ages (hundreds to over 10,000 years old) enclosing lagoons which, due to erosion from land and high calcification rates at sea, are quite shallow from infilling. These lagoons are about 1 m deep and usually murky on the northern shores. On the southern (windward) shores they are 2-3 m deep and clearer. In both cases, they are mostly silt- covered flats with occasional coral heads. With notable exceptions, neither the lagoons nor the outer reefs support "coral gardens" as might be expected from the location of Samoa in the tropics. Although the reason for the poor health of the coral reef is not yet understood, runoff (with its sediment load) and human destruction are the likely causes (Zann, 1991).

The south shore of Upolu, from Falelatai to Aleipata, supports the largest area of mangroves in eastern Polynesia (D. Su'a, pers. comm.). Saanapu Bay supports a large mangrove area which is considered to be the most important fish nursery habitat in Samoa (D. Su'a, pers. comm.). The two major mangrove areas on the north shore, at Apia and Vaiusu, are already polluted and are being further jeopardized by human activity (Zann 1991).

Most Samoan villages are located near the sea. While the population density of the country is 56/km^2, the coastal density is 75/km^2. In 1989, 59% of Western Samoan households engaged in fishing and 65% used local fish in their meals (Zann 1991). The fishing pressure on the reef has increased dramatically during this century as the population of Samoa increased six fold. As a response to intense fishing pressure, the productivity of the lagoon area has decreased. Unregulated use of nets, toxins and dynamite and the constant fishing by divers who work the remaining habitats available to reef animals result in fewer and smaller fish and shellfish being caught. Juvenile fish and shellfish and, during the breeding season, female crabs and lobsters with eggs are commonly sold in the market. As pressure on the reefs increases, damage to breeding grounds (drainage and reclamation of marshes, clearing and pollution of mangrove swamps, erosion and coastal dumping) has reduced the ability of the system to replenish the species being fished.

Since 1954 or earlier, pollution and sediment deposition have resulted in a steady replacement of corals with sea grasses since 1954 or earlier. This has resulted in a collapse of some reef species and a tenuous future for others (Zann 1991). Zann further shows that over-fishing within the lagoon and the resulting difficulty in catching fish has been instrumental in a drastic decrease in per capita fish consumption since 1983.

Fishing grounds are presently under the control of the village that traditionally controlled each part of the reef as defined by the Fono Act of 1990. Many villages have barred all others from fishing on "their" reef, although boundaries have not been established and are a politically sensitive topic. In the meantime, reef fauna are poorly protected. Some relatively ineffective traditional conservation practices still exist: in certain villages the consumption of turtle or large trevally are restricted to the matai (chiefs). Likewise, some particularly destructive traditional fishing methods are still practiced, including the system where large coral "heads" are smashed and all edible creatures are caught and collected by the fishers.

The only law now in force to protect inshore fisheries is the prohibition of the use of dynamite and poisons to catch fish. Enforcement is the responsibility of the police. The Fisheries Division is presently drafting regulations which will define fishing seasons, fishing gear and minimum sizes for the fish and shellfish caught.

2.3.2 Off Shore

Western Samoa is located in the northern current of the South Pacific cyclonic gyre which carries water from east to west. The ocean water temperature ranges from 27-29°C and, due to the dynamics of the tropical ocean, is very low in primary productivity.

Samoans are not generally open water fishermen and the fishing fleet in Western Samoa is relatively small. Of over 370 aluminium- hull fishing catamarans (*alias*) built since 1975, only 80 were still in the fleet before Cyclone Val (December, 1991). Trolling, long-line and vertical long-line methods are used by Samoan fishermen during single-day, daytime excursions. The various tuna species, snapper, grouper and trevally comprise the bulk of the fish caught (Zann 1991). Much of the catch is sold at the market in Apia but some snapper are frozen and exported to American Samoa.

In 1987, the government began patrolling their 200 mile Exclusive Economic Zone. Since that time the number of foreign fishing vessels seen has steadily decreased (D. Su'a, pers. comm.). Regardless, open ocean catches by Samoan fishermen have decreased and it is believed that region- wide over fishing by foreign-owned boats is the cause.

2.4 Terrestrial Ecosystems

Ecological surveys were taken of Western Samoa before Cyclone Ofa (Dahl 1986; Pearsall 1988; Pearsall and Whistler 1991) and another was commissioned afterwards to assess the damage derived from that cyclone (Park, in progress). These studies show that important biodiversity still exists, mostly associated with the flora and fauna in the indigenous forests. Dahl (1986) lists rain forests, cloud forests, scrub and grasslands, crater marshes/swamp forests and mangroves in Savai'i as rich in endemic flora which should be conserved. Upolu, where the largest mangrove swamps in the Pacific are found, also adds fernland, crater lakes, upland wetlands, streams and other freshwater habitats to the list of important environments available in Western Samoa. Several of the ecosystems identified were considered threatened.

Western Samoa is fortunate in having 57% of its land area suitable (with little or moderate limitations) to agricultural and forestry development (ANZDEC 1990). Although agriculture does not require this much land in Samoa, nearly 25% of agriculture/forestry is practiced in unsuitable areas (Tables 3 and 4, and Figure 7). Over 42% of the indigenous forests which used to cover these sensitive soils have been cleared for agricultural purposes. Soils are usually rocky and of low nutrient status but support a large range of crops, including taro, coconut, cocoa, bananas and breadfruit. Although many other crops can be grown, extensive and low- maintenance subsistence crops are usually planted. A few individuals carry out intensive farming of vegetables, mostly for the local market. One hydroponic operation supplies tomatoes to the major hotel in Apia.

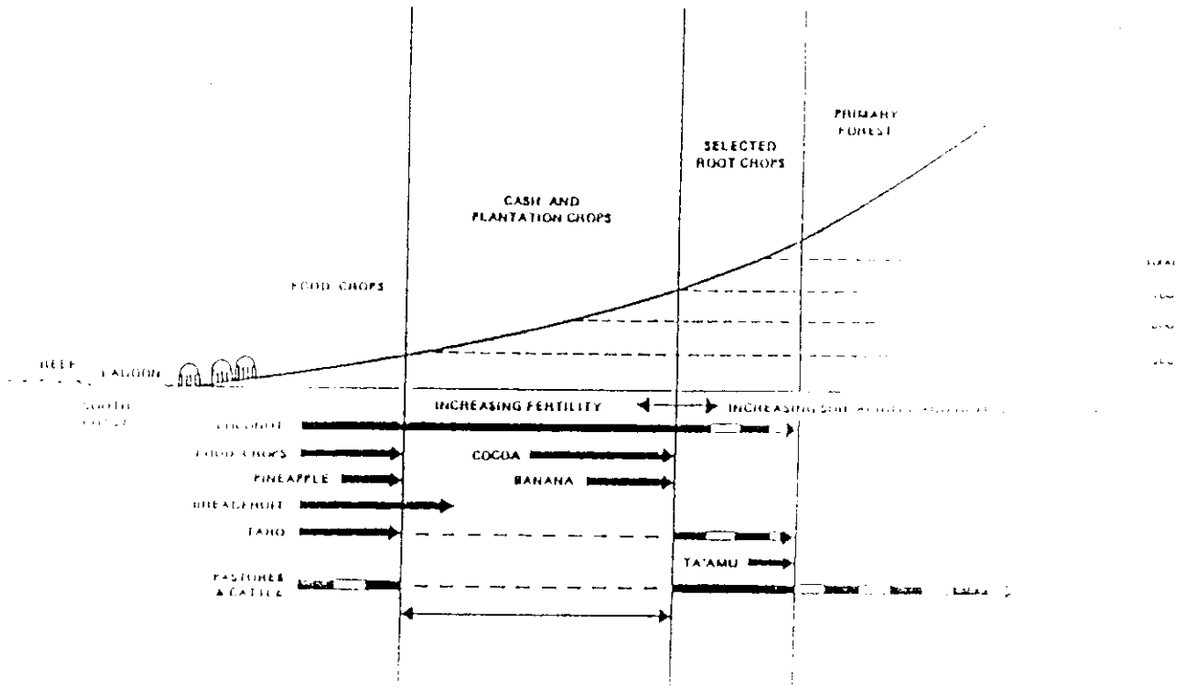


Figure 7: Typical landuse pattern in Western Samoa.
(Fox and Cumberland, 1972)

Table 3: Land use in Upolu and Savai'i, percent of total land.
(ANZDEC, 1989)

Land Use	Upolu ha	%	Savai'i ha	%	Total ha	%
Indigenous forest	49 407	17	109 304	38	158 711	55
Plantation forest	34	[a]	5 345	2	5379	2
Livestock	7 267	3	2 644	1	9 911	4
Cropping [b]	56 515	20	53 173	19	109 688	39
Total	113 223	40	170 466	60	283 689	100

[a] Insignificant
[b] Includes cultivated land, land left fallow, land now overgrown, and the Apia district and other residential land areas. (Estimates of other residential land using GIS database are 2064 ha for Upolu and 1019 ha for Savai'i)

Land clearing is proceeding at 4000-8000 ha/year in Western Samoa, 2000 ha/yr being native rainforest M. Ikopo, Asst. Dir. Forestry, personal communication). There are slightly more than 16,000 ha of indigenous forest in Savai'i. At the present rate of clearing, therefore, these will be gone in eight years. It is estimated that the commercial forestry programme will begin to produce timber in 1998. Its production will be below projected levels, however, due to extensive damage done to all forests by cyclones Ofa (Feb 1990) and Val (Dec 1991). For example, 90% of all indigenous and plantation trees on Savai'i were defoliated during cyclone Val while 40% of indigenous and 47% of plantation trees were snapped in half or uprooted.

Table 4: Land use in Westerrn Samoa, by land capability in '000 ha.
(Div. of Environment and Conservation, 1991)

Land use	Land ca				Total
	Class 1	Class 2	Class 3	Class 4	
Coconut	11.5	25.1	5.3	5.9	47.8
Cocoa	0.3	4.2	2.2	0.2	6.9
Coconut and Livestock	0.4	3.0	2.2	0.1	5.7
Coconut and Cocoa	1.7	24.3	5.9	2.5	37.4
Other crops (a)	1.4	2.4	0.8	9.0	13.6
Livestock	2.4	6.1	1.0	0.4	9.9
Plantation forest	0.1	2.3	1.3	1.7	5.4
Total	**20.8**	**67.4**	**8.7**	**19.8**	**126.7**
Indigenous forest	19.7	52.7	43.9	42.4	158.7

(a) Includes banana, coffee, coconut and coffee, swamps (0.60) and other activities not stated elsewhere.

2.5 The Socio-Economic Environment

2.5.1 Population

Population growth rate in Western Samoa has decreased over the past forty years (Figure 8). In the most recent survey available (1986), 5.7 children were born to each female in Western Samoa. This resulted in an estimated gross population growth rate in 1991 of 2.6%. This would result in a population doubling time of 27 years. The net population growth rate, however, was 0.6% in 1986 with the other 2% being lost to emigration (National Population Policy Committee 1991). If all these factors are maintained, the resulting doubling time would be 117 years. However, if emigration were to be restricted, as is the purpose of recent legislation in the USA, New Zealand and Australia, or if emigrants were to return home for any reason, which has been the effect of the recent economic downturn in New Zealand, the population in Western Samoa could increase extremely rapidly with its associated requirements on goods, services and infrastructure. This could be catastrophic to social order in the country.

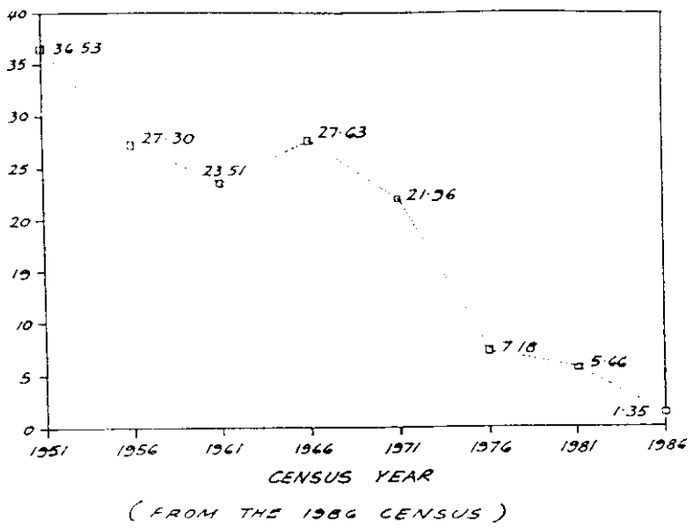


Figure 8: Mean annual population rates, per 1000, 1951-86.
(National Population Committee, 1991)

Men and women leave Samoa in equal numbers, predominately those 15-24 years old (Figure 9), resulting in a high ratio of the dependent population (the young and the aged) to the productive population among those left behind. With recent declines in the birth rate, dependency ratios have declined from 105 in 1976 to 80 in 1986. This is still considered to be an extremely high ratio.

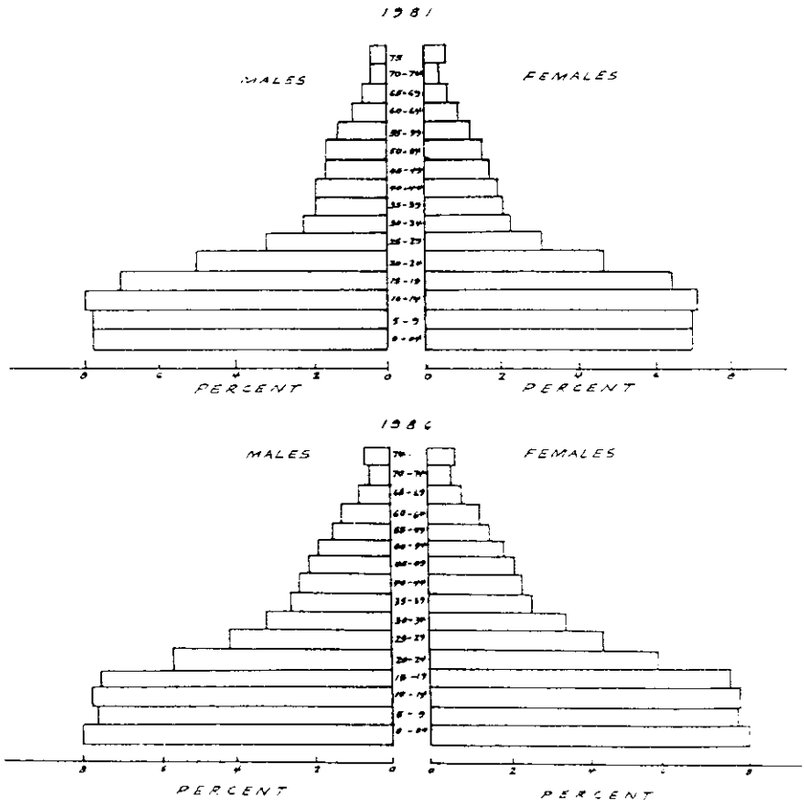


Figure 9: Distribution of population by age and sex, 1981 and 1986.
(National Population Committee, 1991)

The population of Western Samoa in 1986 was listed as 157,158 with nearly 70% living on Upolu and a few hundred people living on two small islands between Upolu and Savai'i. The largest city, Apia, is the nation's capital with 32,200 inhabitants. The population density is 57/km^2 country wide and 537/km^2 in Apia.

2.5.2 Health

The disease pattern here is in transition with infectious diseases being replaced with those derived from lifestyle (diabetes, hypertension and cancer). Malnutrition and undernutrition in the young (0-5 years) increased over the decade 1969-1979 to 6% in rural Savai'i and 20% in Apia. In 1984, iron deficiency anemia was found in 63% of the children 0-15 years old in rural and urban areas and 56% of the pregnant women who visited the National Hospital in 1980.

Obesity, on the other hand, was prevalent in the 35-64 age group with 74.4% of the females 35-44 years old falling in this category. Hypertension increases with age and body weight and affects nearly 34% of urban men and women over 20, nearly twice that found in the rural areas. Similarly, diabetes is higher (10.1%) in the urban areas than in the rural (3.6%).

2.5.3 Social Structure

Land tenure was identified by Hardin & Associates (1989) as an impediment to "developing land in a profitable and sustainable manner". However true this may be, 81% of the land is under customary (village) control, 16% under Government control and 3% freehold. The matai and land tenure systems as well as the Christian values and beliefs of the people are considered to be strong (though eroding) and capable of rallying support on a grass- roots basis for environmental programmes (National Population Policy Committee 1991). There is evidence, however, that land ownership is now rapidly changing from customary to a de facto system of private control (Omeara, 1987).

Women have always been active in social and economic development in Western Samoa through multi-functional women's groups. Over the last ten years the government has recognised and supported women's inputs into decision making and has recently established the Ministry of Women's Affairs.

2.5.4 Economy

Gross domestic product, after a 2.5% annual growth from 1972-1978, has fluctuated from positive to negative, partially reflecting a constant output from the agricultural sector and fluctuating world commodity prices (Dept. of Economic Development 1984). Due to recent sharp drops in export commodity prices and 15.2% inflation in 1990, the economy is expected to be in decline. The contribution of the agricultural, forestry and fisheries to Gross Domestic Production (GDP) was 35% while that from manufacturing, distribution, hotels and government services was 42% for 1986 (NCDS 1991). Subsistence agriculture provides 78% of the Gross Domestic Product (GDP) in agriculture and 28% in the whole economy.

Few new manufacturing businesses have come to Western Samoa since the UNIDO (1986) survey in 1983. Government policies (including tax exemptions, reduced taxes and import duties, depreciation allowances and bonus incentive schemes for production of taro, bananas, coconut and cocoa) encourage business investment. However, several problems (including low personal incentive to earn money, low Central Bank interest rates, land acquisition difficulties, low technical ability in the work force, the inability to use customary land as collateral, geographical isolation and the small size of the domestic market) discourage investment.

According to the Research and Statistics Dept (1991), exports almost doubled during the 1980-1990 decade while imports tripled in value to WS$171m in 1989. While the mix of most imported items remained the same, fossil fuel rose from 4% to 15% of the total. Basic manufacturing and transport equipment comprised 40% of imports. Exports are mostly taro and coconut products. Imported foods alone, many of which could be replaced with locally grown produce, exceeds total exports of all products.

The gap in export earnings and imports (Figure 10) is largely met through remittances of WS$77m (in 1990), grants of WS$39m (25% of the total 1990 budget - Figure 11) and from tourism.

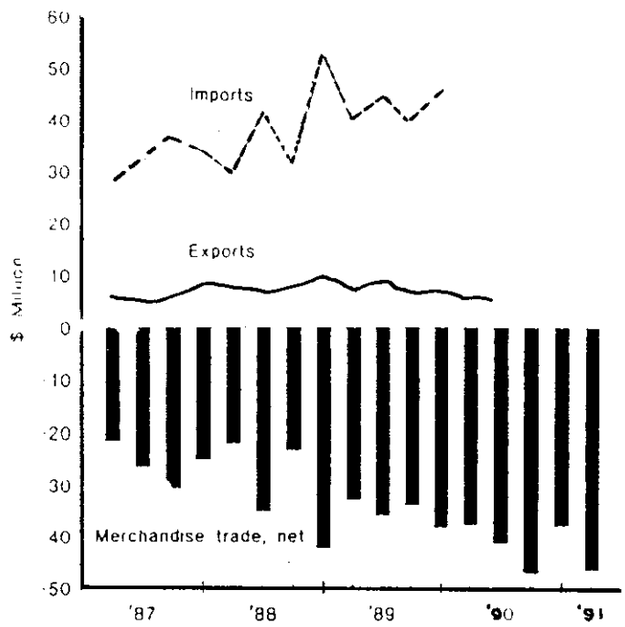


Figure 10: Merchandise Trade in Western Samoa, 1987-91.
(Research and Statistics Dept., 1991)

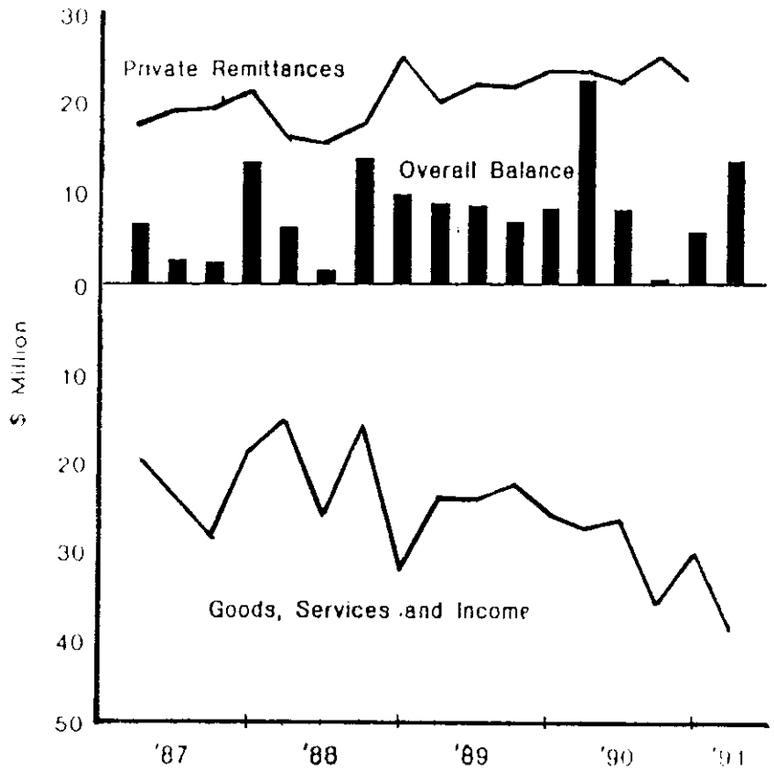


Figure 11: Balance of Payments for Western Samoa, 1987-91.
(Research and Statistics Dept., 1991)

Of the 1991-92 budget, 49% went to sectors which can be expected to improve life in Western Samoa: Public works 24%, education 12%, health 8% and agriculture 5%. One significant problem in development funding from foreign sources is that their projects seldom provide funds for recurrent costs. As a result, maintenance is often poor and the efficiency and longevity of these development interventions is decreased.

3. Current State of the Environment in Western Samoa

3.1 Environmental Concerns

Western Samoa's UNCED report (DEC 1991) lists and discusses the environmental concerns as they were perceived at the time it was written. Subjects of concern were:

- Water supply management
- Land and resource management
- Management of coastal and lagoon ecosystems
- Energy supply
- Marine resources
- Conservation and bio-diversity (deforestation and habitat loss; introduced species; natural threats; lagoon ecosystems)
- Control of population growth
- Health
- Urban structure and planning

3.2 Overview of Current Environmental Management

Samoa's UNCED report (DEC, 1991) also discusses the responses to development and environmental issues to date. These include changes in government policy, additional institutional development and the initiation of specific programmes and projects. These are summarised below:

- Watershed management initiatives: The Vaisigano Pilot Watershed Management Project (UNDP/FAO funded). 1989

- Conservation agreements: The Falealupo Conservation Agreement (1989) and the Tafua Peninsula project (in preparation)

- Reserves: The National Parks and Reservations Act (1974) and Forests Act (1967). In 1990, five reserves were listed. (DEC 1990).

- Species Conservation: Cabinet decree banning fruit bat export sales (1989). The TSCP (1990) has recommended that sea turtles and selected plants, specifically orchids, be protected.

- National inventory of terrestrial and marine resources: The Pearsall and Whistler ecosystem survey of Western Samoa (1991) and the upcoming post-cyclone Ofa inventory of terrestrial and marine resources.

- Fisheries management: The inshore fisheries and resources survey (Zann 1991)

- Environmental management planning: Samoa's 5th annual development plan, for the first time, lists protection of the environment and conservation of the natural resources as a national goal, although economic growth is listed as the primary goal. The environment continues to take a secondary position in government planning but, with the establishment of the Division of Environment and Conservation in 1990 within the Dept. of Lands and Environment and UNDP funding for a National Environment Management Strategy (beginning in 1991), environmental planning now has official government status. The KRTA (1988) and TCSP (1990) are both pressing for better mechanisms and more action to protect the Western Samoan natural environment.

- Pollution control and monitoring: Water quality and quantity monitoring has just begun as a part of the Vaisigano Catchment Project (Stednick 1990).

- Establishment of a conservation group: The O Le Siosiomaga Society, an NGO, was established in 1990 and works as a lobby group in close collaboration with the Div. of Environment and Conservation (DEC).

- International liaison: The DEC maintains direct liaison with a large number of international organizations. It has received funding from ten of these and other forms of assistance from these and others.

- Liaison with government agencies and community groups: DEC works with the Visitor's Bureau, Education Dept., National Youth Council, Boy's Brigade, Rotary Club, Lions Club, SPREP and the local newspapers to inform the public on environmental and conservation matters.

- Small scale diversification: DAFF has begun a programme of farm diversification aimed at protecting farmers from volatile price fluctuations. This should have an additional benefit by reducing land left idle and, therefore, reduce land clearing.

- Environment week: The Department of Agriculture organised this activity from 1978 until 1990, when DEC took over the responsibility for this annual event.

Not mentioned but valuable for land use planning was the completion of the ANZDEC (1990) Geographical Information System (GIS) land use/resource study.

Since the UNCED report was produced, DEC held an Interdepartmental Meeting on Climate Change and Sea Level Rise which was attended by representatives from the Prime Minister's Office, Treasury, Foreign Affairs, Public Works, Agriculture Forestry and Fisheries, the Apia Observatory and Lands Survey and Environment which resulted in an ongoing working group to coordinate environment-related activities.

The UNCED report suggests that there is considerable scope for interaction between the Visitor's Bureau and DEC since both have similar views of the importance of protecting natural areas and increasing public awareness, among others. In fact, the Tourism Council of the South Pacific, in their draft of the Western Samoa Tourism Development Plan (TCSP 1991), devotes an entire chapter to environmental considerations and emphasises the importance of protecting Western Samoa's natural habitats if "eco-tourism" is to provide badly needed revenue for the country.

4. The Potential Effects of Climate Change on Western Samoa

4.1 Overview of Possible Effects

During the December, 1991 pre-mission meeting, a list was compiled of possible problems that Western Samoa might face if predicted changes in climate were to occur. This list, given below, was used as a basis of discussion during the mission.

4.1.1 Sea Level Rise

- ❑ Inundation of parts of Apia and areas of importance.
- ❑ Erosion and retreat of beaches, marshlands.
- ❑ Reduction of some coastal habitats.
- ❑ Increased exposure of structures (roads, piers) to waves.
- ❑ Increased inland flooding during rains as water table is.raised.

4.1.2 Increase in Temperature, Rainfall and Evapo-transpiration

- ❑ changes in crop and tree production methods.
- ❑ increase in general discomfort.
- ❑ increased energy use for air conditioning.
- ❑ decreased productivity in outdoor labour.
- ❑ Increased erosion and sedimentation in reservoirs resulting in decreased storage capacity and poorer quality water.
- ❑ Increased reef damage from silt deposits.
- ❑ Increased runoff/humidity in wet season.
- ❑ Increased drought during dry spells (water/power availability, need for irrigation, crop loss, etc.

4.1.2 Increase in Storm Strength and Frequency

- ❑ Damage to:
  - roads/ground transport.
  - telecommunications.
  - water supplies.
  - power supplies.
  - shipping.
  - homes.
  - businesses.
  - crops/trees.
  - terrestrial ecosystems.
  - marine ecosystems.
- ❑ Increased frequency and severity of dry spells following cyclones with all the related problems.
- ❑ Decrease in tourist potential.
- ❑ Increased emigration.
- ❑ Diversion of government spending from development to reconstruction.
- ❑ Diversion of economically effective labour to reconstruction of family homes and farms.
- ❑ Increased dependency on foreign aid.

4.2 Analysis of Potential Threat to Western Samoa

After discussions with representatives of government and interested NGOs, an analysis of the effects of each the climatic threats listed has been analysed for the different ecological zones in Western Samoa.

4.2.1 The Effects of Sea Level Rise

1. Reefs

(a) The future of the seaward reef face is unsure. Since sea level rise will be associated with many other climate-related factors (the most important being the possibility of increased sedimentation and cyclone damage) it is difficult to assess whether the outer reefs will respond to deeper water by growing or by dying back further and ultimately being destroyed and removed by storm waves. There is reasonable to believe that they will survive in some areas and be torn apart in others over the coming century as variable factors impact on their health and growth.

(b) Where the lagoons survive, there is a reasonable chance that an increase in sea level will improve the lagoonal environment. Coupled with workable conservation regulations, a higher sea level could be a powerful force in rejuvenating this very important resource.

(c) The survival of the intertidal environment is of great concern. Already under intense human pressure, the associated vertebrate and invertebrate nurseries hold the key to the survival of the reef communities and their support of the people who depend on them for food. In many nursery areas, landward slopes reflect nearshore topography so that a simple increase in sea level would not result in substantial losses of nursery area. Where slopes become steeper inland or where people are reluctant to give up the land to the sea, however, the present intertidal environments could be threatened as sea levels rise.

2. Lowlands

(a) The inundation of land just above the high tide mark also causes serious concern. Structures built here (ports, landings, harbours, breakwalls, buildings on reclaimed lands, etc) will have to at least be raised or be relocated. Many of Western Samoa's coastal villages as well as the capital city of Apia could be partially inundated by a significant rise in sea level (Figure 12). The international airport, which is located at about 1 m above sea level, could also be at risk. Planning for this possibility will be essential when buildings, roads and other structures of long life expectancy are to be built to avoid expensive, and otherwise needless, relocation.

Sewerage facilities, which will soon be built under the high tide mark in Apia, will not be greatly affected. Repair and maintenance would become more difficult, however, if the water rises further, resulting in the pipes being deeper and less accessible. Very little agriculture is practiced on land below 10 m in elevation so minimal impact is expected on food security (IPCC 1990).

(b) Inland lowlands in many areas will become more swampy and springs more prevalent as the rising water table brings ground water nearer the surface. Where ground water flowing toward the ocean meets the less-permeable soils of the ancient swamplands (a common case all around coastal Upolu and in some areas of Savai'i) the ground water will come to the surface as it does today after heavy, long-duration storms (K. Doig, Personal Communication). Where these points of emergence are constant, suitable drainage will be required but if new areas of intermittent ground water emergence result from a higher water table, areas now inhabited may become uninhabitable.

2. Rainfall

Western Samoa has a relatively high annual rainfall at present. This is predicted to increase if global temperatures rise due to the increased ability of warmer air to hold moisture (McGregor 1990). Because the geology and hydrology of the country precludes building effective water storage dams in most stream valleys, increased intensity of rainfall will not improve the problems of seasonal water shortage in the municipal water supply systems. On the other hand, increased runoff would increase erosion on land, speed sedimentation in the existing water catchment system, lower the quality of the water entering treatment plants and untreated supply systems and increase the sediments dumped on the reefs. Because erosion is already considered a serious environmental problem in Western Samoa, many people believe this is the major environmental threat of the future. Similarly, increased rainfall would not greatly improve the hydroelectric production in most of the country. Only the new Afulilo hydroelectric dam would have the ability to contain large amounts of water in a shallow basin.

Some of the archeological sites that occur in valleys may be at risk if Western Samoa experiences heavier flooding. One such site, an octopus mound, has recently been inspected. It has already sustained considerable damage from stream flooding. Few of the known archeological sites are prone to destruction from floods or wave action. However, this may simply be due to the lack of information available on archeological sites at present.

3. Evapo-transpiration

In a warmer world, the periods between rainfall could become drier as evapo-transpiration rates increase due to the increased ability of warmer air to hold water. For municipal water supplies, the rapid drying of the limited water catchment areas could result in more periods without surface runoff available for use. In agriculture, higher evapo-transpiration would result in higher demands for irrigation water from supplies that are already in short supply. These problems would probably be more pronounced in the leeward side of the main islands where the dry season droughts are already a problem.

Hydroelectric generation in existing systems would be affected in the same way as municipal water, increasing the frequency and length of time that power generation from fossil fuels will be required. For the Afalilo hydroelectric facility, high evaporation rates from the shallow basin may result in a decrease in the usefulness of this important hydroelectric facility.

4.2.3 The Effects of Increased Storm Strength and Frequency

1. Reefs

Where the reef front is healthy, it will continue to grow and protect the lagoons and shores. Where reef fronts are not as resilient, they may not be able to recover from storm damage so that subsequent storms could destroy this protective area resulting in degraded reefs similar to those seen between Luatuanu'u and the beach at Solosolo. If this happens, lagoons and shores would be exposed to increased wave damage which would have serious effects on the entire reef ecosystem.

After cyclones Ofa and Val, many reef tops were found to be in surprisingly good condition, probably due to the natural selection of coral species that are well adapted to that environment. Deeper reefs on exposed shores, however, were seen to sustain considerable damage from storms. Casual but wide-ranging surveys made by the principal author after both storms revealed that the cyclones totally destroyed exposed inshore reefs to a depth of 8 metres and damaged reefs to much greater depths. In Aganoa Bay, for instance, one of the few "coral gardens" of South Pacific fame in Western Samoa was destroyed by Cyclone Ofa in 1990. The rubble that was left after the storm was covered with algae and mold for months as the animals below the rubble decomposed. Divers from the Solomon Islands say that their reefs required 20-40 years to recover from similar storm damage suffered earlier in this century.

Protected reefs or reefs away from the shore can survive storms, however. At Aganoa Bay, a sunken reef 80 m from shore and 6-20 m deep sustained little damage from either cyclone. Because flora and fauna found on the exposed reefs are also found on those in slightly deeper water, biodiversity should not be threatened. The impact on the quantity and the availability of these reefs for fishing or tourists, however, may be important to the economic viability of these activities and could increase the pressure on remaining reefs. The lack of easily accessible coral reef has already limited the scope of tourist attractions in Western Samoa.

2. Lagoons

Where reef fronts can keep up with storm damage, the increase in sea level and the resulting increase in circulation may help rejuvenate healthy, protected lagoons. However, storms and cyclones can take their toll in exposed or degraded parts of lagoons, burying corals and other animals in sediments. The only mariculture project in Western Samoa, a commercial clam farm on Upolu, suffered 100% loss from Cyclone Val.

During some cyclones, wave action within the lagoon throws broken coral and animals onto the outer reef platform, forming a "storm rampart" which can restrict circulation between the ocean and the lagoon. While the effect of storm ramparts on the health of reef fronts is not known, the restriction in circulation caused by the ramparts may have a negative effect on lagoon ecosystems.

3. Intertidal zones

In all cases, increased storm strength will increase the erosive power of waves in the intertidal zone. Increased erosion on exposed shorelines and the resulting increases in land lost to the sea could cause even more concern than inundation caused by the predicted rise in sea level. Where reefs loose their capacity to absorb the force of the waves, permitting larger waves to reach the shore, the land would be eroded back until new, stable shorelines are established. This could destroy mangrove swamps and other important nursery areas. It would require villages, roads and all other infrastructure near the shore to be moved inland or to be protected at great expense. The soil eroded from the shore would be carried directly onto the reef, further degrading the entire ecosystem and speeding up the cycle of reef and land destruction.

4. Lowlands and highlands

Lowlands beyond the reach of storm waves are grouped with highlands because both would sustain considerable damage from wind. Here, wind damage (in addition to rain damage, discussed above) would be the major cause of human suffering and potential environmental damage. Proper building restrictions and other precautions can limit human loss. However, the long term effect of the diversion of human and financial resources to rebuilding and replacement rather than development would be to slow Western Samoa's progress toward economic independence.

The potential for irreversible damage to biodiversity is another serious and long-term problem. The areas that previous studies have identified as important for conservation (Pearsall and Whistler 1991) are often one-of-a-kind ecosystems. They have been greatly limited in extent by human activity, making them particularly vulnerable to destructive storms or storms of sufficient frequency to preclude their recovery. This could result in the degradation and eventual loss of species, communities and entire ecosystems.

5. Assessment of Awareness and Ability to Respond to Climate Change in Western Samoa

5.1 Awareness: Present and Future

Western Samoa is fortunate to have a Division of Environment and Conservation (DEC) which is housed in the Department of Lands, Surveys and Environment. It has well-trained and motivated but limited staff. The DEC's view is that the key concern of climate change for Western Samoa, based on the current level of understanding, is increased cyclone activity. Its future efforts will reflect this understanding.

The DEC enjoys the strong and able support of the Western Samoa Visitor's Bureau. The Visitor's Bureau has recognised the importance of preserving Western Samoa's native habitats and will be basing much of their promotion on the growing international "eco-tourism" market. This market is recognised as highly compatible with what Western Samoa has to offer and has the potential to provide badly needed foreign currency to the country's economy (TCSP 1991).

Individuals from many government and non-government agencies provide support for environmental initiatives and are aware and concerned about the potential problems related to climate change. A two-day interdepartmental seminar held in March, 1991 helped to solidify and organize this support by creating a committee of interested government representatives willing to work together to provide recommendations on environmental questions.

In terms of the general populace, DEC has been particularly active and effective in "getting the message to the people". With a full-time Education Officer, along with a staff willing to write and speak, they provide one local newspaper with half-page articles on environmental subjects in each issue and the radio with a half-hour programme each week on environmental awareness as well as daily and monthly environmental quizzes with prizes given. Frequent talks are given at schools and seminars held at the DEC offices. Through these efforts and others (see section 3.1), Samoans are becoming more aware of environmental concerns. Coincidentally, while the Task Team was in Samoa, the DEC gave a one-hour radio presentation, in Samoan, on the effects of climate change.

As long as other government departments perceive the interactions between the DEC and the public as both responsible and supportive of positive change, the DEC will continue to have a positive impact on environmental awareness in both the private and public sectors in Western Samoa.

In the past there have been no provisions for the DEC to give input on planning or development activities in Western Samoa. Presently, there are no statutory requirements within the planning office of the Department of Works or the Prime Minister's office to include environmental considerations in their activities. As a result, staff of the DEC feel that they have been under-utilised by other government agencies, even when they had considerable expertise to offer. One example of this is the placement of the new Apia city dump. When the government decided to move the dump, the DEC completed an Environmental Assessment of alternate dump sites. Cabinet was provided with a summary of this study which recommended the most environmentally sound site. Although there appears to be some confusion over what happened, the dump was subsequently relocated to a site which was not studied. The environmental impact of the new dump site was completely unknown (Dept. of Lands, Survey and Environment).

Steps are being taken to change this situation. The Secretary of the Prime Minister's office explained that, in the future, the DEC will have input on all planning matters that are reviewed by that office. This includes the National Planning Office and the Policy Co-ordinating Unit as well as via the newly created Cabinet Development Committee. This will permit DEC to have input "at the highest levels" on all long-term planning.

Most people contacted by the task team said that the politicians who make up the government were not as concerned about the potential threat of climate change as they would like. This is to be expected. Unless they are experts in the matter at hand, politicians should not be expected to favour expensive precautions against problems that have not yet been well defined by the experts. It is up to the experts to change decision-maker's minds with facts and viable alternatives. Because the available scenarios concerning life in a warmer world are confusing if not conflicting, perhaps a better way to provide the least confusing information to decision makers is through "sensitivity studies". Here, no scenario is required, only an analysis of the suceptability of any specific activity to changes in those climate parameters that are most likely to change (Basher, et al 1992 p. 33).

5.2 Ability to Respond

In discussing the concerns about the potential effects of climate change and the possibility of mitigating these effects, it became apparent that there are some areas that, although affected by climate change, will respond as required without outside influence. Others, however, will require varying amounts of forward planning and effort to minimise any negative impact of climate change.

5.2.1 Areas Requiring Minimal Response

The agricultural sector is, by its very nature, undergoing constant change in response to market, labour and environmental changes. Even if global warming results in a 2 m rise in sea level and rainfall and storm patterns change, the farming community would accommodate these changes without much notice by the farmers whose agricultural methods change with each crop. The response to Cyclone Ofa is an excellent example. While staple crops were scarce after Ofa and vegetables were not seen in normal quantities for ten months after that storm, the rapid availability of vegetables in the market after Cyclone Val plus the increased availability of "ta'amu" (*Alocasia macrorrhiza*) taro and other "storm resistant" crops show that farmers responded quickly to the first cyclone. Farmers have also changed their planting schedules to avoid cyclone damage to crops (T. Tavita, personal communication). In adapting temperate forestry concepts to the tropics, the higher temperatures in the tropics required the use of new tree planting and husbandry methods which protect workers and seedlings from the sun and from storm damage (M. Iakopo, personal communication). Ongoing changes will continue to adapt these activities to future changes in the environment. An increase of a few more degrees will require new but, probably, less fundamental changes in technique.

The telephone company has begun replacing the old pressurized telephone cables with grease-filled cables which will function under water (including sea water) for decades. They have a programme to place cables under ground which is only hampered by lack of funds. Until instant and guaranteed communication, particularly during times of crisis, is considered to be sufficiently important to the Western Samoan people, "storm proofing" the telephone system, particularly outside Apia, will remain a low priority. Cables will continue to be replaced and buried, however, but at a rate controlled by economic factors and changes in attitude.

The Water Division of Public Works sees little it can do to prepare for the possible changes in environment. The topography and geology of the islands will not permit much latitude in the design of municipal catchment systems and wells are not expected to be greatly influenced by a higher sea level or by storms. Damage to the distribution system caused by storms are being minimised by re- routing pipelines away from the shoreline and by burying pipes. This process will continue as shorelines change. Individual water collection and storage systems have, as yet, not been widely developed in Western Samoa. The DEC and Forestry Division, however, consider watershed management to be an increasing priority. The Western Samoa government and the Asian Development Bank have both expressed interest in increasing efforts in this area.

While some countries have "cyclone proofed" their electric transmission systems by placing them underground, Western Samoa's EPC prefers to keep lines above ground. Because of the great amount of village-based construction and other activities requiring excavation, they consider the high risk of electrocution from buried wires much more serious than the problems of replacing wires after storms (John Roberts, personal communication).

5.2.2 Areas Where Response Efforts are Under Way

Through establishing the beginnings of environmentally sound legislation, Western Samoa has come a long way toward an environmental awareness during the past two decades. Through the establishment and activities of the DEC during the past four years, an awareness is being created among the population and the government which will permit appropriate responses to environmental problems. At present there are several activities which, once completed, can greatly enhance Western Samoa's ability to respond to environmental challenges either by making pertinent information available to the appropriate audience or through improving systems within the government to make it more responsive to environmental factors. These are listed here, in no order of importance, to show what Western Samoa is presently doing to improve their ability to prepare for and respond to environmental change.

1) Regulations have been proposed requiring effective environmental impact assessments (EIA) for all large government projects including a review of all EIA submissions by the appropriate government departments. They have not yet been accepted.

2) The National Disaster Plan was nearly ready for publication at the time of our study. Once available to the public, it should provide a basis of discussion, further planning and action. Specifically, the DEC should develop discussion points from the Disaster Plan concerning long-term environmental questions which are not fully addressed in the Plan. The DEC document should be foundation for the long- range planning of public and private construction and other related activities.

3) The DEC is preparing a paper on climate change to present to Cabinet. DEC's continuing efforts to establish a good rapport with the Cabinet will be essential in assuring top-level support for environmental concerns.

4) Regulations controlling fishing methods, seasons, reserves and size limits are being drawn up. These regulations and a workable means to enforce them must be enacted as a first step to create awareness and effect some control over the future of reef productivity.

5) Fisheries has begun an evaluation of mangrove swamps and other marine nurseries. These types of activities must continue using the expertise available in the Department. Funding and training may be issues to resolve.

6) Flinders University (South Australia) has proposed installing a facility at the Apia wharf in 1992 which will monitor sea level. AIDAB-funded, the 25-year study will be supported by the National Surveying Institute of Australia.

7) Mr. B. Crawley, working with the Western Samoa Meteorological Observatory, completed a UNEP/UNITAR training programme which developed a Geographical Information System (GIS) using satellite imagery to predict the effects of sea level rise on Apia (Figure 12). Due to the high quality and graphic nature of this work, it should be published in both the local popular press and in a regional journal. This would provide quantitative data on an important subject that had been discussed in a more qualitative form in earlier papers (Nunn 1990 a&b).

5.2.3 Areas Where Additional Response Efforts are Recommended

Although funding, training and staff shortages are continual constraints, Western Samoa has the government agencies in place to gather information, plan, seek expert advice, coordinate and act on relevant problems brought on by climatic change. The problems that were voiced by those interviewed during this mission were usually specific in nature, related to individual needs in their own areas of interest or expertise. Two underlying difficulties were repeated frequently, however. First was the need for reliable information and, second, was the lack of means to assure that environmental considerations are used in the planning system and result in environmentally sound decisions. Where sound decisions are made by the experts available, there remains the possibility that they are changed by senior decision makers for political reasons. The following are recommendations to remedy these problems.

1. *Information*

- Climatic Data:

While the Meteorological Office has considerable international support and small programmes are being developed to increase their ability to gather and store data, the fact is that the buildings and equipment have suffered badly from Cyclone Ofa and lack of consistent support. The Apia Observatory's long history of data collection and its physical location among the other observatories in the Pacific ocean make it an important part of regional climate studies. The report by Brook, et al (1991) expresses the authors' belief that "there is an excellent opportunity for Western Samoa and donors to collaborate to restore the Apia Observatory and its meteorological service to their former high standing in the region". They believe that assistance would be required for development planning, equipment provision, staff training, technical maintenance and building rehabilitation.

Beyond this, there is a need for up-to-date information on specific effects of climate change as it affects Samoa (and other South Pacific countries) upon which the government can plan and act. It is the dearth, complexity and contradictions of existing information on climate change that makes it difficult for governments to take the first steps in preparation for predicted changes. Some organized system is required which has a particular interest in the South Pacific countries and which can guide and summarise research on the subject of climate change and its affects on the region.

- Reef Ecology

Through the work conducted by Fisheries staff and that of consultants and advisors an understanding of the ecosystem on the reef and intertidal areas is beginning to form. Most of the reef and lagoon ecosystems in Western Samoa are so degraded that they now lack the natural resilience necessary to adapt to externally- induced change. A better understanding of both the reef and shoreline ecosystems will be important to permit short-term as well as long-term planning. While Zann (1991) defines many of the problems that exist in this area, research programmes have been designed to provide the information required to respond to these problems. These programmes must be supported and the results of the research published.

The changes in the dynamics of the sea in response to environmental change is the most difficult to predict and to prepare for. Spennemann *et al.* (1990) determined that, in Tonga, an increase in sea level may actually improve the near shore environment by increasing circulation. In Western Samoa, sea level rise could be of assistance in rehabilitating the lagoons if increased circulation within the barrier reef could decrease the effect of pollution, runoff and siltation (Zann 1991). If the outer edges of the reef are in poor health and cannot respond to sea level rise by upward growth, however, increased wave activity on the shoreline could enhance environmental damage through increased coastal erosion. Particularly in the case of nursery areas for vertebrate and invertebrate species, destruction of these habitats could have a serious impact on the nearshore environment and the lifestyle of the people who depend upon it. If Western Samoa is to be able to protect its reefs today and respond to the changes in sea level and storm activity in the future, a better understanding of the dynamics of the reef ecosystem must be developed.

- Land Ecology

Considerable work has been done in defining and describing the environments of Western Samoa (Pearsall 1988; Paine 1989; ANZDEC 1990; Pearsall and Whistler 1991; Park in progress). Many of the sites identified in recent surveys as having high conservation value, particularly lowland habitats from coastal/marine wetlands to forest types, are presently very limited in size and occurrence. Even if they can be protected from local human activities, they can be extremely vulnerable to inundation (eg. mangrove swamps) and cyclone damage (eg. upland native forest communities) which could eliminate these one-of-a-kind ecosystems. Some of these areas may be too limited and fragile to save but a programme to protect those which are deemed desireable and practical to save must be developed.

- Food Security

Western Samoa farmers are changing their agricultural methods in response to the ever-changing agricultural environment, including that brought about by the recent cyclones. This is an ideal opportunity for USP/Alafua to begin a documentation, research and information programme for the region on stabilizing food security after severe cyclones. Identifying the best short-term crops and the best planting techniques for long-term crops to avoid or minimise damage from storms would be of great help to all commercial and subsistence farmers in the region.

2. *Planning*

The planning of major construction activities in Western Samoa does not yet take into consideration the possible effects of climate change. For example, most of the roads washed away during the two recent cyclones are being rebuilt in susceptible areas. New private and public building construction is underway in reclaimed land and other fragile coastal areas. Private construction is frequently not up to cyclone-proof standards. Existing port facilities have been inadequate to protect boats and material on the docks from damage during the two recent cyclones and, in some cases, inadequate construction caused damage as buildings disintegrated. Presently, there are inadequate "safe harbours" and boat removal facilities available to boats during storms. While the creation of the Interdepartmental Working Group may provide a forum to discuss these needs, there is no specific method yet in place to propose a development plan to respond to required infrastructure.

Government planning can have considerable effect on the well being of the environment. Realizing the importance of this link, the Planning Section of the Prime Minister's Office has created a review panel for all project proposals submitted to that office. The panel includes a representative for the Division of Environment and Conservation. Several people interviewed expressed the belief, however, that the planning process might be better served if, in addition to this "high-level" input (after the plans have been completed), there was more direct interaction between the DEC and other agencies such as the planning section of Public Works. In this way, environmental concerns could be addressed from the beginning of the planning process. It is suggested that by requiring DEC to "sign-off" on all plans submitted to the Prime Minister's office, rather than just being represented on a committee which gives final approval to the plans submitted to that office, DEC input would be sought early in the planning process.

Further, a means must be found to ensure that environmentally sound plans developed by government experts and their advisors are not changed to suit political goals. To minimise the likelihood of last-minute changes to well-designed plans, public input should be sought on all Environmental Impact Assessments (EIAs). This will permit the public to be well informed on important environmental issues and will also create resistance to uninformed changes to the plans discussed at public meetings. A mechanism to permit public involvement in EIAs is presently in an advanced draft form and should be put to Cabinet during 1992.

6. Specific Recommendations

The DEC has made considerable progress in increasing environmental awareness in Western Samoa, particularly considering the limited staff and range of expertise available to them. To respond to the needs listed above, the study team, in conjunction with the DEC, recommend three in-country activities, an international information network and continued small "desk-top" studies.

6.1 Upgrade the Meterological Observatory

The importance of Western Samoa's Meteorological Observatory to the country and to the Region was spelled out in a recent study (Brook *et al.,* 1991). A proposal is being prepared by Samoa's Meteorological Office requesting a consultant with sufficient experience in both international and local meteorological observation activities, data analysis and equipment used to assess the needs of the Western Samoa's observatory and staff. Adherence to WMO and Regional standards and data transfer systems should be required and an increased in-house analytical capacity is desirable. Specific reference should be made in the proposal to adding studies which will help monitor the effects of global warming and specific suggestions should be made on how to establish the position discussed in 6.4, below. The proposed study should also identify the source of funding and expertise to provide the equipment and training recommended.

Recommended personnel: One person experienced in the WMO network is required. Allen Sharp and Ed de Ste. Croix of the New Zealand Meteorological Service, Wellington, have had considerable experience with Western Samoa's meteorological observatory and could arrange for an appropriate consultant.

Recommended study period: Six weeks in Samoa, two weeks at home.

Recommended study dates: To be completed during 1992.

Estimated Cost: Approximately $15,000 USD.

6.2 Improve the Knowledge of Western Samoa's Reefs

The Fisheries staff stressed that they have sufficient expertise available from within their section and in the country to conduct surveys of the nearshore ecosystem. They added that they would require some equipment, minimal funding, some expert input on planning and, in some areas, project initiation and technical support. An assessment of research, training and equipment needs for an efficient, long-term programme within the Fisheries Division is recommended to assure the success of the required research.

Recommended Personnel: Dr. Leon Zann, Great Barrier Reef Marine Park Authority, Townsville, Aust.

Recommended study period: Two-three weeks in Western Samoa, 5-10 days in Australia.

Recommended study dates: To be completed during 1992.

Estimated cost: $8,500 - $9,000 USD.

6.3 Develop a Land- and Coastal Water-Use Plan

The shortcoming in planning and development mentioned in section 5.2.3 (*2*), above, suggest that a comprehensive plan is needed in Western Samoa to plan for all long-term and large scale human construction in the nearshore and coastal areas. To help gain the government support required to begin developing such a plan, decision makers need to be given the most authoritative information on the subject.

DEC suggests that SOPAC be invited to present a workshop on coastal zone management, including harbour and port construction. Experts in the field would be brought to Samoa to work with government representatives and planners to discuss the problems involved in coastal zone management and the best methods available to accomplish the results that Government defines as most important. Such workshops, involving the input of regional and international agencies, can be arranged only on invitation from the Government, itself. This and similar workshops should be developed to continue improving the understanding of key government technicians and decision makers of the importance of long-term environmental planning and how to proceed.

Recommended Personnel: Jim Eade, Deputy Director, SOPAC, Suva can make the arrangements.

Recommended study period: 1-2 week workshop.

Recommended study dates: Late in 1992 or early 1993.

Estimated cost: up to $30,000 USD, depending on length of time and number of outside consultants required.

6.4 Establish a Regional Information System on the Effects of Climate Change

No Pacific Island Country can afford the expertise required to interpret weather and climate data in the context of climate change and to determine what it means to each country or the Region as a whole. While there is interest in this subject among many people in many countries, to ensure consistent, respected and focused support for the governments and people of the Pacific Island Countries, one qualified person must be designated as being responsible for this activity. The DEC suggests that this be a part- or full-time job for someone located in one of the Meteorological centres in Australia or New Zealand but who will have a direct responsibility to report to SPREP or to individuals within each of the countries served. Although a more accurate definition of this position is requested from the study discussed in 6.1, above, the position is roughly outlined here:

Recommended Personnel: Climatologist with specific interest in the effects of climate change in the Pacific.

Recommended study period: Continuous.

Recommended study dates: Beginning late in 1992 or early 1993.

Estimated cost: None (if volunteered by existing agency) to $100,000 USD/year if a full time professional is located at SPREP.

6.5 "Desk-Top" Studies

There are many additional studies required to provide the information needed by Western Samoa in order that decision makers can develop realistic, efficient and effective plans to minimise the negative effects (and take greatest advantage of any positive effects) of the predicted climate change. The studies listed here are mostly regional or global in scope and highly technical in nature. As such, they should be conducted anywhere at any time where interest, expertise and information are available. This means that most of this work would be carried out at universities, research centres or observatories in larger countries. It is recommended, however, that they include as much participation as possible from regional technicians and scientists to assure their relevance to Western Samoa and other individual Pacific island countries. These might be financed as independent studies or as part of a larger programme.

A co-ordinator must be designated to help define and guide these "desk-top" studies, however. Whether this should fall under direct SPREP responsibility or be part of the job description for the head of the Regional Information System, as recommended in 6.4 above, will depend on how the latter position is defined and funded.

Some general subjects for such studies are listed below to provide examples. This list is not meant to be comprehensive. Additional study topics will be continuously identified by those interested in the effects of global warming in the Pacific as more information is gained about this broad subject.

1) Improve existing studies on the relative suceptability of individual island countries to climate change, such as the Pernetta (1990) analysis, by including a more comprehensive range of projected effects in the analysis. Simple comparisons of this nature can be of considerable use in approaching decision makers about the problem of climate change.

2) Identification of dependable and quantifiable indicators to gauge the effects of climate change on Western Samoa and other island countries and the region. Because of the considerable short-term changes in weather, long-term changes are not evident to decision makers or to the public. Consistent indicators can decrease the confusion caused between predicted changes and local weather variation. Sea level rise is one such indicator of climate change but others are needed.

3) Conduct "sensitivity studies", as described in Basher, et al (1992), on island (land and near-shore) ecosystems, agriculture, near-shore and off-shore fishing, forestry and other important aspects to the well being of humans and the ecosystem in Samoa.

4) Continue to improve the existing weather/climate models with the goal of providing reasonably accurate predictions on sub-regional and local changes in climate and weather due to the effects of climate change.

5) A study of the spacial and temporal distribution of cyclones. By understanding what cyclones have done in the past we should be able to better predict what areas in the Pacific will be most affected by such storms in the future and whether changes in patterns are predictable. This study might help to resolve the question of whether the two highly destructive storms that hit Western Samoa within a two-year period are the beginning of a series of very bad storms or if this was a chance occurrence.

6) Studies of atmospheric and oceanic temperatures and their relationship to cyclone frequency and strength in the Samoan region. This would help predict the potential change in storm damage to all South Pacific island countries as global warming continues. As a possible beginning to this type of study, Dr. R. Basher, NZMS, expects to publish a scientific study on cyclone frequency as a function of sea surface temperature and the Southern Oscillation Index - a measure of the strength of "el Nino". This study will improve our understanding of cyclone frequency in various subregions of the Pacific and has a potential to be extended to address particular country needs and risks.

7) Studies on historic temporal and spacial rainfall distributions, the potential effects of increased atmospheric and oceanic temperatures on rainfall frequency and predicted flooding and drought potentials under various predicted world temperature regimes.

8) Studies of prehistoric weather patterns and climate changes which will provide clues to how weather patterns may shift in the future in response to climate change.

Stednick, J.D. 1990. *Water quality and quality monitoring programmes for the Vaisigano catchment, in particular, and Western Samoa in general.* FAO field document No 3, 8851 - SAM.

Sullivan, M. and L. Gibson. (1991). *Environmental planning, climate change and potential sea level rise: report on a mission to Kiribati.* SPREP report No. 50, Noumea, New Caledonia.

TCSP. 1990. *Guidelines for the integration of tourism development and environmental protection in the South Pacific.* Tourism Council of the South Pacific, Fiji.

TCSP. 1991. *Western Samoa tourism development plan 1992 - 2001.* Tourism Council of the South Pacific, Fiji.

Wright, A.C.S. 1963. *Soils and land use of Western Samoa.* New Zealand Soil Bureau Bulletin No. 22. Government printers, Wellington.

Wyrtki, K. 1990. Sea level rise: the facts and the future. *Pacific Science,* 44:1-16.

Zann, L. 1991. *The inshore resources of Upolu, Western Samoa: coastal inventory and fisheries database.* FAO/UNDP project SAM/89/002 Field Report No. 5.

7. References

ANZDEC. 1990. *Land resource planning study - Western Samoa.* Asian Development Bank TA No 1065-SAM, New Zealand.

Basher, R., B. Collen, B. Fitzharris, J. Hay, B. Mullan and J. Salinger 1992. *Preliminary studies for South Pacific climate change.* New Zealand Meteorological Service, Wellington.

Brook, R.R., R.E. Basher, J.P. Bruce, S.A. Parsons and M.E. Sullivan 1991. *The changing climate in paradise.* A report to the WMO. Bureau of Meteorology, Dept of the Arts, Sport, the Environment, Tourism and Territories, Australia.

Burgess, S.M. undated. *The climate and weather of Western Samoa.* Wellington: New Zealand Meteorological Service, Wellington.

Carter, J. 1984. *Pacific islands year book.* 15th edition. Pacific Publications, Sydney.

Dahl, A.L. 1986. *Review of the Protected areas System in Oceania.* IUCN Conservation Monitoring Centre, Cambridge, United Kingdom.

Department of Economic Development 1982. *Western Samoa's fifth development plan.* DED, Apia.

Div of Environment and Conservation. 1991. *National Report for UNCED: Western Samoa.* Dept of Lands and Environment, Div. of Environment and Conservation.

Fox, J.W. and K.B. Cumberland. 1962. *Western Samoa: Land, life and agriculture in tropical Polynesia.* Report commissioned by the Ministry of External Relations and Trade, Wellington.

Hardin & Assoc. Pty Ltd. 1989. *South Pacific Project Development Facility: Western Samoa.* Report for the South Pacific Trade Commission, Sydney.

Hughes, P. and M. Sullivan. 1990. Climate change and agricultural production in the highlands of Papua New Guinea. pp. 270-279 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

Hulm, P. 1989. *A climate of crisis. Global warming and the island South Pacific.* Prepared for the South Pacific Regional Environment Programme. Association of South Pacific Environmental Institutions, Port Moresby.

IPCC. 1990. Adaptive responses to climate change: Coastal zone management workshop. The *Proceedings of the Intergovernmental Panel on Climate Change Response Strategies Working Group.* Australian Govt. Publishing, Canberra.

KRTA. 1988. *Environental planning for tourism in Western Samoa: A report to the Government of Western Samoa and the South Pacific Regional Environmental Programme.* KRTA Ltd, Auckland, New Zealand.

McGregor, G. 1990. Possible consequences of climatic warming in Papua New Guinea with implications for the tropical southwest Pacific area. pp. 25-40 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

National Disaster Council. 1991. *Preliminary damage assessment report for cyclone Val, 6-9 December, 1991.*

National Population Policy Committee. 1991. Is there a need for a national population policy for Western Samoa? (prepared for the National Population Policy Workshop) Western Samoa Health Association, Apia.

NCDS. 1991. *National centre for development studies database: Western Samoa.* Australian National University, Canberra.

Nunn, P.D. 1990a. Potential impacts of projected sea level rise on Pacific island states (Cook Islands, Fiji, Kiribati, Tonga, and Western Samoa): a preliminary report. pp. 127-148 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

Nunn, P.D. 1990b. Recent coastal changes and their implications for future changes in the Cook Islands, Fiji, Kiribati, the Solomon Islands, Tonga, Tuvalu, Vanuatu and Western Samoa. pp. 149-160 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

Omeara, J.T. 1987. Samoa: Customary individualism. pp 74-113 *In* R.G. Crocombe and S. Arutangi (eds.) *Land Tenure in the Pacific.* University of the South Pacific, Suva.

Park, J. (in progress). *National ecological survey for Western Samoa.* Dept of Conservation, Wellington.

Paine, J.R. 1989. *Western Samoa: an overview and description of its protected areas.* World Conservation Monitoring Centre, Cambridge, U.K.

Pearsall, S.H. 1988. *Preliminary technical report for Western Samoa terrestrial ecosystem mapping.* Prepared for World Wildlife Fund, Australia.

Pearsall, S.H. and W.A. Whistler. 1991. *Terrestrial ecosystem mapping for Western Samoa: project report, and proposed national parks and reserves plan.* SPREP and East-West Center, Environment and Policy Institute, Honolulu.

Pernetta, J.C. and G. Sestini. 1989. *The Maldives and the impact of expected climatic changes.* UNEP Regional Seas Reports and Studies No. 104, UNEP, Nairobi.

Pernetta, J.C. 1990. Projected climate change and sea level rise: a relative impact rating for the countries of the Pacific Basin. pp. 14-24 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

Research and Statistics Dept. 1991. *Bulletin for the Central Bank of Samoa.* Vol. VI No. 2. Central Bank of Samoa, Apia.

Reti, M.I. 1990. *Report of the UNDP workshop on "New challenges to Western Samoa's environment".* Div. Environment and Conserv., Dept of Lands, Serveys and Environment, W. Samoa.

Spennemann, D.H.R., L.H. Belz and G. Byrne. 1990. The potential impacts of projected climatic change and sea level rise on Togatapu, Kingdom of Tonga. *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128. pp. 161-192.

Annexes

Annex 1: Terms of Reference

1. Under the supervision and guidance of the SPREP Climate Change Task Team Leader, a two-person mission will visit Western Samoa for approximately 7 days. The main purpose of the mission is to prepare, in close consultation with national counterparts identified by the Government of Western Samoa, a proposal for a programme of assistance to undertake an in-depth study of the potential impact of expected climatic changes (primarily sea level and temperature rise) on the natural environment and the socio-economic structures and activities of the host country, including the identification of response options which may be suitable and available to avoid or mitigate the expected negative impact of climatic changes.

2. Specifically, while in Western Samoa, the two senior experts from the UNEP/SPREP Task Team on climatic change will:

   (a) examine and evaluate the available information affecting the physical and biological environment (terrestrial and marine) of the islands comprising the country;

   (b) examine and carry out a preliminary assessment of the available demographic, social (including archaeological and cultural) and economic data;

   (c) present, via a public lecture or radio broadcast as appropriate, an overview of the current state of knowledge concerning the greenhouse effect and its possible consequences for Pacific Island nations;

   (d) present to the national authorities, organisations, institutions and experts the results of UNEP-sponsored studies, specifically those conducted in the South Pacific (eg. Kiribati) and South Asian Seas areas outlining the potential applicability of these studies to the host country;

   (e) discuss with the national authorities, organisations, institutions and experts their perceptions of the consequences of the potential impacts of climatic change and seek their views on the suitable response options; and

   (f) identify national authorities, organisations, institutions and experts which may participate in the in-depth study expected to follow the mission, and determine the modalities of co-operation between the legal and administrative structures of the country with the team which will assist in the implementation of the in-depth study.

3. On the basis of the activities referred to in paragraph 2 above, as well as information collected by the experts prior to their mission to the host country, the experts will prepare a joint report containing:

   (a) a general overview of the climatological, oceanographic, geological, biological and socio-economic factors which may be relevant to or affected by the potential impacts of expected climatic changes;

   (b) a preliminary identification of the most vulnerable components and sites of the natural environment, as well as the socio-economic structures and activities which may be most critically affected by expected climatic changes;

(c) an overview of current environmental management problems in the country and an assessment of how such problems may be exacerbated by climatic changes;

(d) a detailed proposal for a joint programme of assistance to host country for the in-depth evaluation of potential impacts of expected climatic changes on the natural environment and the socio-economic structures and activities of Western Samoa including the identification of policy or management options suitable to avoid or mitigate the impact of climatic changes; the proposal should identify the workplan, timetable and financial requirements of the in-depth evaluation as well as the possible institutional arrangements for carrying out the evaluation.

4. Prior to leaving the country, the mission will present and discuss with the authorities identified by the Western Samoan Government the outline of the proposed programme, as well as the major findings of the mission. The comments and suggestions of these authorities will be duly taken into account in preparing the final report of the mission.

5. The final report of the mission, prepared as the experts joint report and as specified in paragraph 3 above, will be simultaneously submitted to the SPREP Climate Change Task Team Leader, the Director of UNEP OCA/PAC and the SPREP Director for clearance. Submission of the report will be made no later than 30 days following the completion of the visit.

6. The final report of the mission will be transmitted by SPREP to the Western Samoan Government together with the comments of SPREP and UNEP and will be used as the basis for subsequent assistance to Western Samoa in formulation and implementing suitable response options to the expected impacts of climatic change.

Annex 2: List of Materials used in the Presentation on Climate Change and its Possible Effects on Western Samoa and the Pacific

An overview on the current state of knowledge concerning greenhouse effect and its possible impact in the Pacific was prepared based on the following readings, and presented in a seminar for government officials before the commencement of the study and again on a radio broadcast. The seminar was conducted at the board room of the Department of Lands and Environment on the 28th of January and was attended by many of the government officials who later participated in the preparation of this report. The references listed below were used in preparation for these presentations and are recommended reading on the subject of climate change.

ASPEI Task Team members. 1990. Overview of potential impacts of climate change in the SPREP region. pp. 1-13 *In* Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview*. UNEP Regional Seas Reports and Studies No 128.

Buddemeier, R.W. and J.A. Oberdorfer. 1990. pp. 56-67 *In* Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview*. UNEP Regional Seas Reports and Studies No 128.

Chapell, J. 1990. The effects of sea level rise on tropical riverine lowlands. pp. 68-75 *In* Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview*. UNEP Regional Seas Reports and Studies No 128.

Conell, J. and P. Roy. 1990. The greenhouse effect: the impact of sea level rise on low coral islands in the South Pacific. pp. 88-115 *In* Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview*. UNEP Regional Seas Reports and Studies No 128.

de Freitas, C.R. 1991. The greenhouse crisis: myths and misconceptions. *Area* 23. 1:11-18.

Garrett. J. 1991. Greenhouse: the state of play. p.27 *In Pacific Islands Monthly,* Sept. 1991.

Goldemberg, J. 1990. Policy responses to global warming. pp. 166- 184 *In* Leggett, J. (ed) *Global warming. The Greenpeace Report.* Oxford: Oxford University Press.

Hackett, C. 1990. Plant ecophysiological information for contingency thinking in the southwest Pacific in the face of the greenhouse phenomenon. pp. 76-87 *In* Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview*. UNEP Regional Seas Reports and Studies No 128.

Haines, A. 1990. The implication for health. pp. 149-162 *In* Leggett, J. (ed) *Global warming. The Greenpeace Report.* Oxford:Oxford University Press.

Hulm, P. 1989. *A climate of crisis. Global warming and the island South Pacific.* Prepared for the South Pacific Regional Environment Programme. Association of South Pacific Environmental Institutions, Port Moresby.

Jacobs, B.C. 1990. CO2, climate change and crop physiology in the South Pacific. pp. 1-23 *In* Hughes,P.J and G McGregor (eds) *Global warming-related effects on agriculture and human health and comfort in the South Pacific. A report to the South Pacific Environment Programme.* The Association of South Pacific Environment Institutions, University of Papua New Guinea.

Kelly, M. 1990. Halting global warming. pp 83-112 *In* Leggett, J. (ed) *Global warming. The Greenpeace Report.* Oxford: Oxford University Press.

Leggett, J. 1990. The nature of the greenhouse threat. pp 14-43 *In* Leggett, J. (ed) *Global warming. The Greenpeace Report.* Oxford:Oxford University Press.

McGregor, G. 1990. Possible impacts of climatic change on human thermal comfort in the western tropical Pacific. pp 98-113 *In* Hughes,P.J and G McGregor (eds) *Global warming-related effects on agriculture and human health and comfort in the South Pacific. A report to the South Pacific Environment Programme.* The Association of South Pacific Environment Institutions, University of Papua New Guinea.

McLean, R.F. 1989. *Kiribati and sea level rise. Report of field visit in May 1989 to consider implications of projected sea level rise for Kiribati.* Commonwealth Secretariat.

Myers, N. 1990. Tropical rainforests. pp. 372-399 *In* Leggett, J. (ed) *Global warming. The Greenpeace Report.* Oxford:Oxford University Press.

Nunn, P.D. 1990a. Potential impacts of projected sea level rise on Pacific island states (Cook Islands, Fiji, Kiribati, Tonga and Western Samoa): a preliminary report. pp. 127-148 in Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No 128.

Nunn, P.D. 1990b. Recent coastline changes and their implications for future changes in the Cook Islands, Fiji, Kiribati, the Solomon Islands, Tonga, Tuvalu, Vanuatu and Western Samoa. pp. 149-160 *In* Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No 128.

Nunn, P.D. 1991a. Sea-Level changes during the past 8000 years in Fiji, Tonga and Western Samoa: implications for future coastline development. In *Workshop on Coastal Processes in the South Pacific Island nations.* Lae, Papua New Guinea 1-8 Oct 1987. SOPAC Technical Bulletin 7: 79-80

Nunn, P.D. 1991b. Keimami sa vakila na liga ni kalou (Feeling the hand of God) *Human and non human impacts on Pacific Island environments.* Environment and Policy Institute East West Center Occasional Paper No 13.

Nurse, G.T. 1990. Possible effects of climatic change on health in the Pacific Island countries. pp 114-121 *In* Hughes,P.J and G McGregor (eds) *Global warming-related effects on agriculture and human health and comfort in the South Pacific. A report to the South Pacific Environment Programme.* The Association of South Pacific Environment Institutions, University of Papua New Guinea.

O'Collins, M. 1990. Social and cultural impact: a changing Pacific? pp. 116-126 *In* Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No 128.

Overton, J. 1990. Socio-economic change in Fiji agriculture: past, present....and future? pp 85-97 *In* Hughes,P.J and G McGregor (eds) *Global warming-related effects on agriculture and human health and comfort in the South Pacific. A report to the South Pacific Environment Programme.* The Association of South Pacific Environment Institutions, University of Papua New Guinea.

Pernetta, C.J. 1990. Projected climate change and sea level rise: a relative impact rating for the countries of the Pacific Basin. pp. 14-24 *In* Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No 128.

Schimel, D. 1990. Biochemical feedback in the earth system. pp 68- 82 *In* Leggett, J. (ed) *Global warming. The Greenpeace Report.* Oxford: Oxford University Press.

Schneider, D. 1990. The science of climate-modelling and a perspective on the global warming debate.pp 44-67 *In* Leggett, J. (ed) *Global warming. The Greenpeace Report.* Oxford:Oxford University Press.

Sestini, G., L. Jeftic and J.D. Milliman. 1989. *Implications of expected climate changes in the Mediterranean region: an overview.* UNEP/ Mediterranean Action Plan. MAP Technical Reports Series No 27.

Singh, U., D.C. Godwin and R.J. Morrison. 1990. Modelling the impact of climate change on agricultural production in the South Pacific. pp 24-40 *In* Hughes,P.J and G McGregor (eds) *Global warming-related effects on agriculture and human health and comfort in the South Pacific. A report to the South Pacific Environment Programme.* The Association of South Pacific Environment Institutions, University of Papua New Guinea.

Sullivan. M and J.Pernetta. 1990. The effects of sea level rise on atolls and motu. pp. 46-55 *In* Pernetta, J.C and P.J. Hughes(eds) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No 128.

Sullivan, M. and L. Gibson. 1991. *Environmental planning, climate change and potential sea level rise: report on a mission to Kiribati.* A report produced for the Association of South Pacific Environmental Institutions (ASPEI) to the Government of Kiribati and to the South Pacific Regional Environment Programme (SPREP). SPREP Reports and Studies No 50.

Thaman, R.R. 1990. Coastal reforestation and coastal agroforestry as strategies to address global warming and to promote sustainable development in the Pacific Islands. pp. 65-84 *In* Hughes,P.J and G McGregor (eds) *Global warming-related effects on agriculture and human health and comfort in the South Pacific.* A report to the South Pacific Environment Programme. The Association of South Pacific Environment Institutions, University of Papua New Guinea

Woodwell, G.M. 1990. The effects of global warming. pp. 116-132 *In* Leggett, J. (ed) *Global warming. The Greenpeace Report.* Oxford: Oxford University Press.

Wyrtki. K. 1990. Sea level rise: the facts and the future. *Pacific Science,* vol.44, no.1:1-16.

Annex 3. List of People Consulted during the Mission

The following people were consulted during the study. We hope we have accurately presented their views.

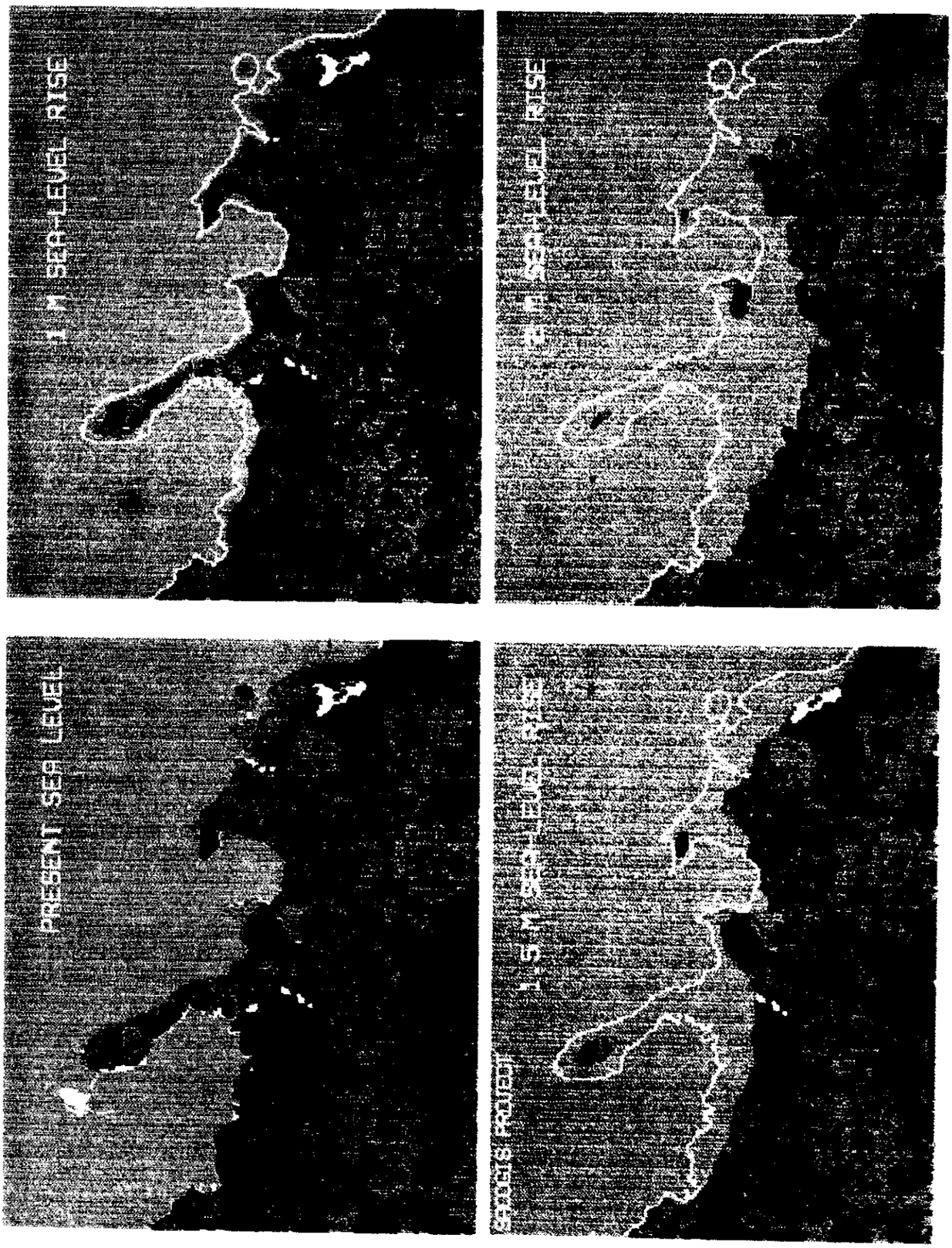
In Western Samoa:

Roger Cornforth, Environmental Planning Advisor, Div. of Environment and Conservation.
Bismarck Crawley, Met. Observer, W.S. Meteorological Office
Folasaitu Crawley, Acting Deputy General Manager, Engineering, EPC
Kevin Doig, Senior Water Engineer, Public Works
Malu Faalogo, Ministry of Transport.
Roger Hazelman, Treasury Depart.
Geoff Hyde, Tourism Advisor, Western Samoa Visitors Bureau.
Malaki Iakopo, Assistant Director, Forestry Depart.
Tuu'u Ieti, Urban Planner and Assistant Director Public Works.
Fiu Mataese Elisara Laulu, Director of Lands, Surveys and Environment.
Pati Liu, Act. Head, Div. of Environment and Conservation.
Atonio Mulipola, Fisheries Officer, Fisheries Div.
Clarke Peteru, O Le Siosiomaga Society Inc.
John Roberts, Chief Engineer - Posts and Telecommunications.
Florence Saaga, Western Samoa Visitors Bureau.
David Salomon, Water Engineer, Public Works
Rusty Strickland, Australian Volunteer in Fisheries, Asau Savai'i
Dan Su'a, Senior Marine Biologist, Fisheries Div.
Tupuola Tavita, Director, Div. of Agriculture, DAFF
Ausitalia Titimaea, Superintendent, W.S. Meteorological Office
Nofo Vaaelua, Secretary for Transport.

Others Consulted:

Reid Basher, NZ Met Service, Wellington, NZ
Jim Eade, Deputy Director, SOPAC, Suva, Fiji
Ed de Ste. Croix, NZ Met service, Wellington, NZ
Leon Zann, Great Barrier Reef Marine Park Authority, Townsville, Australia

Figure 12: The coastline of Apia, Western Samoa, assuming four sea levels and no effects from erosion or human intervention.
(Crawley, unpub.)



4.2 Analysis of Potential Threat to Western Samoa

After discussions with representatives of government and interested NGOs, an analysis of the effects of each the climatic threats listed has been analysed for the different ecological zones in Western Samoa.

4.2.1 The Effects of Sea Level Rise

1. *Reefs*

   (a) The future of the seaward reef face is unsure. Since sea level rise will be associated with many other climate-related factors (the most important being the possibility of increased sedimentation and cyclone damage) it is difficult to assess whether the outer reefs will respond to deeper water by growing or by dying back further and ultimately being destroyed and removed by storm waves. There is reasonable to believe that they will survive in some areas and be torn apart in others over the coming century as variable factors impact on their health and growth.

   (b) Where the lagoons survive, there is a reasonable chance that an increase in sea level will improve the lagoonal environment. Coupled with workable conservation regulations, a higher sea level could be a powerful force in rejuvenating this very important resource.

   (c) The survival of the intertidal environment is of great concern. Already under intense human pressure, the associated vertebrate and invertebrate nurseries hold the key to the survival of the reef communities and their support of the people who depend on them for food. In many nursery areas, landward slopes reflect nearshore topography so that a simple increase in sea level would not result in substantial losses of nursery area. Where slopes become steeper inland or where people are reluctant to give up the land to the sea, however, the present intertidal environments could be threatened as sea levels rise.

2. *Lowlands*

   (a) The inundation of land just above the high tide mark also causes serious concern. Structures built here (ports, landings, harbours, breakwalls, buildings on reclaimed lands, etc) will have to at least be raised or be relocated. Many of Western Samoa's coastal villages as well as the capital city of Apia could be partially inundated by a significant rise in sea level (Figure 12). The international airport, which is located at about 1 m above sea level, could also be at risk. Planning for this possibility will be essential when buildings, roads and other structures of long life expectancy are to be built to avoid expensive, and otherwise needless, relocation.

   Sewerage facilities, which will soon be built under the high tide mark in Apia, will not be greatly affected. Repair and maintenance would become more difficult, however, if the water rises further, resulting in the pipes being deeper and less accessible. Very little agriculture is practiced on land below 10 m in elevation so minimal impact is expected on food security (IPCC 1990).

   (b) Inland lowlands in many areas will become more swampy and springs more prevalent as the rising water table brings ground water nearer the surface. Where ground water flowing toward the ocean meets the less-permeable soils of the ancient swamplands (a common case all around coastal Upolu and in some areas of Savai'i) the ground water will come to the surface as it does today after heavy, long-duration storms (K. Doig, Personal Communication). Where these points of emergence are constant, suitable drainage will be required but if new areas of intermittent ground water emergence result from a higher water table, areas now inhabited may become uninhabitable.

3. Uplands: Fresh water wells

According to the Senior Water Engineer, sea level rise may have little or no impact on existing water sources in Western Samoa. Wells are drilled inland and rely on the fresh water lens which floats on the salt water beneath. Required precautions would be the same at any sea level; only the intake pipe would have to be elevated to continue drawing from the centre of the lens.

4.2.2 The Effects of Increased Temperature, Rainfall and Evapo-transpiration

1. Temperature

Some Pacific countries already experience the temperatures that are predicted for Western Samoa. Hughes and Sullivan (1990) suggest that temperature zones will simply move uphill in PNG and may have some beneficial effects. Predicted temperature increases may stimulate more changes in the workplace but the effect on productivity may not be too great. There are already many examples of changes in work habits and habitats in Western Samoa in response to heat. Most of the government buildings visited were already air conditioned and, in the field, plantation forestry now practices "line-harvesting" and "line-planting" to provide an overstory to shade the workers and the young trees below. Subsistence agriculture might change somewhat, using the cooler hours of the early morning or late evening to complete the required work. Although predicted increases in temperatures may result in some changes in the biological environment, any changes would be slight as compared with the ongoing response of the ecosystem to the continuous, short-term environmental changes that naturally occur and to the effects of human activity.

Although Western Samoa does not presently support a major fishing industry, pelagic fishing will undoubtedly increase in importance in the near future. Increased air temperature is associated with increased sea temperature which will undoubtedly have some impact on open ocean fisheries.

The dynamics of the open ocean results in the sea surface being low in nutrients. Increased water temperature decreases the density and viscosity of water. Dead animals and plants would sink slightly faster through warmer water into the zone below usable sunlight, accelerating the mechanism which removes the nutrients from the zone where the primary producers live in the ocean. In addition, plants and animals living in warmer water would respire faster, requiring more food to keep them alive. The effects this would have on the entire food chain, including the fish presently caught for food, is unknown. Samoa, which already complains of decreasing returns for its efforts in the pelagic fisheries, might find open-ocean fishing seriously limited in practical terms if the seas warm up.

The effects of a warmer earth, including a warmer sea, are not well understood, however. Localised changes may oppose the regional changes experienced. For example, if areas of ocean upwelling move near the Samoan islands, local fishing could improve regardless of what happens in the region. The problem is that, while the state of the art of predicting weather in a warmer world is crude, our ability to predict what will happen to individual countries is nearly non-existent (Basher et al., 1992). Until the present weather systems are understood, we are limited in our ability to create accurate models to predict changes in weather patterns due to changes in temperature. Until we can provide Pacific island countries with information they can have faith in, they can not be expected to invest their severely limited funds on expensive projects to prepare for uncertain problems caused by a predicted increase in global temperatures. Accurate, relevant information on what countries can expect in a warmer world must be produced and made available in clear language to each of the South Pacific island countries.

2. Rainfall

Western Samoa has a relatively high annual rainfall at present. This is predicted to increase if global temperatures rise due to the increased ability of warmer air to hold moisture (McGregor 1990). Because the geology and hydrology of the country precludes building effective water storage dams in most stream valleys, increased intensity of rainfall will not improve the problems of seasonal water shortage in the municipal water supply systems. On the other hand, increased runoff would increase erosion on land, speed sedimentation in the existing water catchment system, lower the quality of the water entering treatment plants and untreated supply systems and increase the sediments dumped on the reefs. Because erosion is already considered a serious environmental problem in Western Samoa, many people believe this is the major environmental threat of the future. Similarly, increased rainfall would not greatly improve the hydroelectric production in most of the country. Only the new Afulilo hydroelectric dam would have the ability to contain large amounts of water in a shallow basin.

Some of the archeological sites that occur in valleys may be at risk if Western Samoa experiences heavier flooding. One such site, an octopus mound, has recently been inspected. It has already sustained considerable damage from stream flooding. Few of the known archeological sites are prone to destruction from floods or wave action. However, this may simply be due to the lack of information available on archeological sites at present.

3. Evapo-transpiration

In a warmer world, the periods between rainfall could become drier as evapo-transpiration rates increase due to the increased ability of warmer air to hold water. For municipal water supplies, the rapid drying of the limited water catchment areas could result in more periods without surface runoff available for use. In agriculture, higher evapo-transpiration would result in higher demands for irrigation water from supplies that are already in short supply. These problems would probably be more pronounced in the leeward side of the main islands where the dry season droughts are already a problem.

Hydroelectric generation in existing systems would be affected in the same way as municipal water, increasing the frequency and length of time that power generation from fossil fuels will be required. For the Afalilo hydroelectric facility, high evaporation rates from the shallow basin may result in a decrease in the usefulness of this important hydroelectric facility.

4.2.3 The Effects of Increased Storm Strength and Frequency

1. Reefs

Where the reef front is healthy, it will continue to grow and protect the lagoons and shores. Where reef fronts are not as resilient, they may not be able to recover from storm damage so that subsequent storms could destroy this protective area resulting in degraded reefs similar to those seen between Luatuanu'u and the beach at Solosolo. If this happens, lagoons and shores would be exposed to increased wave damage which would have serious effects on the entire reef ecosystem.

After cyclones Ofa and Val, many reef tops were found to be in surprisingly good condition, probably due to the natural selection of coral species that are well adapted to that environment. Deeper reefs on exposed shores, however, were seen to sustain considerable damage from storms. Casual but wide-ranging surveys made by the principal author after both storms revealed that the cyclones totally destroyed exposed inshore reefs to a depth of 8 metres and damaged reefs to much greater depths. In Aganoa Bay, for instance, one of the few "coral gardens" of South Pacific fame in Western Samoa was destroyed by Cyclone Ofa in 1990. The rubble that was left after the storm was covered with algae and mold for months as the animals below the rubble decomposed. Divers from the Solomon Islands say that their reefs required 20-40 years to recover from similar storm damage suffered earlier in this century.

7. References

ANZDEC. 1990. *Land resource planning study - Western Samoa.* Asian Development Bank TA No 1065-SAM, New Zealand.

Basher, R., B. Collen, B. Fitzharris, J. Hay, B. Mullan and J. Salinger 1992. *Preliminary studies for South Pacific climate change.* New Zealand Meteorological Service, Wellington.

Brook, R.R., R.E. Basher, J.P. Bruce, S.A. Parsons and M.E. Sullivan 1991. *The changing climate in paradise.* A report to the WMO. Bureau of Meteorology, Dept of the Arts, Sport, the Environment, Tourism and Territories, Australia.

Burgess, S.M. undated. *The climate and weather of Western Samoa.* Wellington: New Zealand Meteorological Service, Wellington.

Carter, J. 1984. *Pacific islands year book.* 15th edition. Pacific Publications, Sydney.

Dahl, A.L. 1986. *Review of the Protected areas System in Oceania.* IUCN Conservation Monitoring Centre, Cambridge, United Kingdom.

Department of Economic Development 1982. *Western Samoa's fifth development plan.* DED, Apia.

Div of Environment and Conservation. 1991. *National Report for UNCED: Western Samoa.* Dept of Lands and Environment, Div. of Environment and Conservation.

Fox, J.W. and K.B. Cumberland. 1962. *Western Samoa: Land, life and agriculture in tropical Polynesia.* Report commissioned by the Ministry of External Relations and Trade, Wellington.

Hardin & Assoc. Pty Ltd. 1989. *South Pacific Project Development Facility: Western Samoa.* Report for the South Pacific Trade Commission, Sydney.

Hughes, P. and M. Sullivan. 1990. Climate change and agricultural production in the highlands of Papua New Guinea. pp. 270-279 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

Hulm, P. 1989. *A climate of crisis. Global warming and the island South Pacific.* Prepared for the South Pacific Regional Environment Programme. Association of South Pacific Environmental Institutions, Port Moresby.

IPCC. 1990. Adaptive responses to climate change: Coastal zone management workshop. The *Proceedings of the Intergovernmental Panel on Climate Change Response Strategies Working Group.* Australian Govt. Publishing, Canberra.

KRTA. 1988. *Environental planning for tourism in Western Samoa: A report to the Government of Western Samoa and the South Pacific Regional Environmental Programme.* KRTA Ltd, Auckland, New Zealand.

McGregor, G. 1990. Possible consequences of climatic warming in Papua New Guinea with implications for the tropical southwest Pacific area. pp. 25-40 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

6) Studies of atmospheric and oceanic temperatures and their relationship to cyclone frequency and strength in the Samoan region. This would help predict the potential change in storm damage to all South Pacific island countries as global warming continues. As a possible beginning to this type of study, Dr. R. Basher, NZMS, expects to publish a scientific study on cyclone frequency as a function of sea surface temperature and the Southern Oscillation Index - a measure of the strength of "el Nino". This study will improve our understanding of cyclone frequency in various subregions of the Pacific and has a potential to be extended to address particular country needs and risks.

7) Studies on historic temporal and spacial rainfall distributions, the potential effects of increased atmospheric and oceanic temperatures on rainfall frequency and predicted flooding and drought potentials under various predicted world temperature regimes.

8) Studies of prehistoric weather patterns and climate changes which will provide clues to how weather patterns may shift in the future in response to climate change.

National Disaster Council. 1991. *Preliminary damage assessment report for cyclone Val, 6-8 December, 1991.*

National Population Policy Committee. 1991. Is there a need for a national population policy for Western Samoa? (prepared for the National Population Policy Workshop) Western Samoa Health Association, Apia.

NCDS. 1991. *National centre for development studies database: Western Samoa.* Australian National University, Canberra.

Nunn, P.D. 1990a. Potential impacts of projected sea level rise on Pacific island states (Cook Islands, Fiji, Kiribati, Tonga, and Western Samoa): a preliminary report. pp. 127-148 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

Nunn, P.D. 1990b. Recent coastal changes and their implications for future changes in the Cook Islands, Fiji, Kiribati, the Solomon Islands, Tonga, Tuvalu, Vanuatu and Western Samoa. pp. 149-160 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

Omeara, J.T. 1987. Samoa: Customary individualism. pp 74-113 *In* R.G. Crocombe and S. Arutangi (eds.) *Land Tenure in the Pacific.* University of the South Pacific, Suva.

Park, J. (in progress). *National ecological survey for Western Samoa.* Dept of Conservation. Wellington.

Paine, J.R. 1989. *Western Samoa: an overview and description of its protected areas.* World Conservation Monitoring Centre, Cambridge, U.K.

Pearsall, S.H. 1988. *Preliminary technical report for Western Samoa terrestrial ecosystem mapping.* Prepared for World Wildlife Fund, Australia.

Pearsall, S.H. and W.A. Whistler. 1991. *Terrestrial ecosystem mapping for Western Samoa: project report, and proposed national parks and reserves plan.* SPREP and East-West Center, Environment and Policy Institute, Honolulu.

Pernetta, J.C. and G. Sestini. 1989. *The Maldives and the impact of expected climatic changes.* UNEP Regional Seas Reports and Studies No. 104, UNEP, Nairobi.

Pernetta, J.C. 1990. Projected climate change and sea level rise: a relative impact rating for the countries of the Pacific Basin. pp. 14-24 *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128.

Research and Statistics Dept. 1991. *Bulletin for the Central Bank of Samoa.* Vol. VI No. 2. Central Bank of Samoa, Apia.

Reti, M.I. 1990. *Report of the UNDP workshop on "New challenges to Western Samoa's environment".* Div. Environment and Conserv., Dept of Lands, Serveys and Environment, W. Samoa.

Spennemann, D.H.R., L.H. Belz and G. Byrne. 1990. The potential impacts of projected climatic change and sea level rise on Togatapu, Kingdom of Tonga. *In* J.C. Pernetta and P.J. Hughes (Eds.) *Implications of expected climate changes in the South Pacific region: an overview.* UNEP Regional Seas Reports and Studies No. 128. pp. 161-192.

Stednick, J.D. 1990. *Water quality and quality monitoring programmes for the Vaisigano catchment, in particular, and Western Samoa in general.* FAO field document No 3, 8851 - SAM.

Sullivan, M. and L. Gibson. (1991). *Environmental planning, climate change and potential sea level rise: report on a mission to Kiribati.* SPREP report No. 50, Noumea, New Caledonia.

TCSP. 1990. *Guidelines for the integration of tourism development and environmental protection in the South Pacific.* Tourism Council of the South Pacific, Fiji.

TCSP. 1991. *Western Samoa tourism development plan 1992 - 2001.* Tourism Council of the South Pacific, Fiji.

Wright, A.C.S. 1963. *Soils and land use of Western Samoa.* New Zealand Soil Bureau Bulletin No. 22. Government printers, Wellington.

Wyrtki, K. 1990. Sea level rise: the facts and the future. *Pacific Science,* 44:1-16.

Zann, L. 1991. *The inshore resources of Upolu, Western Samoa: coastal inventory and fisheries database.* FAO/UNDP project SAM/89/002 Field Report No. 5.