Capacity-Building Activities Related to Climate Change Vulnerability and Adaptation Assessment and Economic Valuation for Fiji

Report to the World Bank
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The International Global Change Institute

Te Wānanga o ngā Rere Kētanga-a-Taiao

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Objectives

The Terms of Reference for this work specified three objectives to the Fiji component:

Objective 1a: to provide a prototype FIJICLIM model (covered under PICCAP funding)

The two main tasks were to:
- construct a prototype software package, known as FIJICLIM, for the PICCAP programme in Fiji (PICCAP Fiji), incorporating features specified in the ToR;
- develop a FIJICLIM Users' Guide which provides information on all the model components and a detailed, illustrated, step-by-step guide for the use of the scenario generator and sectoral impact models.

Objective 1b: to provide training and transfer of FIJICLIM

The main task was to:
- facilitate the transfer of FIJICLIM to PICCAP Fiji by developing and implementing a short training course (2 days) in Fiji.

Objective 1c: to present and evaluate World Bank study findings and to identify future directions for development and use of FIJICLIM (2-day workshop)

The mains tasks were to:
- Participate in a one-day "in-house" workshop co-ordinated by PICCAP Fiji;
- Contribute to a one-day national workshop that will focus on presentation, discussion and ground-truthing of the findings of the World Bank study on climate change vulnerability and adaptation, as well as the economic valuation.

Outcomes

Proceedings of the training course and workshop were prepared by the Fiji Department of Environment. The summaries from these proceedings reflect a very high degree of success with the contracted activities (Annex 1).

All of the objectives were completed in the specified time-frame:

- The prototype version of FIJICLIM was completed, evaluated and installed on CD-ROM in preparation for transfer to PICCAP Fiji;
- A FIJICLIM description and Users' Guide was prepared (Annex 2);
- A training schedule, powerpoint presentations, and training exercises, were prepared for transfer of FIJICLIM through a 2-day training course (Annex 3);

- The consultants participated in the "in-house" workshop, facilitated by Mr Leone Limalevu (PICCAP coordinator for Fiji);
- Contributions were made to the one-day national workshop, through presentations on the Vulnerability and Adaptation study, and participation in discussions that followed. Powerpoint presentations are attached (Annex 4).

Annex 1

Summaries of training course and workshop proceedings prepared by the Fiji Department of Environment

FIJICLIM PROTOTYPE TRAINING WORKSHOP.
CENTRA, SUVA

28TH FEB — 29TH FEB 2000.

Workshop Proceedings

Organized by
The Climate Change Country Team

Compiled by
Leigh-Anne Buliruarua
Climate Change Project Officer

CLIMATE CHANGE FIJICLIM PROTOTYPE TRAINING WORKSHOP
CENTRA, SUVA
28TH-29TH FEB 2000

The two day workshop comprised of a hands-on FIJICLIM Prototype Training on the 28th – 29**th** February. Organisations hosting the workshop included PICCAP-Fiji (Department of Environment), PICCAP-SPREP, International Global Climate Institute (IGCI) University of Waikato and the World Bank.

1.0 WORKSHOP OBJECTIVE

The main objectives of the workshop were:

- To familiarize experts and representatives from the feur main sectors in Fiji of the FIJICLIM Prototype based on Viti Levu.
- To evaluate the FIJICLIM Prototype model

The various organizations that were represented included:

- Government Sector Representatives
- Statutory Organization Representatives and
- The Climate Change Country Team

(ref. Appendix 2– List of Participants)

2.0 PROGRAMME

2.1 FIJICLIM TRAINING

The FIJICLIM prototype is based on PACCLIM, which was developed by the International Global Climate Institute (IGCI) as part of the Pacific Islands Climate Change Assistance Programme (PICCAP), executed by the South Pacific Regional Environment Programme (SPREP). The PACCLIM model consisted of example applications that were incorporated for Fiji and Kiribati (Viti Levu and Tarawa).

Additional funding from the World Bank and at the request of the PICCAP Fiji coordinator, a part of the PACCLIM model that was incorporated for Fiji was used to develop the FIJICLIM prototype. Development of the FIJICLIM prototype has involved the linking of historical climate data and a scenario generator with sectoral impacts for four key sectors: agriculture, coastal zone, human health and water resources.

The first day was mainly focussed on presentations and an introductory training exercise of the FIJICLIM model, while the second day involved problem solving exercises. (FIJICLIM Users guide and Training Manual included in Appendix).

Day 1
Facilitators – Dr. Gavin Kenny, Dr. Neil de Wet, Mr. Wei Ye.

1. Opening – Dr. Graham Sem (SPREP)
2. Presentation of FIJICLIM (Scenario generator) – Dr. Gavin Kenny (IGCI)
3. Sectoral model for Agriculture – Dr. Gavin Kenny (IGCI)
4. Sectoral model for Health – Dr. Neil de Wet (IGCI)
5. Sectoral model for Coastal and Water resources – Mr. Wei Ye (IGCI)
6. Introductory Training Exercise with participants being guided through the range of applications in FIJICLIM – Dr. Neil de Wet, Mr. Wei Ye, Dr. Gavin Kenny (IGCI)

Day 2
Facilitators – Dr. Gavin Kenny & Dr. Neil de Wet (IGCI)

7. Problem solving exercise involving:

- Reproducing selected results from the World Bank V & A study with the use of additional tools (such as IDRISI GIS) as aids to interpreting data.
- Presenting results and findings from the critique of the World Bank study.
- Review and provide critique of FIJICLIM model.

(The papers presented are included in the appendix.)

3.0 FRAMEWORK FOR WORKSHOP DISCUSSIONS

3.1 FIJICLIM TRAINING

After presentations by the IGCI consultants on the FIJICLIM model, the workshop participants were divided into 2 groups representative of the Agriculture and Human health sectors.

3.1.1 Group 1: Agriculture

Discussion Issues:

- Focus on sugarcane
- Plantgro gives estimate of biomass yields that occur with the different scenarios, in the north-west of Viti Levu
- What implications do these changes have on sugar production?

(Presentation included in the appendix).

The DKRZ Model illustrated yield declines for the mid-range and high-range scenarios for the years 2025, 2050 and 2100. Rainfall was shown to be the limiting factor for sugarcane yields.

The CSIRO Model illustrated yield improvements over the years 2025, 2050 and 2100. Under similar temperature and rainfall changes with increase in emissions, it was apparent that yields improved. However, when there was a dramatic change in rainfall, yields tended to decline.

The El Nino event indicated a 60% decline in production while the La Nina event indicated an 8% increase in production.

3.1.2 Group 2: Health

Discussion Issues:

- Describe the changes in the epidemic potential of dengue in Viti Levu for the 2 scenarios compared to the baseline.
- Determine the epidemic potential in Suva and Nadi for the 1990 baseline, the first scenario and for the second scenario.
- Explain the significance of these changes in terms of the future incidence of dengue fever in Viti Levu.
- Determine whether this analysis is useful in determining an appropriate adaptation response? What would constitute an appropriate adaptation to increased transmission efficiency related to climate change.

(Presentations included in Appendix)

From the current baseline scenario for 1990, the epidemic potentials for Suva and Nadi were 0.13 and 0.17. Changes in the epidemic potentials for Suva and Nadi showed a significant increase for both the high and best guess scenarios (see appendix 4).

Significance of such changes in terms of the future incidence of dengue fever in Viti Levu are:

- Higher transmission risks via the vector population.
- Increased frequency of epidemics
- Minimal vector populations could pose higher epidemic risks
- Higher incidence of human exposure.

Appropriate adaptation response options to increased transmission efficiency related to climate change are:

- Vector control — chemical, biological and proper sanitation that would discourage the breeding of mosquito vectors.
- Preventing exposure such as wearing protective clothing, netting/ screening and repellents.
- Strict quarantine measures are needed to prevent the introduction of vectors into all ports of entry.

- Preparedness and response such as a management plan of action, mobilizing community participation and conducting clinical and laboratory surveillance.
- Formulating action plans and policies on urban housing, sanitation and water supply.

3.1.3 Review of FIJICLIM Model

The afternoon session of the 29th comprised of discussions and presentations on the possible future directions and limitations for the FIJICLIM model.
The following suggestions were brought up in the discussions for the general progress of FIJICLIM and for sectoral model improvements.

- One of the issues on FIJICLIM was that people were expressing a desire to input their own data so that people could customize it more to their own purposes. Such a capability is currently being investigated at IGCI to develop more of these tools so that they are more flexible in terms of being more "user-friendly".

- Another issue that was brought up was the use of General Circulation Models (GCMs) as a limitation within the FIJICLIM model. It was pointed out that it was unrealistic to expect that GCMs were going to make the connections down to the regional or national scale. Therefore, it is not seen so much as the limitation of FIJICLIM but a limitation in the global modeling.

- Data was obtained from 5 GCMs which appeared to participants to contradict each other. However, IGCI consultants clarified that there are about 10 major groups in the world that work on GCMs. Each of these groups make different assumptions about atmospheric processes. Therefore, different results from different GCMs simply reflect uncertainties from the various modeling groups in terms of the science. Therefore, they aren't really contradictions because all these models are internally consistent in terms of atmospheric physics, interactions of the atmosphere with the oceans. There is internal consistency in those models, but the differences observed are brought about when zoning in at the regional or national level. The models might show similarities globally, but differences regionally. The differences reflect different assumptions of modeling.

- User-group to be set up within the country team to assist in familiarity and to assist in advising on improvements.

- Access to model is with the Department of Environment only. Current status could create conflict of interests among sectors. DOE (plus country team members) are to promote FIJICLIM to policy makers and other stakeholders.

- More training is needed (formal education, conferences and workshops). In fact, it was highlighted that this was the first time that a discussion or training on FIJICLIM, VANDACLIM or PACCLIM has gone right down to the country team level where they can really be involved.

- Economic evaluations to be incorporated perhaps as part of an on-help line.

- Potential to expand onto other sectors such as forestry. There is a possibility to incorporate it into Plantgro model.

- It is possible to include Diarrhoea in the health model as the cases are widely documented and frequently occurring in Fiji (data available).

- Inclusion of extreme climatic events in the models eg. Cyclones, as these cause major damages within all the sectors represented in FIJICLIM.

- Image resolution could be improved to show rivers and other major features on the map clearly.

- In terms of further development for FIJICLIM, the ongoing work would require some careful validation to ensure that the outputs from the model were realistic. It would probably be better that for some of these models, validation activities take place outside of the model. This is because once it is incorporated within the model, it tends to be a bit of work again to go through the different preparations of improving and managing it. For example, the coastal model would have quite a lot of validation work that has to go on outside of FIJICLIM simply because the coastal models that are required for a place like Fiji are not well developed at the moment. More model development work still needs to go on before they can even be incorporated. Different sectors or even different parts of sectors have different requirements in terms of future developments. Fiji is now exceedingly well placed with FIJICLIM and the amount of valuable data here is very rich compared to other Pacific countries.
- FIJICLIM has been developed as a tool to assist PICCAP Fiji in the Vulnerability and Adaptation Report and would advance PICCAP Fiji's contribution to the next National Communications.

4.0 CONCLUSION

The workshop was a success in terms of the initial objectives of the FIJICLIM Training Workshop:

- Through presentation and "hands-on" training on the FIJICLIM prototype model, country team members as well as representatives from the relevant sectors were able to familiarize themselves with the tool that has been used to assist with the Fiji's Vulnerability and Adaptation Report.

- Furthermore, the country team, experts and other representatives from the relevant sectors were able to provide valuable suggestions for the future directions of FIJICLIM.

Appendix 2

List of Participants

Facilitators/ Official

Dr. Gavin Kenny
Dr. Neil de Wett
Mr. Wei Ye
Dr. Graham Sem
Dr. Bob Raucher
Mr. Leone Limalevu
Mr. Simon Motilal

1. Miss Aliti Taumali
   Ministry of Health
2. Mrs. Nazmin Bi — MET Services
3. Mr. Apisai Ketenalagi - PWD

Mrs. Nirmala Kumar
Miss Leigh-Anne Buliruarua
Mr. Krishna Sharma

Others — Government

Miss Ashmita Gosai — MET Services
Mr. Mosese Baravilala - FLIS
Mr. Ashok Kumar - PWD
Mr. Taito Nakalevu - MAFF
Miss Maria Elder - MAFF
Mr. Atish Prasad - MAFF
Ms. Vilimaina Tavaiciia - MAFF
Mr. Sadeesh Chand —

Country Team

Mr. Jone Feresi — L & WRES- MAFF
Mr. Jagat Bhusan — Lands Dept.
Mr. Inoke Ratukalou — Land Use-Koronivia
Mr. Malakai Sevudredre — Forestry Dept.
Mr. Jai Shree Gawander — FSC
Mr. Sadeesh Chand — Ministry of Health
Mrs. Nazmin Bi — MET Services
Mr. Apisai Ketenalagi - PWD

Other Organizations

Dr. Graham Shorten - SOPAC

FIJICLIM

Description and Users Guide

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F I J I C L I M
Description and Users Guide

Prepared for PICCAP Fiji

b y t h e
International Global Change Institute
(I G C I)
University of Waikato
New Zealand

Gavin Kenny, Wei Ye, Richard Warrick, Neil de Wet

February 2000

PART 1: FIJICLIM System Description

1 Introduction

The FIJICLIM prototype is based on PACCLIM which was developed by the International Global Change Institute (IGCI) as part of the Pacific Islands Climate Change Assistance Programme (PICCAP) executed by the South Pacific Regional Environment Programme (SPREP).

Both FIJICLIM and PACCLIM build directly on a comparable model development for New Zealand, known as the CLIMPACTS system (Kenny *et al,* 1995, 1999; Warrick *et al.,* 1996, 1999). The development of CLIMPACTS has been funded by the Foundation for Research Science and Technology since 1993. Its core components, which include a graphic user interface (GUI), a customised geographic information system (GIS), and data compression routines, have provided the basis for the development of FIJICLIM. The development of FIJICLIM is complementary to similar developments that have evolved from CLIMPACTS, for Bangladesh (BDCLIM), Australia (OZCLIM), and for training in climate change V&A assessment (VANDACLIM).

There are a number of distinct advantages to country-scale IAMS:

- They integrate together relevant biophysical information, including both models and data, in a form that is readily accessible to both scientists and policy-makers alike;

- They provide the capacity for consistent application, at the country scale, of user-specified scenarios of climate and sea-level change across a range of sectors;

- By integrating relevant biophysical information and climate change scenarios, they provide the capacity for multiple simulations of climate change impacts in order to examine scientific uncertainties and alternative policy options;

- They are generally easy to use, quick running and, perhaps most importantly, can be readily updated and expanded.

2 Overview of FIJICLIM

The development of FIJICLIM has involved the linking of historical climate data and a scenario generator with sectoral impact models for four key sectors: agriculture, coastal zone, human health, water resources.

FIJICLIM comprises two main components:

- **a scenario generator** which links together historical climate data (temperature and rainfall), patterns of climate change from complex global climate models (GCMs), and output from a global temperature and sea-level change model, called MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change; Wigley, 1994);

- **sectoral models** for agriculture, coastal zone, human health and water resources.

A schematic representation of FIJICLIM is given in Figure 1, which shows the connections between these main components.

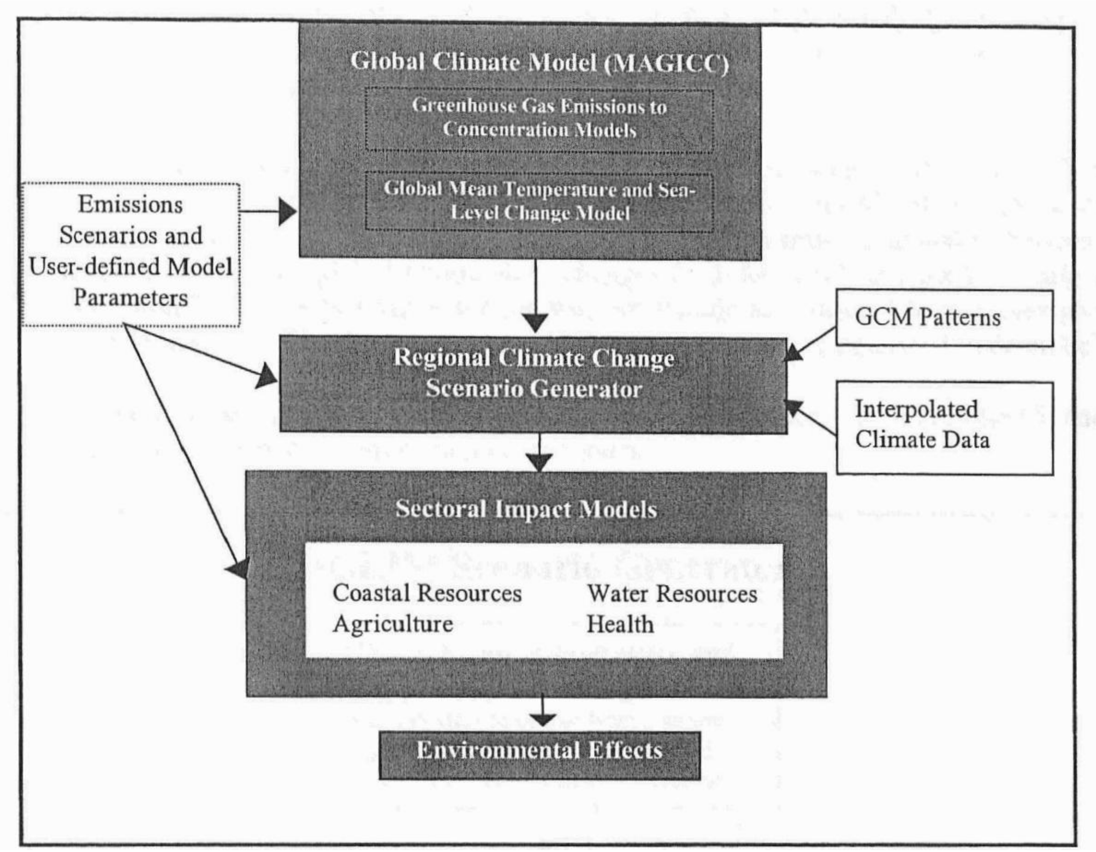


Figure 1: Schematic representation of the FIJICLIM model system

3 Overview of FIJICLIM Scenario Generator

The FIJICLIM Scenario Generator has been developed as a tool to generate scenarios of climate and sea-level change at the country scale using the best available global information.

The main components of the FIJICLIM Scenario Generator are:

1. **Library files** of output from a global temperature and sea-level change model, called MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change; Wigley, 1994);

2. **Patterns of temperature and rainfall change** for the western Pacific, derived from general circulation models (GCMs);

3. Interpolated monthly **climate data** (temperature and rainfall) for Viti Levu.

The scenario generator provides the capacity for generating two types of climate change scenario: **synthetic** and **model-based.**

- The **synthetic scenario** generator enables users to make incremental adjustments to temperature (change in °C) and rainfall (plus or minus percent change). These adjustments are applied uniformly to the baseline climate data.

- The **model-based** generator presently uses the **linked-model** approach. There are two components to this approach. At the "top end" are library files of output from a simple global climate model, called MAGICC' (Wigley, 1994) which provide global temperature and sea-level changes. The global temperature changes from MAGICC are used to *scale* temperature and rainfall patterns of change for the western Pacific as projected by complex global climate models (GCMs). These components, and their application, are described in detail below.

A schematic representation of the FIJICLIM Scenario Generator is given in Figure 2, and shows the connections between these three main components.

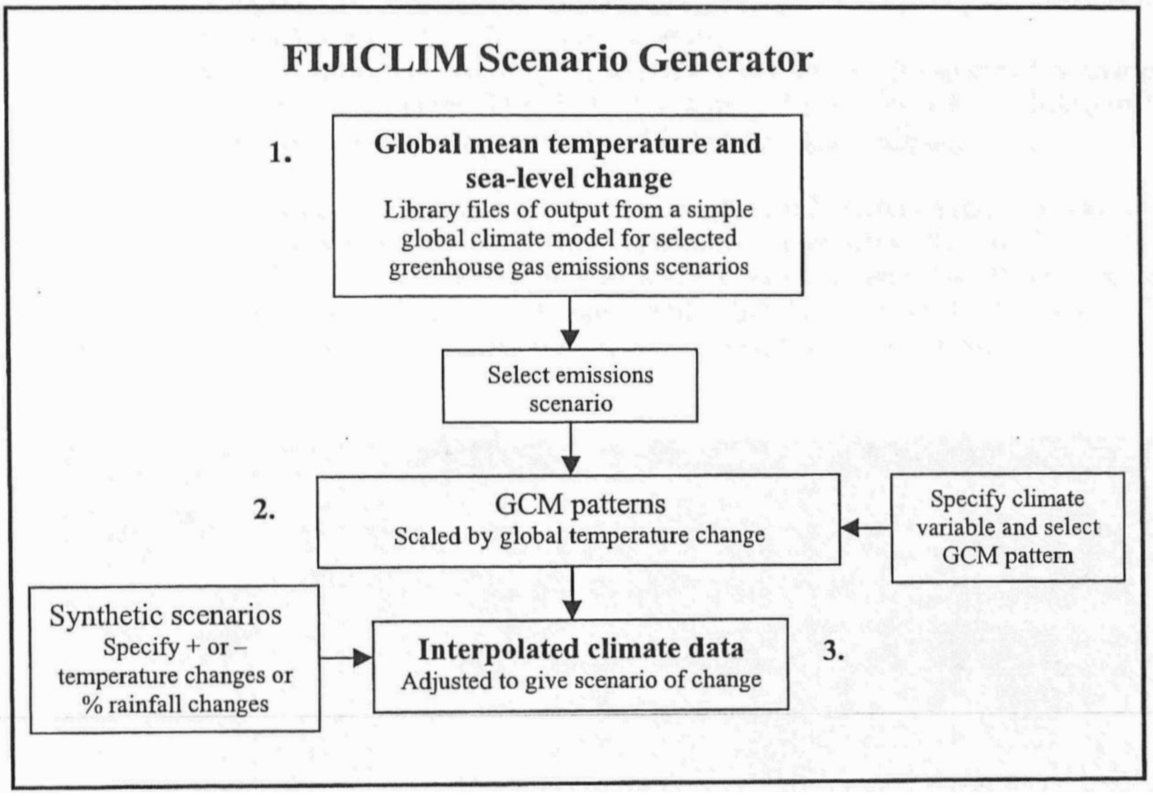


Figure 2: Schematic representation of the FIJICLIM Scenario Generator and its main components

[1]Earlier versions of this model, developed at the Climatic Research Unit, University of East Anglia, UK, were used to make global temperature and sea-level projections for the Intergovernmental Panel on Climate Change (IPCC) 1990 and 1995 reports.

3.1 Library files of output from a simple global climate model

As mentioned above, a simple global climate model, MAGICC (Wigley, 1994) has been used to generate global temperature and sea-level changes. These results are incorporated into FIJICLIM.

The core of MAGICC is a one-dimensional, energy-balance, box-diffusion-upwelling climate model. The inputs to MAGICC are emissions of greenhouse gases, and the outputs are global-mean temperature (and sea-level) changes, given in 5-year increments from 1990 to 2100. It can quickly generate time-dependent global temperature changes for user-selected scenarios of greenhouse-gas (GHG) emissions. The science on which MAGICC is based is continually being advanced, and hence MAGICC is regularly updated. Additionally, scenarios of greenhouse-gas (GHG) emissions can be updated to take account of evolving international policies on emissions. MAGICC is described in more detail by Wigley (1994).

The FIJICLIM Scenario Generator contains library files of output generated from two sets of GHG emissions scenarios:

1) The Intergovernmental Panel on Climate Change (IPCC) 1995 policy scenarios (Houghton *et al.*, 1996), known as the IS92a,b,c,d,e scenarios;
2) The SRES marker scenarios (Al, A2, Bl, B2), which are new (unapproved) scenarios developed for the IPCC, for use in the IPCC Third Assessment Report, due to be published in 2000. Details on these scenarios can be obtained from http://sres.ciesin.org,/.

The example in Figure 3 shows the stored output from the IS92a GHG emissions scenario, showing the high, medium and low estimates of global temperature change from 1990 to 2100. These estimates relate to the range of *climate sensitivity* (the average global temperature change for an equivalent doubling of atmospheric CO_2) generated from complex GCMs. Specifically, the high, medium and low estimates relate to climate sensitivities of 4.5°C, 2.5°C, and 1.5°C respectively.

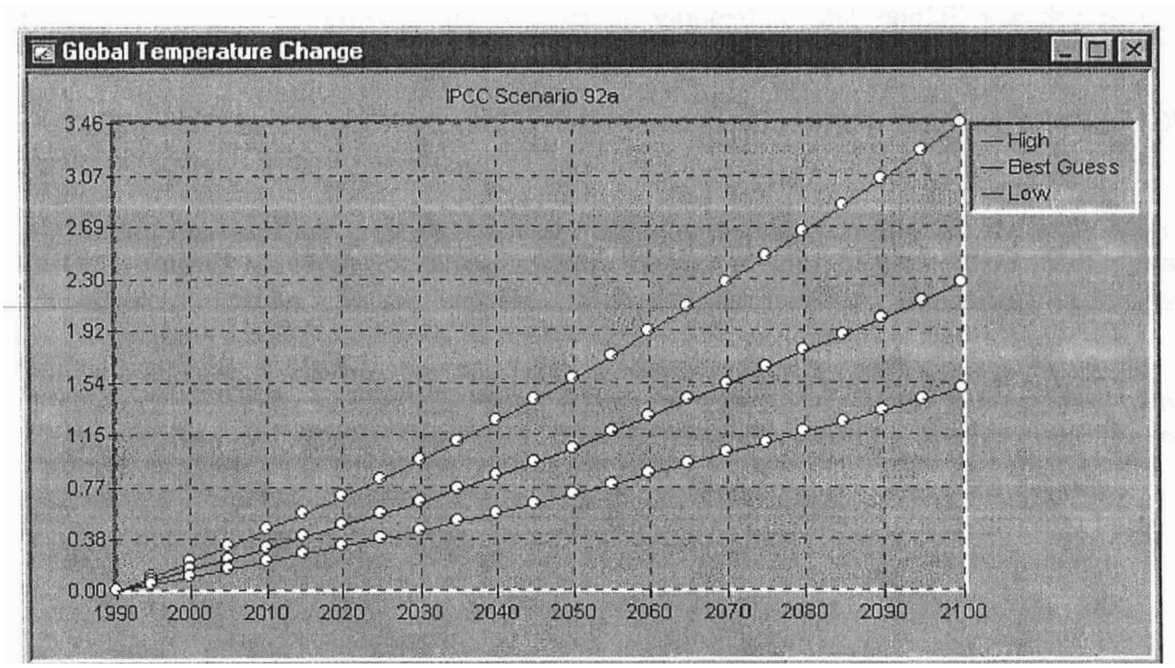


Figure 3: FIJICLIM window showing graphed output from MAGICC (Wigley, 1994) for the IS92a GHG emissions scenario.

3.2 GCM patterns

The Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) Atmospheric Research Division was contracted by SPREP in 1998 to prepare a report on regional climate change scenarios for use by PICCAP (Jones *et al.*, 1999). As part of this work the CSIRO also prepared a **set** of GCM patterns for the region, which have been incorporated into the FIJICLIM. The CSIRO used results from five GCM model runs for this purpose, as summarised below (Table 1).

Table 1: GCMs used in FIJICLIM

Model	**Centre**	**Author**
CSIRO-Mk2	The Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO)	Gordon and O'Farrell (1997)
ECHAM4	The German Climate Research Centre (DKRZ)	Roekner *et al.*, 1996
GFDL-R15	The US Geophysical Fluid Dynamics Laboratory (GFDL)	Haywood *et al.*, 1997
HADCM2	The UK Hadley Centre for Climate Prediction and Research	Cullen, 1993
CGCM1	The Canadian Centre for Climate Modelling and Analysis	Flato *et al.*, 1999

A detailed description of the selection and preparation of these patterns is contained in the CSIRO report (Jones *et al.*, 1999). This report also provides a description of some of the limitations to the patterns and a summary of the regional changes in temperature and rainfall. Some key points from the report are summarised below:

- The GCM patterns provide the changes in temperature and rainfall per degree of global temperature change.

- Temperature changes per degree of global warming are mostly in the range of 0.7 to 1.0°C, for the different GCM patterns and across the region.

- Rainfall increases are greatest where surface temperature increases are highest. Most of the GCM patterns show rainfall increases across the region, with the greatest increases indicated for northern Polynesia. Slight decreases in rainfall are indicated for Melanesia and southern Polynesia by a couple of the GCM patterns.

  (Note: Please refer to the Jones *et al.* report for a summary of the sub-regional changes in temperature and rainfall from each of the GCMs, which can be used to guide the selection of GCM pattern for use in developing a scenario.)

3.3 Climate Data

Historical temperature and rainfall data for Viti Levu was interpolated to a 500 metre resolution grid for Viti Levu, using the ANUSPLIN model[2] (Hutchinson, 1989).

3.4 Developing a climate change scenario

The steps for developing a climate change scenario are shown schematically in Figure 2, which shows the linkages between the different components described above. In order to develop a climate change scenario using FIJICLIM, the user must choose:

- The climate variable of interest (temperature [max, mm, or mean] or rainfall);
- An emissions scenario, and associated with this:
  - the low, best guess, or high case (which encompasses the range of uncertainty **in** model parameter values), and
  - the year of interest (in 5-year increments from 1990-2100);
- A GCM pattern.

The selected GCM pattern, which gives the change per 1°C of global temperature change, is scaled by the selected global temperature change from the MAGICC library. This scaled pattern of change is then used to adjust the baseline climate data, as follows:

- In the case of temperature:

  Future temperature = present temperature + (MAGICC value x GCM pattern of temperature change, in °C).

- In the case of rainfall:

  Future rainfall = present rainfall x (MAGICC value x GCM pattern of rainfall change, in %).

Sectoral impact models have been incorporated for: agriculture, coastal zone, human health and water resources.

4 Coastal zone

A number of complex; dynamic models are available for examining processes related to sediment transport, wave energy effects, beach profile changes, and so on. While the rigour of such models is clearly an advantage for predicting physical changes and examining coastal processes, their application is severely limited for vulnerability and adaptation assessments in Pacific island countries, for two reasons. First, such models often demand good quality, high resolution data for a range of variables and model parameters. In Fiji, good quality data is very limited and therefore the selection of methods in evaluating the vulnerability and adaptation assessment is also restricted. Second, the more complex coastal models are not well suited to addressing the issues of sea-level rise because very different time and space scales are involved. In such circumstances, the detailed processes and predictive accuracy of the model may be less important than the capability to conduct

[2] The ANUSPLIN model is used to interpolate climate data from sites to give a spatial representation of climate. At a large island scale, the site climate data are combined with topographic data to give a spatial climate.

simulations for the purpose of examining model sensitivities and uncertainties under sets of "what if" scenarios on coarse temporal and spatial scales.

Consequently, following the guidance given in the USCSP Handbook (Benioff *et al.*, 1996, Chapter 5.5), two appropriate methods that can be applied satisfactorily to Fiji coastlines are: (1) a variant of the 'Bruun Rule'. This method appears most suitable for impact assessments of beach and dune systems; (2) a simple inundation model (`drowning' concept). This method appears most suitable for low islands and for the coastal floodplains of high islands with very low gradients and low energy environments.

4.1 Bruun Rule

The concept behind the 2-dimensional "Bruun Rule" model is explained in the USCSP Handbook (Benioff *et al.*, 1996). In effect, in the Bruun Rule the equilibrium profile of a beach-and-dune system is re-adjusted for a change in sea level. A rise in sea level will cause erosion and reestablishment of the equilibrium position of the shoreline further inland, as follows:

$\mathbf{C_{eq} = z\ 1\ /(h + d)}$ where:

$\mathbf{C_{eq}}$ is the equilibrium change in shoreline position (in metres)
z is the rise in sea level (in metres)
I is the closure distance (the distance offshore to which materials are transported and "lost", in metres)
h is the height in metres of the dune at the site
d is the water depth in metres at closure distance (1/(d+h) thus gives slope)

There are two important drawbacks to using this simple model to examine shoreline change under a trend of rising sea level. First, it gives only the "equilibrium" (or steady-state) change. In reality, coastal systems do not adjust instantaneously; rather, there is apt to be some time lag in the response. Second, in reality shoreline retreat, as evidenced by historical data on beach profiles, is apt to occur in "fits and starts" over time, not as a steady, year-by-year incremental change. This uneven response of the shoreline is partly a function of the chance occurrence of severe stormy seasons, which often cause erosion (in contrast, a season of very few, or mild, storms may allow the natural system to replenish the sediment supply and the shoreline to advance).

For these reasons, the Bruun Rule was modified slightly to add a response time and a stochastic "storminess" factor as follows:

$\mathbf{dC/dt = (C_{eq} - C)/\tau + S}$ where:

t is time (years)
C is the shoreline position (metres) relative to that of t=0
$\mathbf{C_{eq}}$ is the equilibrium value of C
$\boldsymbol{\tau}$ is the shoreline response time (years)
S is a stochastically-generated storm erosion factor

In other words, the yearly change in shoreline is a function of the difference between where the shoreline *should be* (according to the Bruun Rule) in that year and where it actually is (as a consequence of what has occurred in previous years), as well as the effect of storms. The greater the difference, the greater the potential for erosion in that year, subject to the rapidity at which the system can respond.

The model is forced by changes in sea level (projections selected by the user) and by the randomly selected "storms". The model runs year by year and the results are displayed graphically.

4.2 Inundation Model

One of the more pressing impacts of climate change and sea level rise on the coast will be loss of land due to permanent inundation. Relative sea level change is likely to have serious impacts on the natural and socio-economic resources of Fiji. Land loss due to inundation is a function of slope; i.e; the lower the slope, the greater the land loss.

A simple inundation or 'drowning' concept requires that a high-water mark is vertically shifted landward by the same amount of the relative sea level rise scenario used. This means that if a relative sea level rise scenario is 1.0 m then the high-water mark would be shifted inland to a topographic contour which is 1.0 m higher. In very flat terrain, this could be rather far inland. This concept does not necessarily account for local factors (eg: tidal variations) and the natural system's capacity to adjust through changing patterns of sedimentation.

In FIJICLIM, a simple inundation model is available. There are three components which determine "drowning" of land and which require the user to specify values:

- **Global sea-level rise.** This is a consequence of the emission scenarios chosen and the uncertainty attached to the model parameters. As noted above, one of the choices is the "baseline" scenario, which sets future global sea level rise to zero, thus allowing one to examine storm effects in isolation, as noted below.

- **Net vertical land movement.** Long-term vertical land movements also affect relative sea level — the level of the sea surface *relative* to the land elevation.

- **Storm flooding.** An important additional hazard is storm surges from tropical cyclones. In general, a rise in sea level will mean that flooding from an extreme storm surge of a given magnitude will extend further inland. As well, the frequency of storm surges could well change as a consequence of global warming. The FIJICLIM user can examine the storm surge element by choosing a storm surge with a particular return period. The frequency-magnitude relationship can also be adjusted by the user in-order to examine possible consequences of global warming on severe storm surges.

The combined effect of all three user-defined components can be viewed on the Viti Levu topographic map.

5 Water resources

The **flow analysis/flooding model** is used to assess the climate change impact on surface water as represented by two catchment areas in Viti Levu. A stochastic approach is adopted to analyse the impact on both high and low flow events, which are related closely to the flooding and water quality problems in small island countries.

5.1 Flow analysis/flooding model

The flow analysis/flooding model is built on a stochastic approach, which uses the generalized extreme value (GEV) distribution[3] to analyse the extreme high and low flow events. The generalized extreme-value analysis (Jenkinson, 1955) is widely used for modeling extremes of natural phenomena, and it is of considerable importance in hydrology (Natural Environment Research Council, 1975). Extreme events are defined in terms of unusual values of a sequence of observations of certain meteorological elements. The term "extreme events" is used in a broad sense, encompassing both the occurrence of extraordinary values (i.e., a record-breaking maximum or minimum) and the exceedance above or below a particular threshold level. Typically, the problem is to estimate the probability that an extreme value of a sequence of observations of a meteorological variable will be higher or lower than some constant threshold level, or alternatively, to estimate that threshold value which will be exceeded with a desired fixed, small probability. These extreme values and associated probabilities are then used in the solution of related design problems or cost-risk calculations. Historical observations of the appropriate meteorological variables are used for the identification and fitting of the desired extreme probability distributions. The utility of these estimators depends to a great extent on the length and the homogeneity of the observational record, especially in cases when the record return period of the required design value is significantly longer than the observational record.

6 Agriculture

For examining the impacts on agriculture, the kinds of detailed, process-based crop-simulation models often recommended for use in climate change V&A assessments (e.g. by Benioff et al., 1996; Carter et al., 1994; UNEP, 1996) are simply not appropriate for Pacific island countries. For many plant and tree crops of the Pacific, such simulation models simply do not exist. Even where such models may be available, the detailed data needed to calibrate, validate and run the models are not available.

For this reason, FIJICLIM has adapted a much simpler, indices-based model for use in conducting spatial analyses in which the effects of changes in climate are of principal concern. This model, called PLANTGRO, was developed by Clive Hackett (Hackett, 1988, 1991). PLANTGRO was designed for application in a Pacific Island context as a means of capturing and expressing local knowledge about plants and how they perform in different environments. There are three important components to PLANTGRO: climate files, soil files and plant files. The climate and soil files – provide the basis for examining suitability of specified crops at either specific sites, or over areas. A total of 23 climate and soil factors are considered. There are two key elements to output from PLANTGRO: suitability, which reflects how people perceive plants are suited to their environment; and limitation, which is how plants respond to their environment. The latter concept is based on Liebig's Law of the Minimum, as described in Hackett (1988).

PLANTGRO has been applied in a wide range of contexts, including GIS applications for the Cook Islands and Fiji (through joint ventures with Landcare Research) and for matching trees and sites in Asia (Booth, 1996). The FIJICLIM application is unique in that PLANTGRO is directly linked to

[3] For a theoretical description of the GEV distribution see Annex A.

spatial climate and soils data, and to a scenario generator for evaluating sensitivity to climate change.

In using the FIJICLIM spatial version of PLANTGRO, the user has a large range of options. There are 28 different tropical and sub-tropical plants from which to choose. Additional plant files can be developed and added, as described by Hackett (1991). The user specifies the climate data that drive the model. Typically, for V&A analyses one may wish to run the model under "present" climate (in this case, the 1961-90 reference climatology) and also under the user-defined scenario of future climate change, and compare the results. The planting date option can be used to explore the effects of management decisions for adapting to changed climate conditions for annual crops. As indicators of effects, the user can select one or more of the following model outputs:

- Suitability rating: a composite index taking into account soil and climate conditions at each grid site;
- Greatest limitation: the most critical limiting factor amongst 23 factors;
- Yield: Relative yield in relation to potential maximum yield;
- Growing season length.

The model can be used to answer a vast range of questions in relation to climate change vulnerability and adaptation; for example:

- How well suited is the crop to the present climate?
- What are the limiting factors to production and what would be the effects if they were overcome?
- Is the crop more sensitive to changes in temperature or rainfall?
- What are the threshold levels of climate change that bring about large impacts?
- What other alternative crops could be grown at present? Under future climate change?

It could be argued that the drawback of the PLANTGRO approach is its simplicity, particularly the lack of process-based modelling. However, despite its simplicity — or rather because of it — the strength of the FITICLIM/PLANTGRO system is-its versatility. This versatility is manifested in at least four ways.

First, **data:** as compared to more complex crop models, it can be developed and run with data that are available for many Pacific islands. Data availability is one of the biggest constraints to conducting climate change V&A assessment in developing countries.

Second, **speed:** the model set-up and running time is quick, thus allowing multiple simulations and facilitating sensitivity analyses.

Third, **spatial approach:** the models can be developed for spatial analyses and still run quickly (a single simulation takes about one minute). The ability to provide spatial information, on maps, makes a significant step toward decision making and implementation of adaptation strategies.

Fourth, **local knowledge base:** traditional knowledge about the array of tropical and sub-tropical plants is large, but often not formally documented. In the PLANTGRO system, the user can easily alter the data files, and develop new ones, to incorporate such knowledge – thus blending traditional knowledge with scientific tools.

7 Human health

Assessing the possible impacts of climate change on human health is a complex task. On a purely biophysical level it is possible to characterise relationships between climate and the incidence of various diseases. However, public health effects are considered in a much wider context as is explained in the UNEP Handbook (UNEP, 1996), Chapter 7. Within Fiji there are a wide range of public health issues that may be affected by future climate change. Many of these cannot be characterised in a simple model structure. Many of the public health effects will arise from effects on other sectors, such as agriculture, the coastal zone and water resources.

The UNEP Handbook (UNEP, 1996) describes a range of approaches to assessing impacts of climate change on human health. Two broad approaches are used here:

(1) biophysical indices which estimate risk of vector-borne disease as influenced by temperature and rainfall;
(2) an integrated approach, which requires the user to evaluate effects on the other three sectors included within FIJICLIM, in combination with relevant socio-economic information, to determine possible secondary effects on public health.

7.1 Vector-borne Diseases (Malaria and Dengue Fever)

Several models have been developed for estimating malaria and dengue fever risks, either for national or global applications. These range from empirical-statistical models (e.g. see the example in Chapter 7 of the UNEP Handbook (UNEP, 1996)) to empirical process-oriented models, such as that developed by Martens *et al.* (1995) for Malaria and Patz *et al* (1998) for dengue fever.

Output from these models has been adapted for application within FIJICLIM. Both these models relate ambient temperature to epidemic potential. Epidemic potential (which can also be understood as transmission efficiency) is an indicator of how easily an epidemic will be triggered and escalate if the disease along with the disease vector were introduced to a susceptible population. Where epidemic potential is high epidemics will occur more easily, grow faster and smaller vector numbers would be required to sustain the epidemic. Conversely, where epidemic potential is low, epidemics will be less likely to occur, increase more slowly and require a larger vector population to be sustained.

- **Malaria risk model**

Epidemic potential is calculated *as* a function of temperature (see Martens *et al,* 1995 for a detailed description). This relationship is described by a third-order polynomial function, with a maximum value of 1. A range of uncertainty in maximum daily survival probability is described for this model. For FIJICLIM, the central estimate has been used. While temperature is a major determinant of epidemic potential, the actual incidence of malaria may also be influenced by moisture levels. For this reason Marten's *et al* (1995) included a rainfall limitation which excludes dry areas from malaria transmission and thus more closely defining present distribution limits of endemic malaria areas. The rainfall limitation is a minimum of 1.5 mm per day, which translates (for application in FIJICLIM) to 45 mm per month on average.

- **Dengue fever risk model**

The dengue fever risk model is similar to the malaria risk model. Based on output from the complex process models CIMSIM and DENSIM, epidemic potential is described as a function of ambient temperature (see Patz *et al*, 1998). This relationship is the basis of the simple biophysical index model used in FIJICLIM which describes relative changes in dengue fever risk resulting from changes in ambient temperature. Unlike the malaria model there is no rainfall limitation. This is because the main dengue fever vector in Fiji, *Aedes Aegypti*, is adapted to the peri-urban and domestic environment where breeding sites may be created by artificial containers of water. Depending on the range of human activities, such container breeding sites may be equally available under low rainfall conditions.

7.2 Integrated approach

Many of the health effects from future climate and sea-level change are likely to be secondary effects arising from impacts in other sectors, including agriculture, coastal zone and water resources. Such effects are not easily modelled, but may require an expert judgement approach which may draw on analysis using the range of sectoral impact models within FIJICLIM.

ENVIRONMENTAL ECONOMIC EVALUATION TRAINING & VULNERABILITY AND ADAPTATION WORKSHOP. CENTRA, SUVA

1ST - 2ND MARCH 2000.

Workshop Proceedings

Organized by
The Climate Change Country Team

Compiled by
Leigh-Anne Buliruarua
Climate Change Project Officer

Contents

ENVIRONMENTAL ECONOMIC EVALUATION TRAINING & VULNERABILITY AND ADAPTATION WORKSHOP
CENTRA, SUVA
1ST - 2ND MARCH 2000

The two days comprised of an In-house meeting followed by and Economic Evaluation Training on the 1st of March and the Vulnerability & Adaptation Workshop on the 2nd of March 2000. Organisations hosting the workshop included PICCAP-Fiji (Department of Environment), PICCAP-SPREP, International Global Climate Institute (IGCI) University of Waikato and the World Bank.

1.0 WORKSHOP OBJECTIVE

The main objectives of the workshop were:

- Provide capacity building on Environmental Economic Evaluation for the country team.
- To formulate a strategy for future activities of the general vulnerability and assessment for Fiji (V & A) activities in Fiji:
- To evaluate the economic assessment of the V & A report for Fiji.

The various organizations that were represented included:

- Government Sector Representatives
- Statutory Organization Representatives and
- The Climate Change Country Team (ref.

Appendix 3 – List of Participants)

2.0 PROGRAMME

2.1 IN-HOUSE CONSULTATION & ENVIRONMENTAL ECONOMICS EVALUATION TRAINING

Day 1

In-house Consultation

Participants – Dr. Gavin Kenny, Dr. Neil de Wet & Mr. Wei Ye (IGCI), Dr. Graham Sem (SPREP), Dr. Bob Raucher (World Bank) PICCAP – Fiji

1. Fiji Vulnerability and Adaptation Work – Current and future activities
2. Fiji PACCLIM Development
3. Economic Evaluation of V & A Report
4. Briefing to Director of Environment, PEO and SEO.
5. Economic Evaluation Training

2.2 VULNERABILITY & ADAPTATION WORKSHOP

Day 2

Vulnerability & Adaptation Workshop

Chairperson – Mr. Jone Feresi

Resource People – Dr. Gavin Kenny & Dr. Neil de Wet (IGCI), Dr. Bob Raucher (World Bank)

6. Opening – Mr. Rishi Ram (Permanent Secretary LGH and Environment)
7. Introduction to the V & A Study, brief overview of the FIJICLIM model & Climate and socio-economic scenarios - Dr. Gavin Kenny (IGCI)
8. Agriculture Impacts – Dr. Gavin Kenny (IGCI)
9. Health Impacts – Dr. Neil de Wet (IGCI)
10. Water Resources – Mr. Leone Limalevu (PICCAP – Fiji)
11. Coastal Impacts – Mr. Simon Motilal & Miss Leigh-Anne Buliruarua (PICCAP –Fiji)
12. Economic Analysis Presentation – Dr. Bob Rancher (World Bank)

(The papers presented are included in the appendix.)

3.0 FRAMEWORK FOR WORKSHOP DISCUSSIONS

3.1 IN-HOUSE CONSULTATION & ECONOMIC EVALUATION TRAINING

The In-house consultation on the 1st of March consisted of reviewing the current and future activities of Vulnerability and Adaptation work for Fiji. It was agreed upon that the report was to be reviewed thoroughly by the country team members on the 2nd of March, with the aim of receiving positive feedback and the possible adoption of the V & A Report.

The FIJICLIM model was also reviewed incorporating most of the issues that were raised on the final day of the FIJICLIM Training workshop on the 28th – 29th Feb, 2000.

The Economic Evaluation of the V & A report involved a presentation by Dr. Bob Raucher. The Economic report was one of two integrated efforts funded by the World Bank: Physical impacts (V & A) update, plus the economics report.

One of the main intentions for the V&A economic analysis is that this type of analysis will be the first of its kind in the world. This is an important report, as this will be tabled at the June 2000 Forum Economic Ministers' meeting. The rest of the world will be observing as to how best we put dollar values on our resources that are currently being impacted by our climate system as well as those projected to be impacted in the future.

As an illustration, the total accounting damages for the drought of 1997/1998 was over F$300 million. An issue brought up here is what if the drought was to become a 1 in 5-year event.

The average cyclone damage was estimated at around $44-45 million. Cyclone Kina cost the country $170 million. An issue brought up here is what would the government of Fiji do to reduce the amount of costs.
Hence, there was a suggestion to incorporate a chapter in the report, as a way forward so we don't just understand the cost implications of the damage, but actions (adaptations) that can be included in the future.

The Economic Evaluation Training consisted consisted of a half-day training on how to conduct environmental economic assessment. The aim was to assist us with capacity building on this type of work. Dr Bob Raucher facilitated the training.

(Presentation included in appendix)

3.2 VULNERABILITY and ADAPTATION WORKSHOP

Following the presentations, the afternoon was spent thoroughly reviewing the Vulnerability and Adaptation report and Economic Evaluation report.

The V & A document was generally viewed the participants at the workshop as quite thorough and a major achievement considering the limited time-span given for completion.
It was agreed amongst the country team IGCI consultants, PICCAP Fiji and the World Bank consultant that the reviews for specific sectors and/ or on the V & A report as a whole, was to be sent to the Department of Environment by Thursday March 6th. DOE would then forward reviews to IGCI to incorporate in the report. Recommendations were to also be included in the executive summary report.

- One of the issues that the report highlighted was the lack of data available in most fields in Fiji. The report shows the need to get together to coordinate what information Fiji already has, and shows the need for more directed funding and concrete research to address the problems posed.

- Possible way forward for data gathering would be for the Department of Environment to coordinate the collecting, assessing and analyzing data, then to direst funding and concrete research to address the problems with data that is not available.

- This report is only the first step in V & A. PICCAP to really focus on adaptations, particularly in the next V & A report. This can be brought about through a process of consultations and deliberations from the V & A report, which still has a lot of gaps. Detailed consultations are needed. Adaptations would be beneficial also for the Economic report because we don't just understand the cost implications of climate change impacts, but these adaptation options can be included in the future to counter such impacts.

- With the climate change concept, climate variability to be included in the introduction of the report. Therefore, would it be possible to include sea level fall in the next report.

- The coastal model in the FIJICLIM is not well developed at the moment. It is for this reason that very limited technical analysis can be done for Fiji. Therefore, it was suggested that the report should point this out as a shortcoming.

- Agriculture sector — valuable amount of data available. Emphasis on flexible farming systems appears too general. There was a suggestion to break it down into strategies.

4.0 CONCLUSION

The workshop was a success in terms of the initial objectives of the Economic Evaluation and Vulnerability & Adaptation Workshop:

- Through presentation, an Environmental Economic Training was able to assist members of the country team with capacity building on this type of work.

- Furthermore, country team members were presented and able to evaluate the Economic Evaluation of the Vulnerability and Adaptation for Fiji.

- Through presentations, recommendations were made for the future activities of the Vulnerability and Adaptation Assessment for Fiji.

Appendix 1

Programme

Vulnerability & Adaptation Assessment Workshop

Thursday

2/3 9.00 a.m.	**Welcome and opening address (P/S-LGH&Env.)**	
9.30 a.m.	Introduction to the V&A study, including brief overview of the FijiCLIM model. (IGCI)	
9.45 a.m.	Climate and socio-economic scenarios (IGCI)	
10.00 a.m.	Agriculture impacts-presentation and discussion.	(IGCI)
10.40 a.m.	**Morning Tea Break**	
11.00 a.m.	Health impacts-presentation and discussion.	(IGCI)
11.40 a.m.	Water resources impacts-presentation and discussion.	(Fiji PICCAP)
12.20 a.m.	Coastal impacts-presentation and discussion	(Fiji PICCAP)
1.00 p.m.	**Lunch Break**	
2.00 p.m.	Economic analysis-presentation and discussion.	(World Bank)
3.30 p.m.	**Afternoon Tea Break**	
3.50 p.m.	Open discussion of future directions	
5.00 p.m.	Close.	

Appendix 2

Opening Statement
Climate Change Vulnerability and Adaptation Assessment Workshop

Centra Hotel
2nd March, 2000

Mr. Rishi Ram
Permanent Secretary-LGH&Env.

Organisations hosting the Workshop: PICCAP-Fiji (Dept. of Environment); PICCAP-SPREP; International Global Institute (IGCI) – University of Waikato; and the World Bank.

Resource People :

Dr. Gavin Kenny	IGCI
Dr. Neil De Wet	IGCI
Dr. Graham Sem	PICCAP-SPREP
Mr. Bob Raucher	World Bank

Participants: The Fiji Climate Change Country Team
(They are representatives from relevant Government Sectors, Statutory and regional organizations)

1.0 Objective of the workshop

(1) To formulate a strategy for future activities of the general vulnerability and adaptation assessment (V&A) activities in Fiji.
(2) To evaluate the economic assessment of the V&A report for Fiji.

2.0 Background

2.1 International Context

All countries who are signatories to the United Nations Framework Convention on Climate Change, are-required--under article 4.1 (e) to cooperate in preparing for-adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone, water resources and agriculture, and for the protection and rehabilitation of areas affected by drought and desertification.
The Conference of the Parties stressed the need for parties to the Convention to take into account the need for establishing implementation strategies for adaptation to climate change and sea-level rise. As such Fiji is required to submit a national communication document that shall include information on climate vulnerability and adaptation implementation policies and strategies.

2.2 National Studies

Fiji's commitment to fulfilling the requirements of the UNFCCC has been supported by the Pacific Islands Climate Change Assistance Programme (PICCAP) coordinated through SPREP and funded by the GEF.

There were two staff, Mr. Jone Feresi from MAFF and Mr. Jagat Bhusan, from the Lands Department, that were trained by IGCI to conduct the national vulnerability and adaptation assessment for Fiji in_ 1998. Their work has further been extended, from November, 1999, by the current study, with the financial and technical assistance from the World Bank in collaboration with IGCI, SOPAC and USP.

As an island nation, it is essential to understand how climate change and sea level rise will affect and impact on our coastal systems, marine resources, subsistence and commercial agricultural developments, domestic and industrial developments, human health, water resources, population, and our economy at large. In order to develop and implement appropriate response strategies, it is essential to establish a comprehensive baseline of the current situation in Fiji and an understanding of the effects of climate change, the degree of vulnerability and the national capacity to adapt.

5.0 Activities of the Workshop

(1) To evaluate the findings of the V& A assessment studies that have been conducted by the Fiji PICCAP Team and supported by the World Bank study team.

(2) To evaluate the findings of the Economic Analysis on the vulnerability and adaptation strategies and options suggested by the V&A assessment.
(A half-day training on how to conduct environmental economic assessment was conducted on Wednesday, the 1/3/00, here at the Centra Hotel. The aim was to assist us with capacity building on this type of work)

(3) To evaluate the FIJICLIM prototype model: a computer model, which has been developed as a tool with the aim of assisting in the V&A assessment work. (A hands on training on how to use the computer model was conducted on Monday and Tuesday, the 28/2 and 29/2 at Centra Hotel)

The significance of a proper vulnerability assessment is that unless we fully understand the issues, we would not be able to formulate specific strategies to adapt to specific climate change impacts. Thus this will be a good chance to evaluate the issues of information gaps and how these can be addressed in future programmes, bearing in mind our resources that we have at our disposal.

As for the V&A economic analysis on the possible impacts of climate change, this type of analysis will be the first of its kind in the world. This is an important report, as this will be tabled at the June 2000 Forum Economic Ministers' meeting. The "eyes" of the world will be on us as to how best we put dollar values on our resources that are currently being impacted by our climate system as well as those projected to be impacted in the future. I urge you to critically evaluate this report in its content and context, in relation to our socio-economic status and unique island setting.

Certainly, with the time frame required for the report to be completed, (as a suggestion) today would be usefully spent on familiarising with the initial findings and for your part to give guidance to the study team. This will allow the team to adequately address all-important issues before a thorough review meeting can be convened within the next two months.

I look forward to receiving the report and to facilitate its adoption through the normal government system.

6.0 Acknowledgment

Also take the opportunity to thank the Fiji Country Team (most of whom are present in the workshop) for assisting the work of the Department of Environment in the general area of climate change for the last two years. Their effort has been greatly appreciated. (Without their assistance, it would have been very difficult, if not, impossible to undertake such a programme, especially when it requires a multi-disciplinary approach.)

Annex 2

FIJICLIM Description and Users' Guide

PART 2: FIJICLIM Users Guide

8 Introduction

When you double click on the FIJICLIM icon an introductory screen will appear. Click "OK" and the main menu will appear (Figure 4).

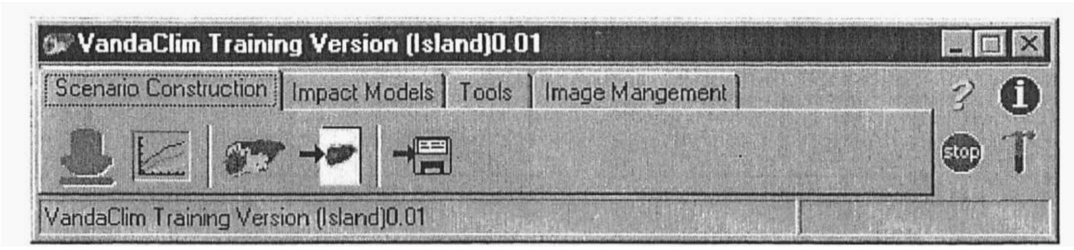


Figure 4: Main menu of FIJICLIM

The menu options that will be used mostly are the Scenario Construction and Impact Models options. The Scenario Construction option can be used to view the baseline climate data, and to develop and view climate change scenarios. The Impact Models option gives access to the sectoral impact models, which can be applied with both baseline climate and user-specified scenarios of climate change.

The Tools option gives access to the daily climate data for Viti Levu, and also an extreme event analysis tool. The latter can be applied to the present climate only. The Image Management option allows the user to retrieve and customise previously saved images. Customising of images can also be made as they are created.

9 Scenario Construction

There are four active icons in the Scenario Construction sub-menu which are described below:

9.1 The MAGICC database tool

The MAGICC database tool contains a library of output files produced from MAGICC. These give time series of global temperature and sea-level changes for a range of GHG emissions scenarios, as well as the time series of associated carbon dioxide changes. This tool (see Figure 5) can be used to extract values for selected scenarios (by scrolling through the time series of values), or to view a selected time series on a graph (by clicking the graph icon at the top left of the menu box).

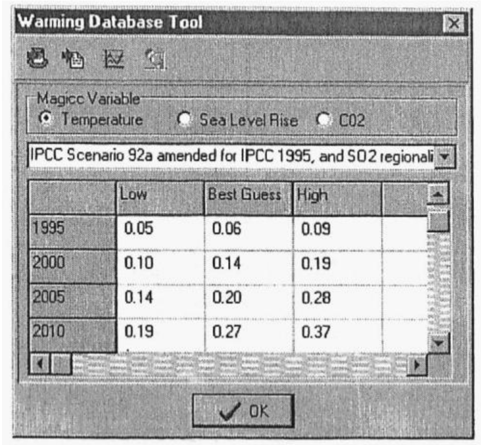


Figure 5: Menu options for viewing MAGICC library file

9.2 Generate a scenario

To generate a baseline or a scenario click the 2nd (from left) active icon in the Scenario Construction sub-menu.

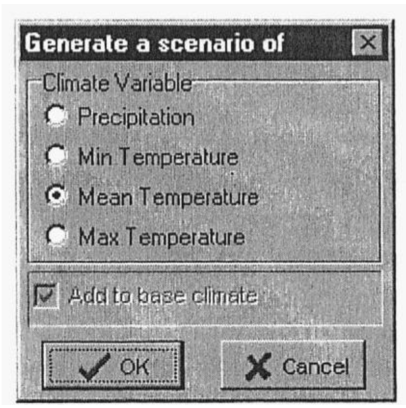


Figure 6: Menu for selecting climate variable for scenario generation

This activates the above menu of choices (Figure 6). Because of the small size of Viti Levu the changes in climate that are generated are uniform across the country. Thus, when a scenario is generated the output is an image which shows the future climate (baseline adjusted by the climate change scenario).

Select the climate variable of interest and the menu shown below (Figure 7) will appear. This is used to select the scenario generation parameters

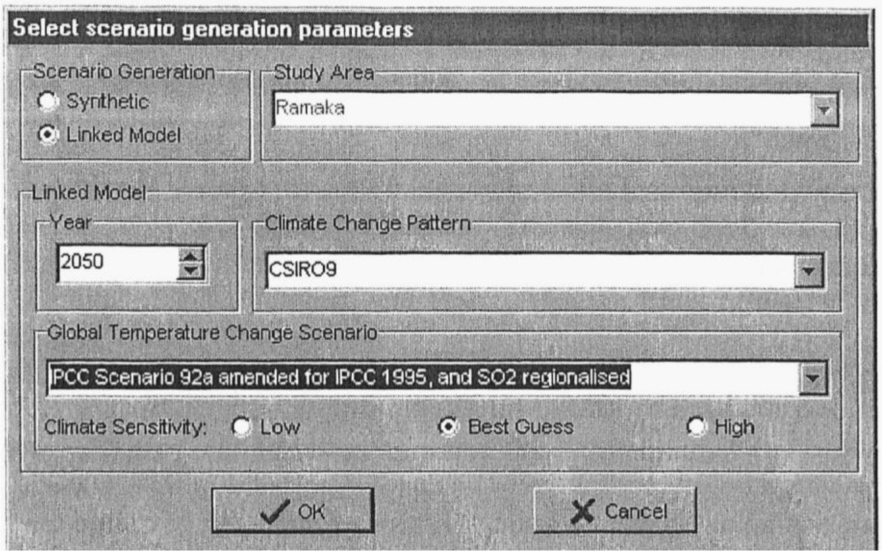


Figure 7: Menu for selection of scenario generation parameters

To generate a baseline, set the Year to 1990 and click OK.

Scenarios can be generated in two ways, by using the Synthetic or the Linked Model options.

- To develop a synthetic scenario, select this option and then specify plus or minus changes in temperature and plus or minus percent changes in rainfall.

- To develop a climate change scenario, the parameters to specify are: Year; Climate Change Pattern; Global Temperature Change Scenario; and Climate Sensitivity. In the above example (Figure 7) the choices are: 2050; CSIRO9 pattern; IS92a GHG emissions scenario; best guess climate sensitivity.

The baseline climate or the specified scenario can be viewed as individual, or combinations, of months simply by checking the boxes (Figure 8). Click OK and the specified image will appear on screen.

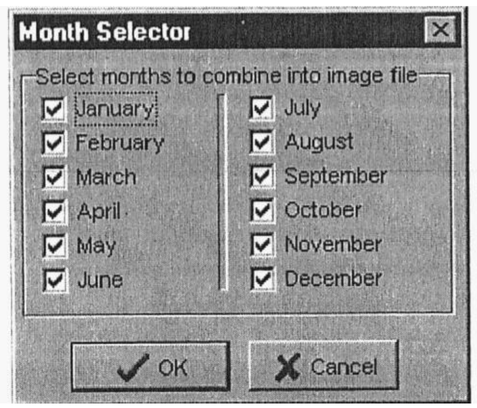


Figure 8: Menu for selecting months or combinations of months

9.3 Extract a raster image from a scenario

This option is presently mis-named. It's primary purpose is to access the stored image files for the baseline climate of Viti Levu.

Click the 3rd (from left) active icon to activate this option. Click Browse to find a Surface Header File. Double click the Viti Levu sub-directory, then double click the BaseClm sub-directory. This contains four header files: Precip.hdr; Tmax.hdr; Tmean.hdr; Tmin.hdr. Select from these to view the climatology of interest, and Open. Use the Month Selector to get the desired combination of months.

9.4 Export a climatology to a text file

This option is available to export surface header files for the baseline climatology to an ASCII format, which is used for images created within FIJICLIM and is also compatible with the IDRISI Geographical Information System (GIS).

10 Impact Models

There are four main options within the Impact Models sub-menu, covering the coast, health, water resources and agriculture sectors (Figure 9).

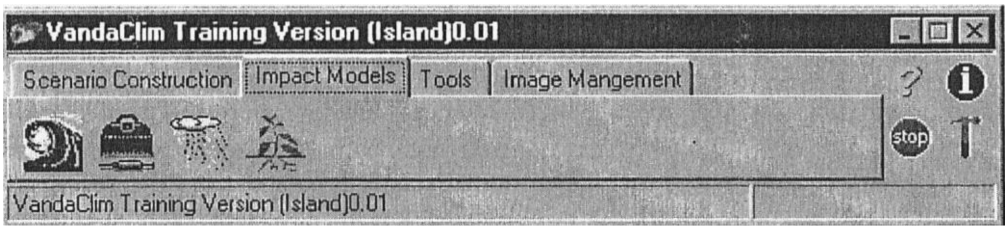


Figure 9: Menu for selecting impact model options

11 Coastal models

Clicking the coastal model icon activates a dialogue box with three model options:

a) shoreline change (sand);
b) shoreline change (coral);
c) coastal inundation.

Ignore the shoreline change (coral) option as this is still under development. The two active models for the coast are for shoreline change (sand) and coastal inundation. These models have a range of options that enable to user to conduct quite detailed *sensitivity* analyses.

11.1 Shoreline change (sand)

In order to use the modified version of the Bruun Rule, the user must then select values for each of the following: site-related model parameters; sea-level rise scenario; and storm characteristics.

Site: There are sites in the Viti Levu for which the modified version of the Bruun Rule is deemed applicable. The user should click on one of the dots provided on the map to choose a site.

For each site, it is necessary to select the values for the model parameters (as noted above):

- The model parameter called ***residual movement*** is the very long term change (on the order of centuries) in shoreline position. This factor largely relates to long-term trends in sediment supply and transport as they affect erosion and accretion.

- The **characteristic response time** (r) governs the responsiveness of the system to sea-level rise in a given year. For example, if T is set to 6, the annual change in shoreline will be one-sixth of the "potential" change indicated by the equilibrium situation (if sea level is constantly rising, the system is continually in dis-equilibrium).

- The **closure distance (1)** is the distance offshore at which sediments are effectively "lost". For Viti Levu, this is nominally taken to be the distance to the edge of the reef.

- The **depth (d)** is the water depth at closure distance at which the sediments are lost. It is assumed that the depth is greater at high wave energy sites.

- **The height (h)** is the "dune" height (or the equivalent thereof for small islands).

For the Viti Levu, as well as for most small islands in the world, there is considerable uncertainty regarding the actual values of these parameters.

SLR Scenario: The input to the model is sea level rise, selected through the user choice of sea-level scenarios. First, the user can set the value for the **residual sea-level rise** (which is the historical trend, in metres per year), assumed to be due to a combination of vertical land movement, global sea-level trends and regional trends. The value chosen will be applied up to the year 1990 and added to the scenario of future sea level rise for 1990-2100.

Second, there is a large library of **future scenarios** of greenhouse gas emissions (for 1990-2100) from which the user can choose. The choice of "baseline" scenario (the last selection in the library) sets future sea-level rise to zero and instead provides a simple extrapolation of the past rate of sea level rise into the future.

Third, there is a choice of **climate sensitivity**. The choice reflects the range of scientific uncertainty in climate and sea level modelling. Here, the user selects a low, best guess or high projection to be associated with the choice of scenario.

Storm Parameters: The model assumes that particularly stormy seasons provide the energy required to potentially erode the shoreline. The "storminess", and thus the *erosion potential,* in any given year is selected randomly from a normal distribution with a mean of one and a standard deviation of 10 metres (default values, selected on an *ad hoc* basis to give a reasonable interannual variability in shoreline change). For randomly-selected values that are zero or negative, the erosive potential is set to zero, which usually allows accretion to occur and the shoreline to advance toward its equilibrium position. Positive values are scaled according to the state of dis-equilibrium and applied to the shoreline erosion. The user is encouraged to change the mean and standard deviation in order to examine the effects on shoreline change on yearly, decadal and longer time-scales.

Each simulation of the model provides a unique sequence of past and future storm seasons. This is useful for looking at short-term variability and extremes in relation to long-term trends in average sea level change as they can potentially affect the coastline.

For more sophisticated analyses in which the user is interested in the statistical properties of the such storm effects, one can perform a **Monte Carlo Simulation** (see dialogue box). With this option, the model is run repeatedly in order to obtain a sample from which the mean and distribution for each year can be described. The user selects *the number of simulations* (i.e. the sample size) and the *confidence interval* to be displayed graphically. This analysis can provide information on the average conditions as well as an assessment of risks arising from the natural variability in the system.

Results: To run the model, click on **Run Simulation** at the bottom of the dialogue box. The model begins running in 1940 (in order to "warm up" the model) and ends in 2100. The results of the analysis immediately appear in tabular form. To view the results graphically, click on a column heading, which will give you the choice of outputs to view. Choose the outputs to view and click OK, which will bring up a graph. In most cases, the key output variable to examine is the ***current shoreline.***

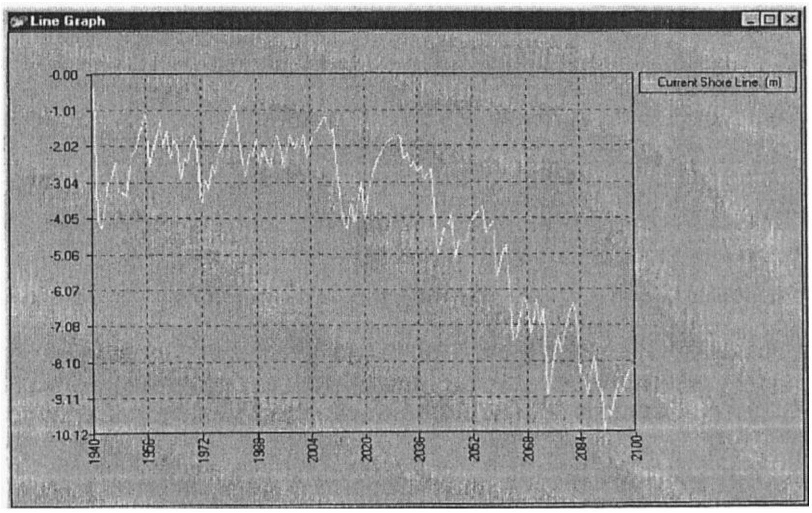


Figure 10: Example of model results showing changes in current shoreline

An example of the model results is shown in Figure 10. Although the model begins in 1940, at least the first decade of results should be ignored as the model is "winding up". The vertical axis shows the change in shoreline position from the "equilibrium" position in 1940 (i.e zero). The negative values indicate shoreline retreat in metres. In order to estimate the result of the chosen scenario of sea level rise, one should take the difference between the average shoreline positions around 1990 and the future date of interest (e.g. 2050). This difference can be estimated visually. For example, in Figure 10, the retreat of the shoreline between 1990 and 2100 is about 7 metres.

11.2 Coastal inundation

As explained in the description of the coastal inundation model there are three important factors which will determine the effects of sea-level rise:

i. the sea-level rise scenario;
ii. net vertical land movement;
iii. storm surge flooding.

How these options might be varied for present and future conditions within the coastal inundation model is explained by referring to Figure 11. The box called **storm surge** shows a curve defining the relationship between storm surge ***heights (h)*** and ***their return periods*** **(r)** – that is, how long, *on average*, between the occurrence of floods of a given height or larger. This provides information about the ***risk*** of storm flooding.

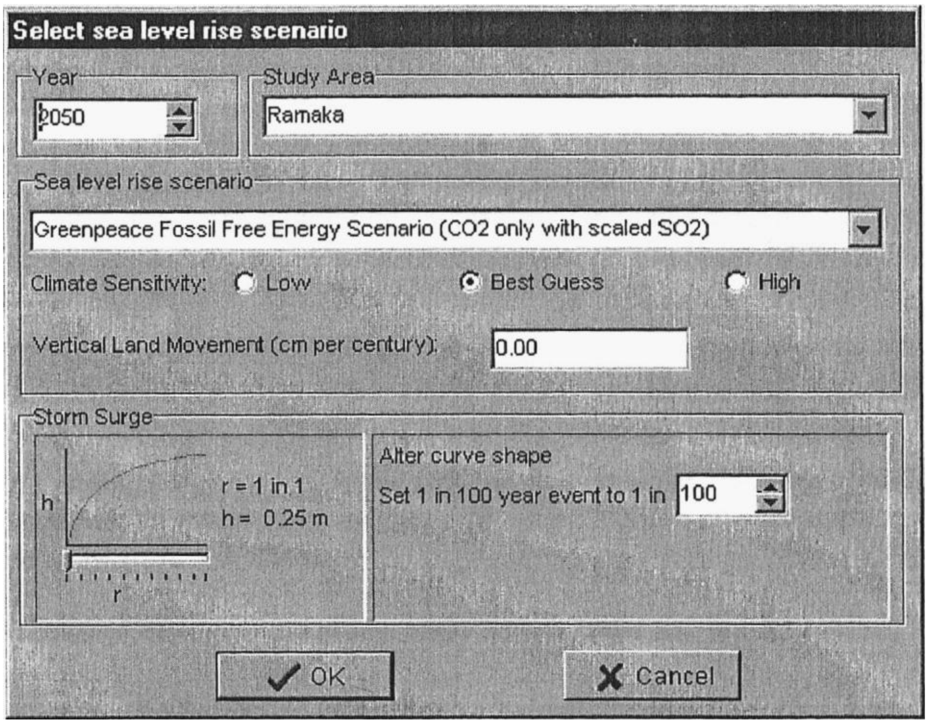


Figure 11: Menu for selection of coastal inundation model options

In order to examine the ***current*** potential flooded area on Viti Levu for floods of given heights and return periods, ensure that the year is set to 1990 and then move the lever under the storm surge curve to select the storm surge height and/or return period of interest. Clicking OK will bring up the map of Viti Levu with the flooded area. The km' of flooded area is noted at the top of the map.

For ***future*** conditions, one can examine the change in flooded area for a rise in sea-level, for a change in storm severity, or both. To examine the effects of sea level rise, choose a year, emission scenario and climate projection, as you have done previously. Then, choose the storm surge height (or return period storm) of interest and click OK. The future rise in sea level will be added to the storm surge, giving a combined flood area (note: setting the lever all the way to the left will minimise the storm effects and isolate the sea level rise effect).

To examine the effects of a possible change in storm severity as a result of global warming, use the box labelled ***alter curve shape.*** This changes the frequency with which storm surges of a given height occur. For example, if one sets the 1-in-100 event to a 1-in-50 event, the curve will automatically be adjusted to give more frequent and severe storms. The effects of this can then be viewed graphically and risk assessments conducted.

12 Health models

Clicking the health model icon activates a dialogue box with two model options:

a) malaria epidemic risk;
b) dengue epidemic risk.

There is not the flexibility to explore sensitivities with the health models, as is available with the coastal, agriculture, and water resources models.
There are three simple steps to running the health models:

i. select the model option (malaria or dengue);
ii. select the scenario parameters (run for 1990 first);
iii. select the month or combination of months for which you want to generate results.

13 Water resources - flow analysis/flooding model

As explained in the description of the flow analysis/flooding model this model uses a stochastic approach to analysis the present and future climate change impact on surface flows in two river catchments in Viti Levu.

The main options that the user must specify (refer to Figure 12) are:

i. scenario;
ii. analysis for low flow or high flow events;
iii. period of analysis.

Use the **scenario option** to select the present (1990) situation or to develop a future scenario.

Select low flow or **high flow,** to examine the effects on river flows of either extreme dry or extreme wet conditions. **Note:** if the high flow option is selected it is also possible to produce a flood map, by selecting the Map Flood option.

The **period of analysis** can be used to specify which part of the historical record is to be used in the GEV analysis. In most cases it is advisable to leave this unchanged, i.e. to use the full period of record.

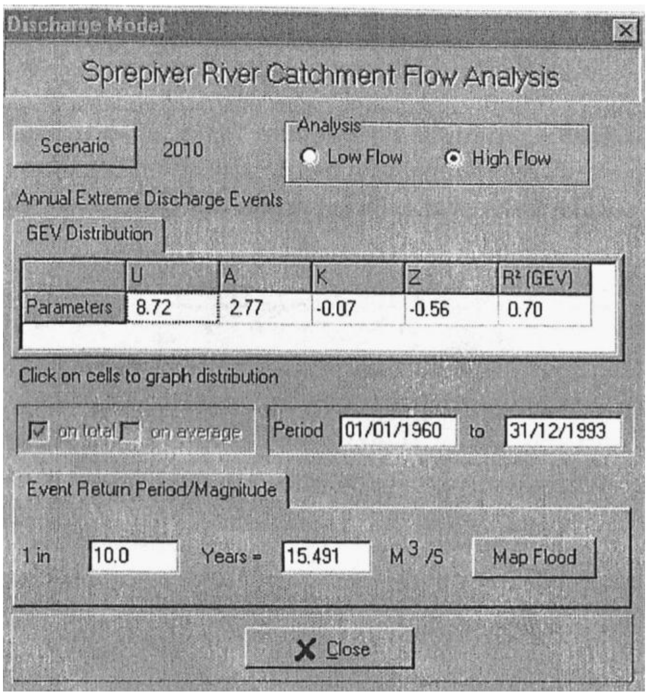


Figure 12: Menu options for running flow analysis/flooding model

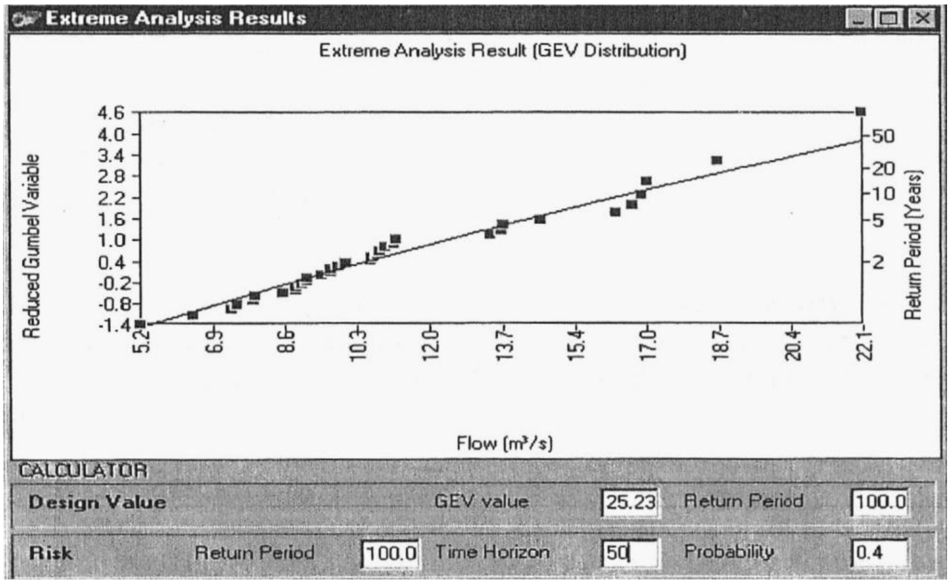


Figure 13: Extreme analysis result for *****

The GEV output values are generated very quickly and are displayed in the same box (see Figure 12). The river flow values associated with specified return periods can also be viewed, simply by editing the return period value in the Event Return Period/Magnitude box. By clicking the Parameters grid, the fitness of the model to the observed data is displayed graphically (Figure 13).

In the Extreme Analysis Results form, a design value and risk exercise can be carried out by using the Calculator at the bottom.

14 Agriculture models

Clicking the plant model icon activates a version[4] of PLANTGRO (Hackett, 1991) developed for application in Viti Levu (Figure 16). These notes do not provide a detailed user guide for PLANTGRO for which purpose it is advised that users obtain a copy of the PLANTGRO manual[5].

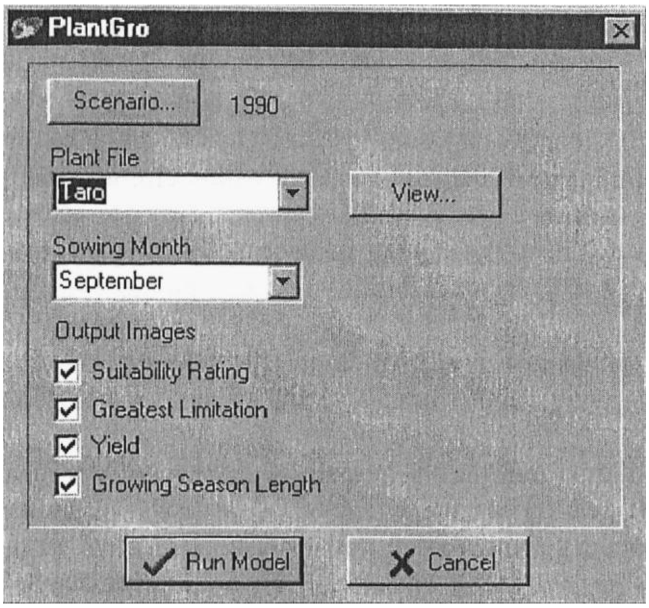


Figure 16: Menu for running FIJICLIM version of PLANTGRC

The PLANTGRO menu requires the user to specify:

i. the scenario;
ii. the plant file;
iii. the sowing month;
iv. the output images.

Under the **scenario option,** either specify a synthetic scenario or a linked-model scenario. By selected the linked-model option PLANTGRO can be run for the present climate and for specified climate change scenarios. The latter are created by selecting the required scenario generation parameters.

Under the **plant file option,** select the crop of interest. The plant file associated with the selected crop can be viewed and modified. In order to modify plant files it will be necessary to spend time reading the PLANTGRO manual. A brief worked example, for taro, is given below.

[4] This version does not contain the full capability of Plantgro, and has been customised for application in Viti Levu by special arrangement with the developer, Clive Hackett.

[5] A full version of Plantgro, and manual, can be obtained from Clive Hackett. Connect to www.ozemail.com.au/–chackett/ for ordering details. Alternatively, an on-line manual is available from www.cad.gu. edit.au/ism/Plantgro/

Modifying a plant file — worked example for taro

Select taro from the plant file menu and click View. The plant file documents the response of taro to 23 soil and climate factors. Relation 17 documents the effects of Heat Damage. In the default file, the following values are given for this Relation:

Reln17. Heat damage (deg. C)

9	0	111	111	111	111	111	111	0	0	Y(SR)
97	100	999	999	999	999	999	999	0	0	X
5	2	0	0	0	0	0	0	0	0	Z (misc)

In this example, null values are recorded beyond the first two columns

The Y values are the suitability ratings (9 = highly suitable; 0 = rapid death). Heat stress is likely to progress from an optimum tolerance range (SR-9) to rapid death (SR=0).

The X values should record, in this example, the temperature thresholds associated with the SR values. At present values of 97 and 100 are given, which are meaningless.

The Z values record, in column 1 the plant part likely to be affected by heat stress (1 = fruit; 2 = flowers; 3 = leaves; 4 = stems; 5 = underground organs), and in column 2 whether air temperature (tmax) or an estimate of soil temperature (tmean) is to be used. 1= air temperature; 2= soil temperature.

Both the X and Z values can be modified. The optimum temperature range for Taro is of the order of 24°C to 28°C, with lower and upper limits of about 20°C and 32°C. Rapid death might occur at about 40°C. These values might apply to heat damage to leaves. Thus the file might be modified as follows:

Reln17. Heat damage (deg. C)

9	0	111	111	111	111	111	111	0	0	Y(SR)
30	40	999	999	999	999	999	999	0	0	X
3	1	0	0	0	0	0	0	0	0	Z (misc)

In this case the upper limit of the optimum range is given as 30°C (SR = 9) and rapid death (SR = 0) is indicated at 40°C. These values apply to taro leaves (Z_1 = 3) and air temperatures (Z_2 = 1).

Use the Save As option to save any changes, or Save if you simply wish to overwrite the existing _ version of the Plant file.

Changes such as these can be used to test the sensitivity of the Plantgro model to climate change.

The only other two specifications that are required are the sowing month (for annual crops) and the output images.

The **sowing month** can be varied to test climate sensitivities at different times of the year, and also to explore the effectiveness of altering sowing time as an adaptation to climate change.

The **output image** of most interest is the Greatest Limitation. This image identifies, spatially, the soil or climate factors that are most limiting to a selected crop on Viti Levu island. Some of these factors, such as soil pH, can be managed quite readily whereas others, such as heat stress require a greater degree of adjustment.

15 Tools

The tools menu provides users with a high degree of flexibility for examining the time series of observed climate data for Viti Levu.

15.1 Climate data browser

This option is used to visualise the historical climate data for Viti Levu. By clicking the site on the Viti Levu map or selecting the site in the site-list box, the user can load the defined data into a table. The time-series of data can be viewed by clicking anywhere inside the table.

Great feasibility is also given in this option for user to handling the data. For example, user can aggregate, calculate and sort the data by choosing appropriate options at the bottom of the form. The proposed data can then be saved into ASCII format by right-click the mouse and select the save option.

15.2 Generalized extreme value analyzer

This form provides the user with a great feasibility of analyzing extreme value events based on observed or user generated climate data. The analysis can be carried out for a variety of time scales. For example, it could be a user specific Julian day, or a fix period, or selected months. The analysis can be based on total amount (i.e., total rainfall of consecutive three days etc.) or based on averaged value (i.e., average maximum temperature of consecutive three days etc.), and based on entire available data (set as default) or user-specified period. Upon the availability of the data, the analysis can be carried out for a variety of climatologies. The FIJICLIM will firstly check the availability of the data. If required data does not exist, either the corresponding buttons are disabled, or an error message pups up. The final result can be visualized by clicking anywhere inside the `GEV distribution' parameter-list table.

Note: Refer to Appendix A of this report for a brief introduction of GEV distribution.

16 Customising images

Below is a result from the malaria epidemic potential model (Figure 17), which is used here to describe the menu options for customising images within FIJICLIM.

Annex 3

Training schedule, powerpoint presentations, and training exercises, prepared for transfer of FIJICLIM through a 2-day training course.

Training in use of FIJICLIM, 28-29 February, 2000
Training facilitators: Gavin Kenny, Neil de Wet, Wei Ye

<u>Training schedule</u>

<u>Monday, 28 February</u>

Morning — Presentation of FIJICLIM and how to use it (facilitated by Gavin)

9.00 am Introductory Remarks and Opening — Graham Sem
Presentation of FIJICLIM
- Scenario generator (Gavin)
- Sectoral models for agriculture, coast, health, water (Gavin, Neil, Wei)

10.40 am Tea break

11.00 am Interactive presentation of FIJICLIM Users Guide (participants will be guided through the range of applications in FIJICLIM)

12.30 pm Lunch

Afternoon — Introductory training exercise (facilitated by Neil)

1.30 pm Introductory training exercise, focussing on:
- Generating baseline information and scenarios (1 hour);
- Using sectoral models (2 hours).

5.00 pin Close for day

<u>Tuesday, 29 February</u>

Start: 9.00 am

Focus for the day is a problem solving exercise, involving:
1) *Reproducing selected results from the World Bank V&A study. This will involve, in some cases, use of additional tools (such as the IDRISI GIS) as aids to interpreting data;*
2) *Providing a critique of parts of the World Bank V&A study, relating to the results generated in 1);*
3) *Presenting results and findings from the critique of the World Bank study.*

This will be facilitated by Gavin and Neil

Close: 5.00 pm

The Prototype FIJICLIM Model

Developed for

Fiji Department of the Environment

(PICCAP Fiji)

by:

International Global Change Institute (IGCI)

with the support of SPREP

supported by;

U N D P - G E F

A P N

World Bank

What is FIJICLIM?

An integrated assessment model for Fiji

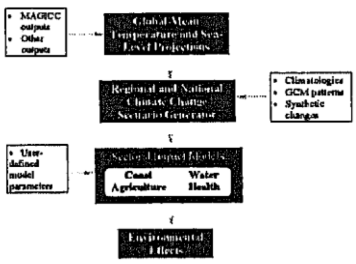
Main Features of FIJICLIM

- Output from a simple global climate model
- Regional patterns of climate change
- Temperature and rainfall climatologies

Sectoral models for:

- —agriculture
- —coastal environment
- —health
- —water resources

FIJICLIM Model Structure



Stages of FIJICCLIM Development

- Stage 1 - training tool for climate change V&A assessment (VANDACLIM)
- Stage 2 - regional climate change scenario generator (PACCLIM)
- Stage 3 - prototype impact modelling for two islands (PACCLIM)
- Stage 4 - prototype development for Viti Levu, Fiji (FIJICLIM)

FIJICLIM can be used to:

- Describe and examine baseline climates
- Create climate change scenarios
- Validate and evaluate impact models
- Conduct sensitivity analyses
- Project sectoral impacts
- Examine uncertainties
- Facilitate integrated impact analyses

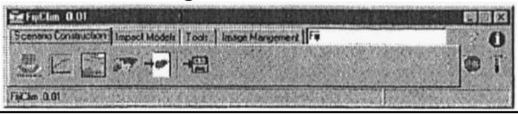
Using FIJICLIM

Creating Climate Change Scenarios

FIJICLIM

(Prototype Version)

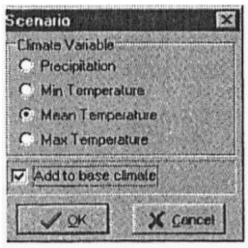
The **main menu** allows the user to:
- create climate change scenarios
- carry out assessments of impacts
- examine data bases and evaluate extremes
- customise images



Developing climate change scenarios using FIJICLIM

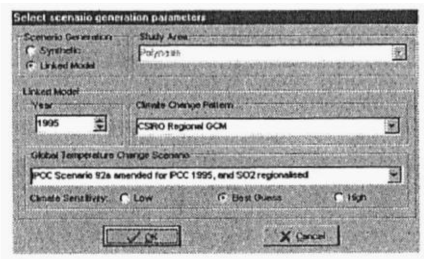
- Select global temperature change -scenario, year and case
- Select regional pattern of climate change
- Scale pattern by global temperature change
- Adjust present climate by change

Choosing the Variable

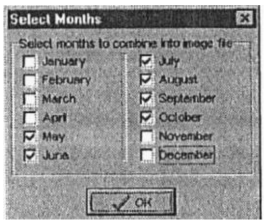


The user selects the climate variable of interest.

FIJICL1M scenario menu options

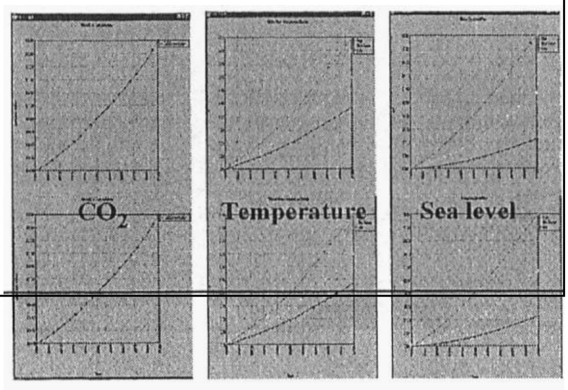


Defining the Season



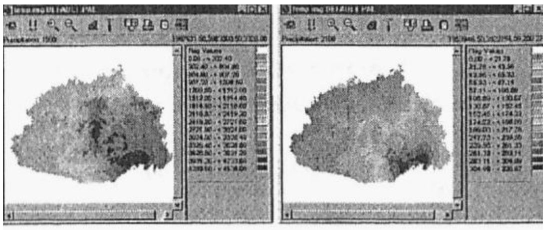
The user can select any combination of months.

- Global -
Projections



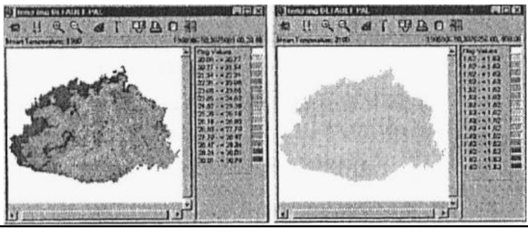
- Viti Levu, Fiji -
Rainfall Change

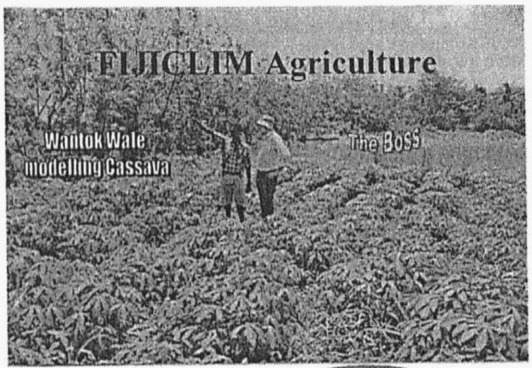
Present **2100**



- Viti Levu, Fiji -
Temperature Change

Present **2100**





Slide 1

Issues to consider

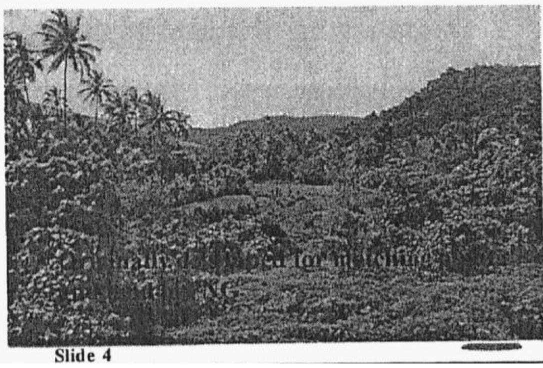
- A few key cash crops
- A wide range of subsistence crops
- Little formal knowledge on plant/climate relationships
- Limited data availability

Slide 2

Modelling Approaches

- **PLANTGRO - designed to capture both formal and informal forms of knowledge on lesser known crops**
- **Process models - limited to a few high value crops, require detailed site data on climate, soil and crop responses**

PLANTGRO



Slide 4

Advantages of using Plantgro in FIJICLIM

- **Already in use by the Land Use Planning Section, Fiji MAFF**
- **Soils data already digitised and made available for incorporation in FIJICLIM**

Slide

What PLANTGRO does

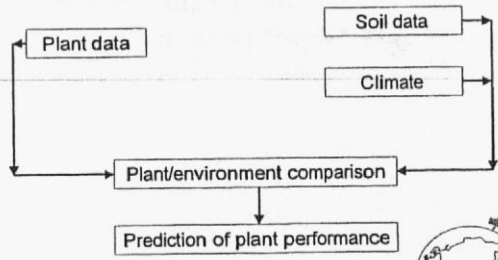
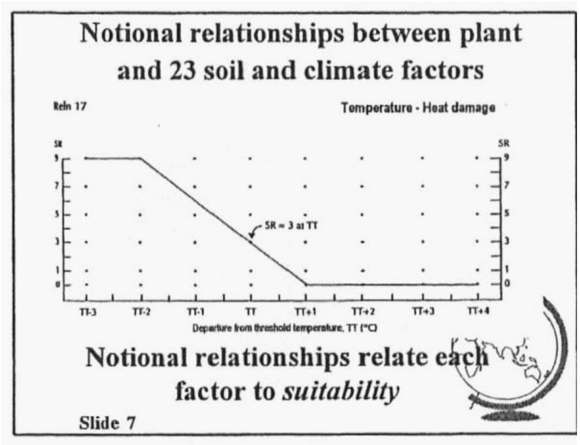
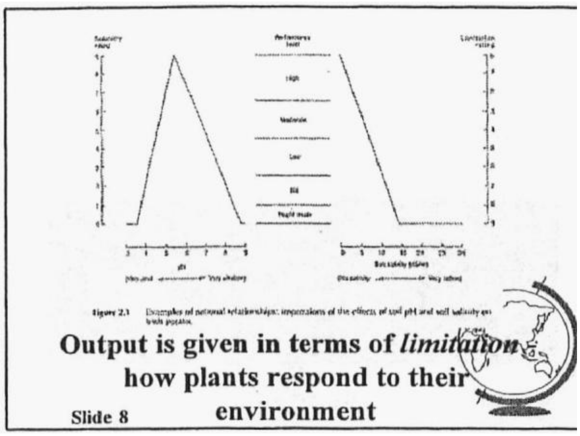


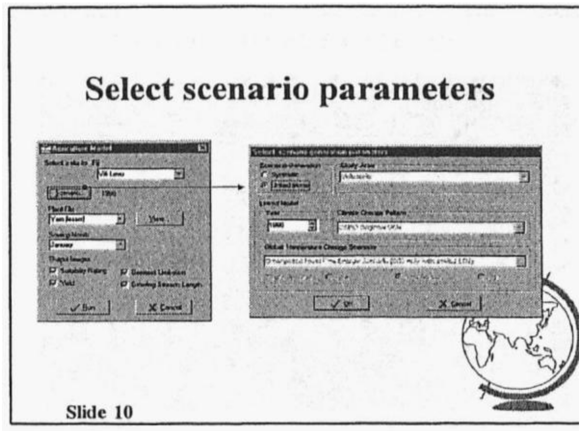
Figure 1 General View of PLANTGRO's functions. (from Hackett, 1991)

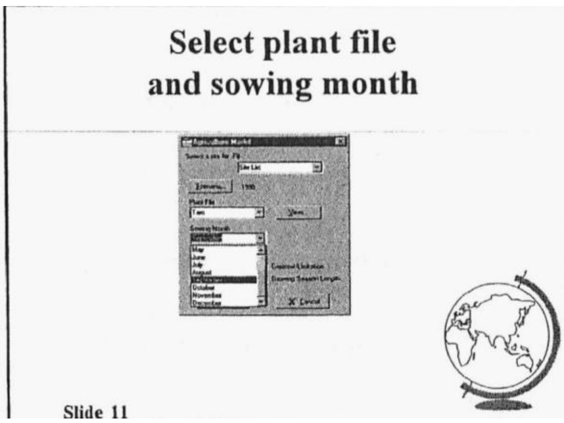
Slide 6

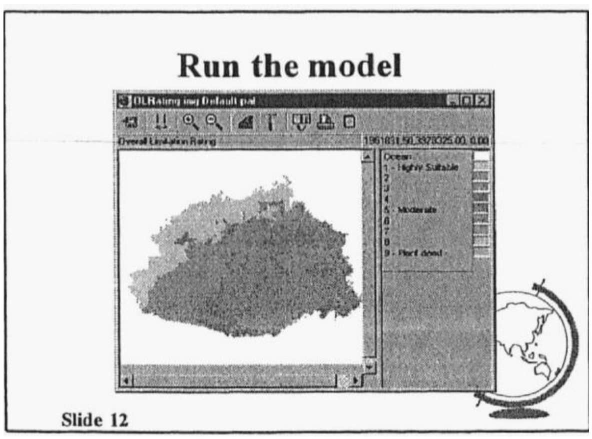

Notional relationships between plant
and 23 soil and climate factors
Reln 17
Temperature - Heat damage
SR
SR = 3 at TT
TT-3 TT-2 TT-1 TT TT+1 TT+2 TT+3 TT+4
Departure from threshold temperature, TT (°C)
Notional relationships relate each
factor to *suitability*
Slide 7

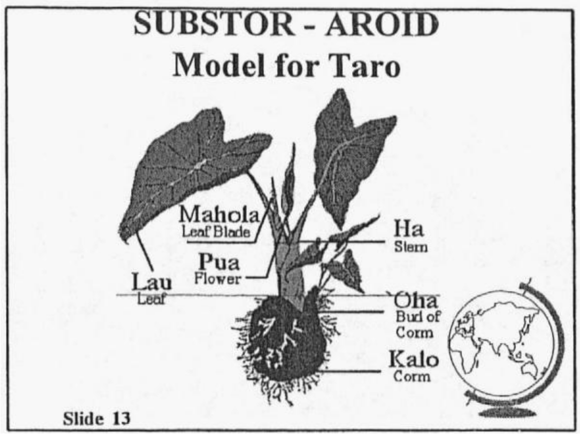

Output is given in terms of *limitation*
how plants respond to their
environment
Slide 8

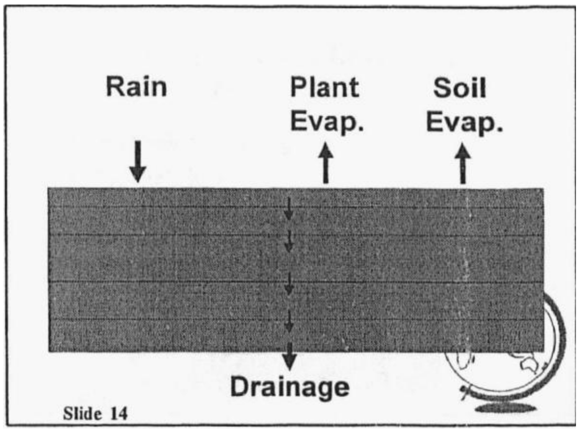

PLANTGRO in PACCLIM
PacClim 0.01
Agriculture Model
Scenario...
1990
Plant File
Yam (lesser)
View...
Sowing Month
January
Output Images
Suitability Rating
Greatest Limitation
Yield
Growing Season Length
Run
Cancel
Slide 9

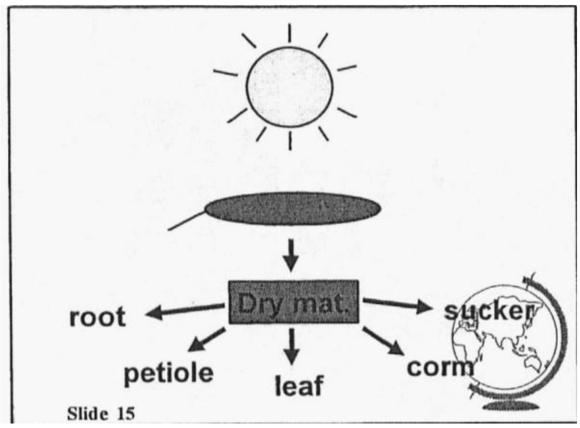

Select scenario parameters
Slide 10

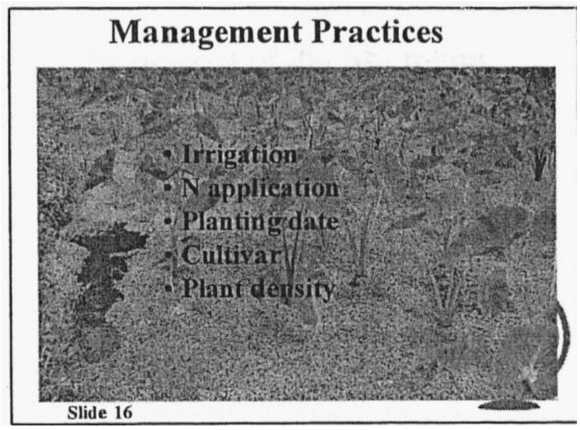

Select plant file
and sowing month
Slide 11


Run the model
Overall Limitation Rating
Ocean
1 - Highly Suitable
5 - Moderate
9 - Plant dead
Slide 12









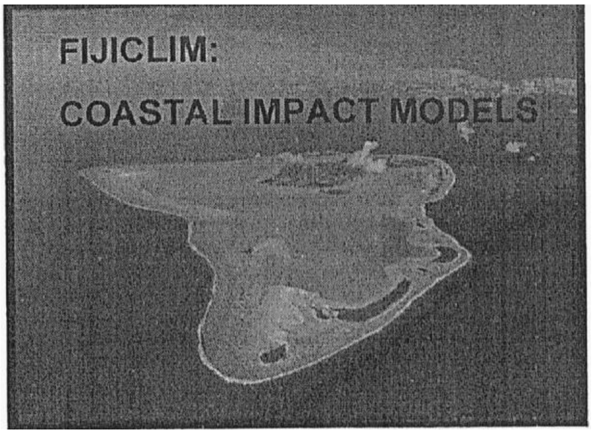
Set weather and soil

- Screen management options for best practices

Set management and soil

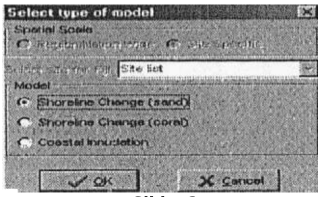
- Quantify production variation
- Climate change impact

Slide 17



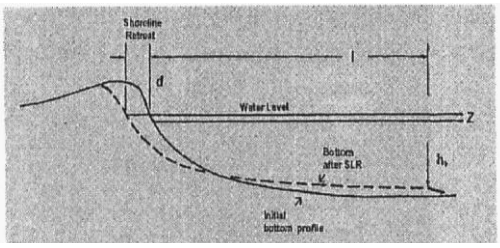
Coastal Impact Models in FIJICLIM?

1. **Shoreline Change**
2. **Inundation**



Slide 2

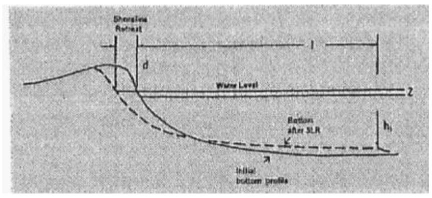
Principles of the Shoreline Change Model



Slide 4

Parameters Required to Run the Shoreline Change Model

Basic equation: $C_{eq} = zl/(h+d)$



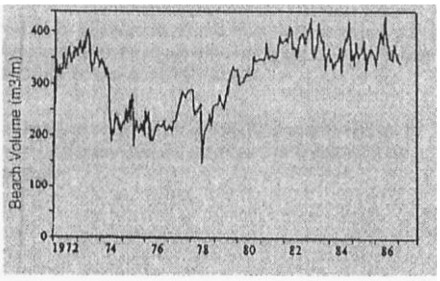
Modifications to Basic Equation

To reflect:

1. Short-term variability in shoreline position (time lag in response) [-u - in years].
2. Interannual variations in storminess [s]

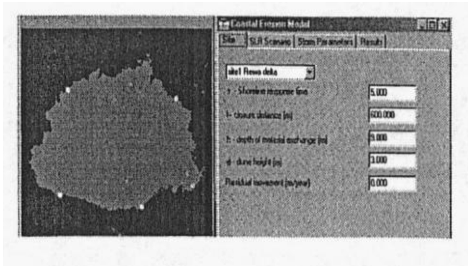
Slide 6

Temporal Changes in Beach Volume



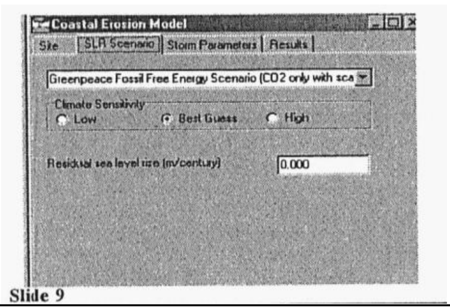
Slide 7

FIJICLIM Input Screens



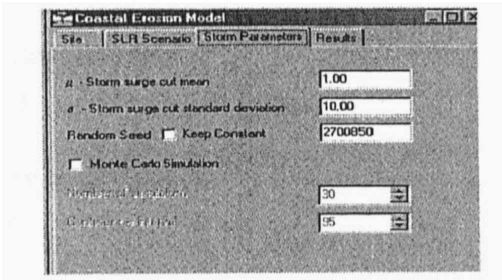
Slide 8

FIJICLIM Input Screens



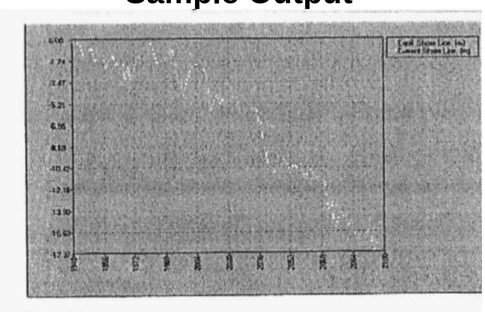
Slide 9

FIJICLIM Input Screens



Slide 10

Shoreline Change: Sample Output



Application of Model

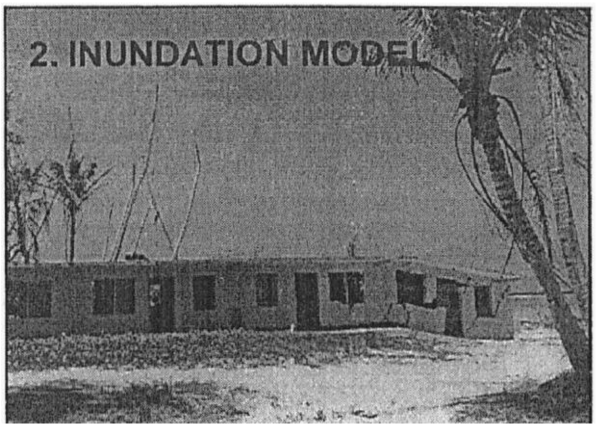
- Provides projections of shoreline movement at a single location.
- Needs to be replicated for the range of different coastal settings.
- Model can be used to generate scenarios of shoreline change under a range of different sea level scenarios.
- Can assess the impact of change in storminess

Slide 12

Application of Model

- Limited to situations where Maximum level of storm surge and wave run-up is lower than the maximum elevation of the coastal margin.
- Parameters need to be carefully considered as in many instances beach profiles are truncated by a reef flat.

slide 13



Principles of the Inundation Model

- **Model based on a simple 'drowning' concept where high water mark is shifted landward by the same amount of projected relative sea level rise.**

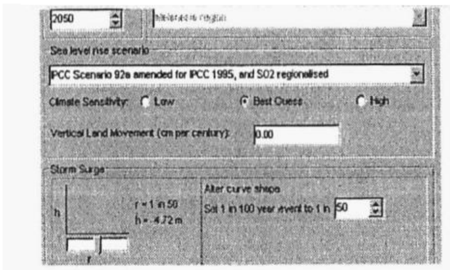
Slide 15

Parameters Required to Run the Inundation Model

- **Sea Level Rise:**
- **Net vertical land movement:**
- **Storm flooding: user defined storm surge magnitude and return period.**

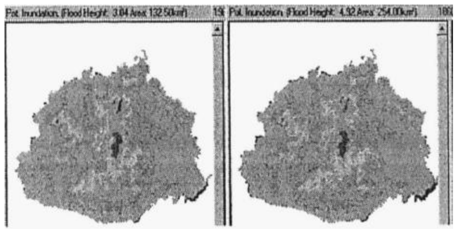
Slide 16

Inundation Model: Sample Output



Slide 17

Inundation Model: Sample Output



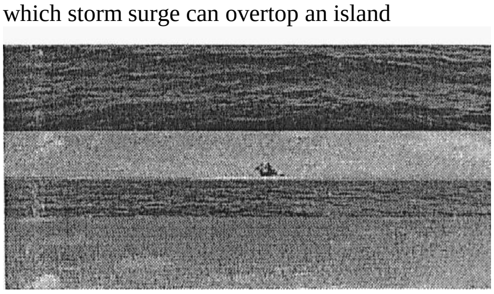
Slide 18

Application of Model

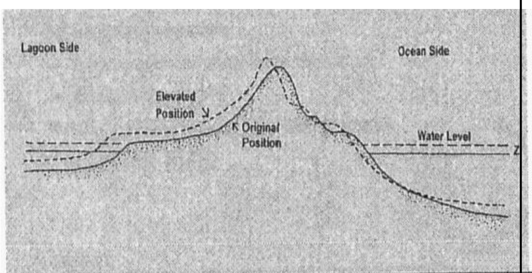
- Provides spatial estimates of inundation.
- Inundation estimates provided for an indivdual year.
- Can manipulate model to determine impacts of increased storminess.

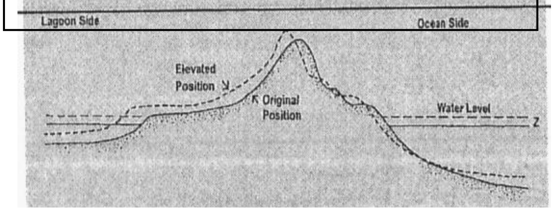
Future Model Development

1. Shoreline Change: To account for situations in which storm surge can overtop an island



2. Generalised Bruun Rule:





Future Model Development

2. Reef Response Model:

To simulate the range of possible reef responses to sea level rise.

Slide 22

FIJICLIM

HUMAN HEALTH

Slide I

Health sector impact models

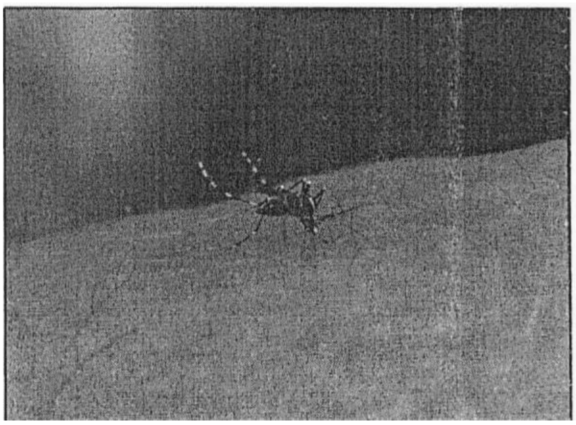
- Mosquito-borne diseases
  - — Dengue fever epidemic potential model
  - — Malaria epidemic potential model

Slide 2

Dengue fever

- **Dengue fever virus (Types** 1, 2, 3 and 4)
- **Mosquito vectors**
  - — *Aeedes Aegypti* (container breeding)
  - — *Aedes Albopiclus*
- **Widely distributed in the Pacific (including FIJI)**

Slide 3



Malaria

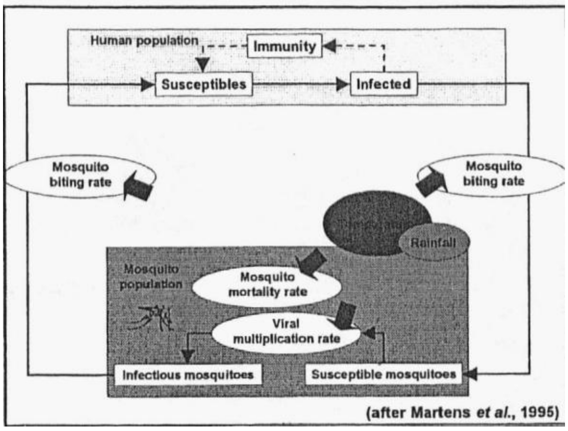
- **Malarial parasites —**
  - ***Plasmodium Jalciparum***
  - ***Plasmodium vivax***
- **Mosquito vectors –**
  - ***Anopheles species***
- **Present distribution in Pacific —**
  - **— Solomon Islands**
  - **— Vanuatu**

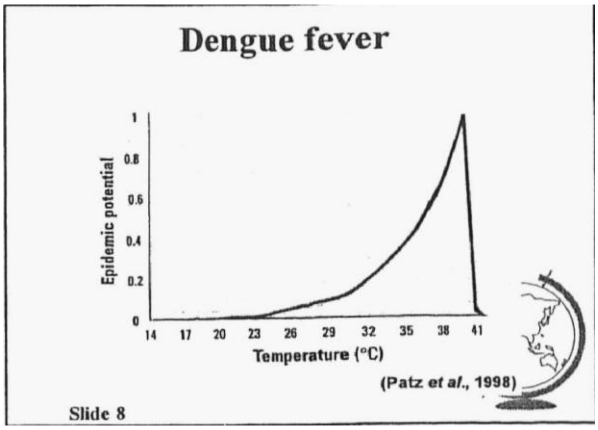
Slide 5

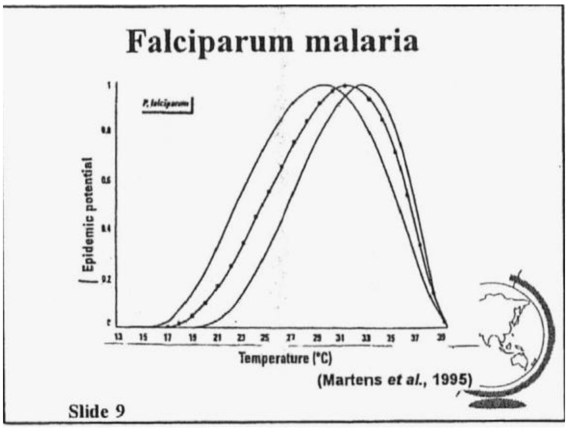
Mosquito-borne diseases

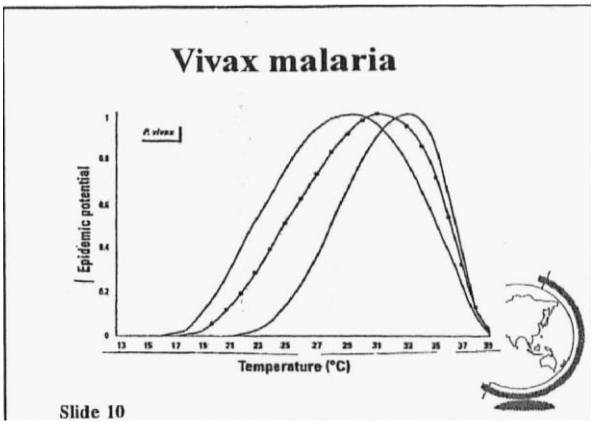
- **Spread of disease requires**
  - — Human population
  - — Mosquito (vector) population
  - — Dengue virus / Malarial parasite
- **Climate ?**

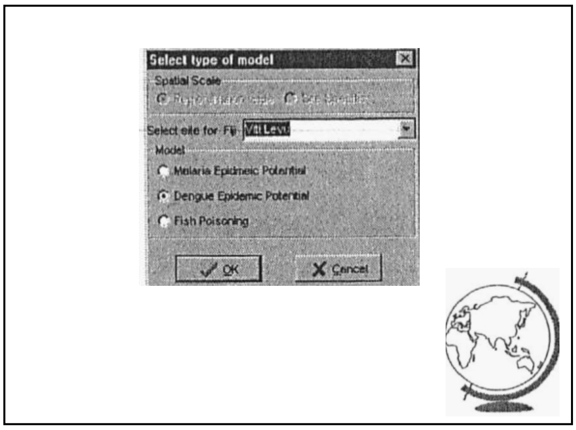
Slide 6

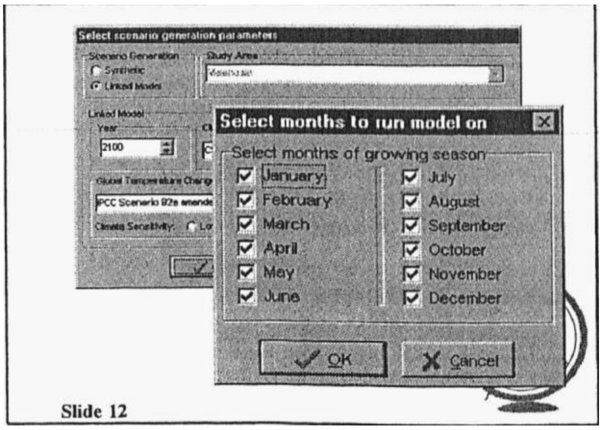

Human population
Immunity
Susceptibles
Infected
Mosquito biting rate
Mosquito biting rate
Rainfall
Mosquito population
Mosquito mortality rate
Viral multiplication rate
Infectious mosquitoes
Susceptible mosquitoes
(after Martens et al., 1995)

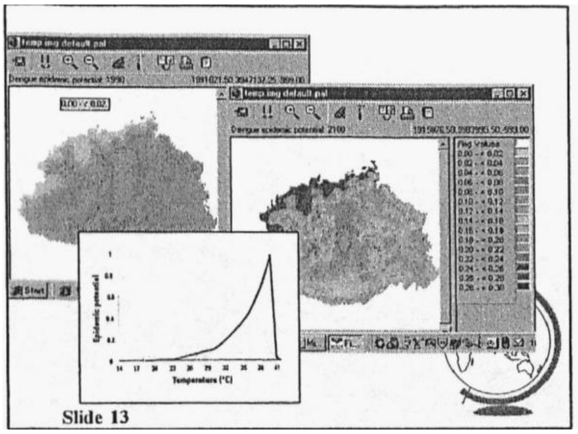

Dengue fever
Epidemic potential
1
0.8
0.6
0.4
0.2
0
14 17 20 23 26 29 32 35 38 41
Temperature (°C)
(Patz et al., 1998)
Slide 8


Falciparum malaria
Epidemic potential
Temperature (°C)
(Martens et al., 1995)
Slide 9

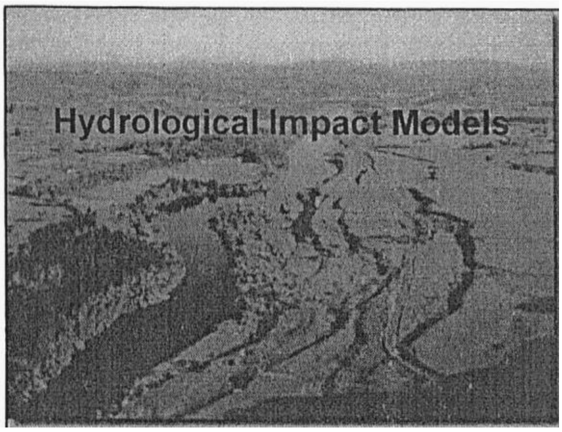

Vivax malaria
Epidemic potential
Temperature (°C)
Slide 10


Select type of model
Spatial Scale
Select site for Fiji: Viti Levu
Model
Malaria Epidemic Potential
Dengue Epidemic Potential
Fish Poisoning
OK
Cancel


Select scenario generation parameters
Scenario Generation
Synthetic
Linked Model
Study Area
Year
2100
Select months to run model on
Select months of growing season
January
February
March
April
May
June
July
August
September
October
November
December
OK
Cancel
Slide 12


temp.img default.pal
Dengue epidemic potential: 1990
Dengue epidemic potential: 2100
Epidemic potential
Temperature (°C)
Start

Slide 13



Hydrological Impact Models

1. Flow analysis model
2. Groundwater model

Hydrology: Flow Analysis Model

This model is used to assess the climate change impact on surface water resources, i.e., the rivers in the Fiji's main island, Veti Levu. The model is used to analysis the impact on both high and low flow events, which are related closely to the flooding and water quality problems.

Principles of the flow analysis model

- The model is a statistical theory
- The model is based on the generalized extreme-value (GEV) analysis
- The generalized extreme-value analysis is widely used for modeling extremes of natural phenomena, and it is of considerable importance in hydrology.

General Extreme Value (GEV)

- Historical observed data are used for the identification and fitting of the desired extreme probability distributions.
- The utility of these estimations depends to a great extent on the length and the homogeneity of the observational record.

General Extreme Value (GEV)

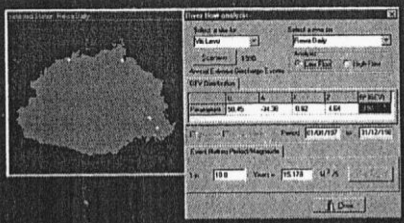
The theory

$Y(m) = (X(m) - U_m)/A_m$, m: Sample size, $A_m > 0$,

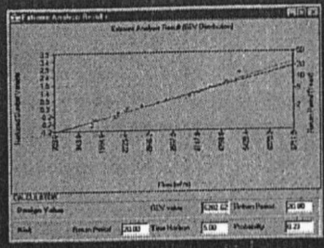
- Gumbal asymptote $G_1 = exp(-e^{-y})$
- Frechet asymptote $G_2 = exp(-y^{1/K})$ $Y>0, K>0$
- Weibull asymptote $G_3 = exp[-(-y)^{1/K}]$ $Y<0, K>0$

K - the shape parameter;
U_m - the location parameter;
A_m - the scale parameter.

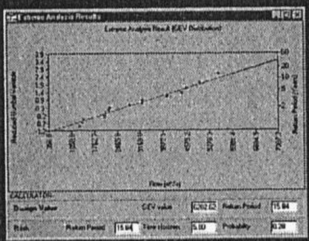
FijiClim Input Screens



FijiClim Output Screens



FijiClim Output Screens



Application of Model

- Provides projections of occurrence of river flow extreme event;
- Provides capacity to carry out risk analysis based on river flow extreme events;
- Generate scenarios of flow extreme event changes under a range of different climate change scenarios;
- Assess the impact of change on flood.

Future Model Development

- Build in appropriate rainfall-runoff model
  - Physical approach
  - Stochastic approach

FIJICLIM prototype training schedule for day 2 (29 Feb)

- 9.00 - problem solving exercise using FIJICLIM
- 10.30 – Tea
- 10.50 - complete exercise and present results
- 12.30 – Lunch
- 1.30 - Future directions for FIJICLIM – small group discussions (to 3.00 pm) presentations and discussion with whole group

Small group facilitators and rapporteurs

- Group I, Jone Feresi
- Group 2, Simon Motilal
- Group 3, Leigh-Anne Buliruarua
- Focus discussion on:
  - needs for future development of FIJICLIM
  - use of FIJICLIM

Problem solylpg exercises

- **Use climate change scenarios provided in the Dept of Environment/World Bank report**
- **Focus on agriculture and water**

Climate change scenarios

GCM	Emissions Scenario	2025 Temp [°C]	2025 Precip %	2050 Temp [°C]	2050 Precip %	2100 Temp [°C]	2100 Precip %
CSIRO9M2	B2 (mid)	0.5	3.3	0.9	5.7	1.6	9.7
	A2 (high)	0.6	3.7	1.3	8.2	3.3	20.3
DKRZ	B2 (mid)	0.5	-3.3	0.9	-5.7	1.6	-9.7
	A2 (high)	0.6	-3.7	1.3	-8.2	3.3	-20.3

El Nino anomalies:
current, +0.5°C, -50% rainfall
2050, +1.5 °C, -60% rainfall
La Nina anomalies:
current, -0.5°C, +50% rainfall
2050, +0.5 °C, +60% rainfall

Agriculture exercise

- Focus on sugarcane
- Plantgro gives an estimate of biomass yield
- What changes in biomass yield occur with the different scenarios, in the north-west of Viti Levu?
- What implications do these changes have for sugar production?

Steps to complete the agriculture exercise

- Create a sub-directory to store the results
- Use FIJICLIM to generate and save YIELD images for each of the specified scenarios
- Use a logical naming system for the stored files: e.g. sugarl.img, sugar2.img ....etc

Steps to complete agriculture exercise cont.

- Use IDRISI (with assistance) to calculate areal average yield for each of the scenarios
- Plot the results (as percent changes from the baseline) using EXCEL
- Provide an interpretation of these results, in terms of implications for sugar production
- Prepare a brief powerpoint slideshow to present the results

FIJICLIM WOKSHOP

Modelling the effects of climate change and sea-level rise in Fiji

28th and 29th February 2000

Suva, Fiji

FIJICLIM TRAINING EXERCISES

Prepared by the
International Global Change Institute
(IGCI)
University of Waikato
New Zealand

• I • G •C• I•

Exercise 1: MAGICC

Examining uncertainties in global temperature and sea-level change using MAGICC

Introduction: When using the scenario generator in FIJICLIM, it is important to have an appreciation for two of the key uncertainties in projecting temperature and sea-level changes, namely the value of the climate sensitivity and possible future greenhouse gas emissions. The scenario generator of FIJICLIM makes use of library files of output from a global temperature and sea-level change model, called **MAGICC** (**M**odel for the **A**ssessment of **G**reenhouse-gas Induced **C**limate **C**hange; Wigley, 1994) which allows the user to examine the effect of these uncertainties in analyses.

Objective of exercise: Use MAGICC to examine the effects on global temperature and sea level change of:

- the value of the climate sensitivity;
- future emissions of greenhouse gases.

A. Climate sensitivity

One of the key uncertainties in climate change science is the value of the "climate sensitivity" (ΔT_{2x}), the equilibrium global mean temperature change for an equivalent doubling of CO_2. The different values of ΔT_{2x} arise from differences in the ways in which General Circulation Models (GCMs) model such factors as changes in clouds, snow cover, sea ice, oceanic effects, etc. As "climate feedback effects", these factors tend to enhance or dampen the direct warming effect of greenhouse gases. It is currently thought that the value of ΔT_{2x} lies in the range of 1.5 to 4.5 degrees for a CO_2 doubling. By following the steps below, use MAGICC to examine the implications of this range of uncertainty in the climate sensitivity:

1. Open MAGICC.
2. On the main toolbar click on the Edit menu. Select 'Emission Profiles'. In the left hand column displayed select IS92c and click on the arrow in the Policy Scenario box. In the left hand column displayed select IS92a and click on the arrow in the Reference Scenario box. Press 'OK'.
3. On the main toolbar click on the Edit menu. Select 'Model parameters'. Set the climate sensitivity to 1.5°C. Press 'OK'.
4. On the main toolbar click on the Run menu. Click on 'Run Model'.
5. On the main toolbar click on the View menu. Under 'Graphs' select 'Temperature and Sea-level'.
6. Select 'Temp' and 'Ref. user'. Note the projected change in global mean temperature for 2100. Compare this to the projection using the best guess climate sensitivity ‘Ref.best’.
7. Select `Sea-level' `Ref. user'. Note the projected change in global mean sea level for 2100. Compare this to the projection using the best guess climate sensitivity ‘Ref.best’.

8. Repeat Steps 3-7, but enter a value of 4.5°C for climate sensitivity at Step 3.
9. Compare the two sets of projections for temperature and sea-level by clicking on 'Ref.range'.

B. Greenhouse gas emission uncertainties

There are considerable uncertainties regarding the future rates of emissions of greenhouse gases, even in the absence of explicit policies to reduce emissions. As a consequence, the IPCC devised a set of six emission scenarios – the IS92a-f scenarios – which reflect these uncertainties. The highest scenario, in terms of radiative forcing, is IS92e, the lowest is IS92c while IS92a is a mid-range estimate. Use MAGICC to examine the implications of this range of emission uncertainty:

1. Open MAGICC.
2. On the main toolbar click on the Edit menu. Select 'Emission Profiles'. In the left hand column displayed select IS92a and click on the arrow in the Policy Scenario box. In the left hand column displayed select IS92e and click on the arrow in the Reference Scenario box. Press 'OK'.
3. On the Edit menu under 'Model parameters' select the default settings by clicking the column of buttons on the right. Press OK.
4. Run the model.
5. On the view menu select temperature and sea-level.
6. Select 'Temp' and both 'Ref.best.' and 'Pol.best.' (Note the values projected for 2050 and 2100.) Now also select 'Ref.range.' and 'Pol.range.' to illustrate the additional range of uncertainty arising from uncertainty in climate sensitivity. To capture this image press CTRL/ALT/PRINT SCREEN. Open MS WORD and press CTRL /V to paste the image.
7. Select 'Sea-level' and both 'Ref. best.' and 'Pol.best.' (Note the values projected for 2050 and 2100.) Now also select 'Ref range.' and 'Pol.range.' to illustrate the additional range of uncertainty arising from uncertainty in climate sensitivity. Capture this image and paste to the same Word document.
8. Compare the projections.

1. What is the difference between the mid-range estimates using IS92a and IS92e?

2. What is the range of uncertainty of the climate sensitivity at 2050 and by 2100?

3. What difference do the emission uncertainties make during the next several decades (say, with the year 2050)? Why? And by 2100?

Exercise 2: FIJICLIM Scenario Generator

Examining baseline climate and constructing climate change scenarios using the FIJICLIM Scenario Generator

Introduction: The FIJICLIM scenario generator allows the user to generate two types of climate change scenario: **synthetic** and **model-based.**

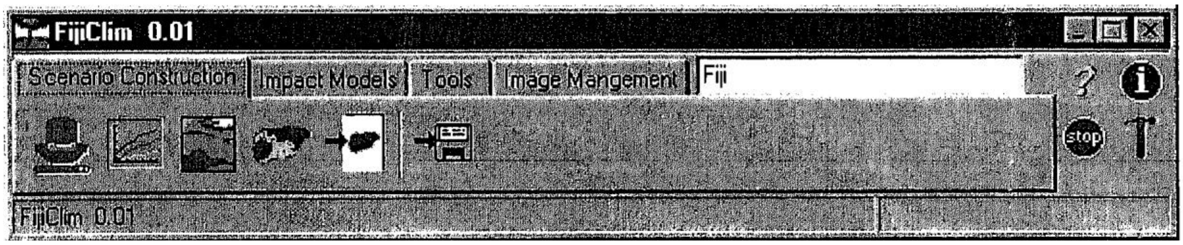
The synthetic scenario generator enables users to make incremental adjustments to temperature and rainfall. These adjustments are applied uniformly to the baseline climate data.

The model-based generator involves the **linked-model** approach. There are two components to this approach. Library files of output from MAGICC describing global temperature and sea-level changes are used as input to the scenario generator. The global temperature changes are used to *scale* temperature and rainfall changes for Viti Levu, which have been .extracted from the patterns of change for the Pacific region as projected by complex global climate models (GCMs). These changes are applied **to** the present climate (1990 baseline) to create climate scenarios for the year of interest (e.g. 2100).

Objective of exercise: Use FIJICLIM to examine present climate and construct two possible scenarios of climate change for Viti Levu using the linked-model approach.

A. The baseline climate and future climate scenarios
Follow the steps described below to produce a baseline climatology (1990 baseline climate) and scenarios of climate change for Viti Levu:

1. Open FIJICLIM. The main menu is displayed.



2. On the scenario construction toolbar click on the icon which is labelled "Generate a scenario".
3. Select mean temperature as the climate variable of interest and click on OK.
4. On the scenario construction window which is displayed select the linked model approach (default setting) and set the year to 1990 (the baseline climate). Click OK.
5. On the month selector window select all the months of the year. Click OK.

6. Leave the resultant image on the screen.
7. Repeat steps 2 — 5 but in step 4 select the following to create a future climate scenario:
   - 2100 time horizon
   - IPCC Scenario 92a amended for IPCC 1995, and S02 regionalised (IS92a)
   - CSIRO Regional GCM
   - Best Guess climate sensitivity.

8. Click OK. To make the legends of the two images the same click on the Link Images tool on one image and then click on the other image. Leave the images on the screen.
9. Construct another climate scenario based on the following:
   6 2100 time horizon
   - IPCC Scenario 92e amended for IPCC 1995, and SO2 regionalised (IS92e)
   - CSIRO Regional GCM

   High climate sensitivity.

10. Click OK. Link the images.
11. Examine the three images and note your observations in the box below and on the next page.
12. Close these images.
13. Repeat the Whole exercise but in step 3 select **precipitation** as the climate variable of interest instead of mean temperature. Compare the 1990 precipitation patterns of Viti Levu with the two scenarios of change for 2100 and note your result& in the box below and on the next page.
14. Repeat the exercise for **precipitation** but use the· DKRZ GCM pattern for the scenario construction.

1. Briefly describe the 1990 baseline climate for Viti Levu. Mean temperature: Mean rainfall:

2. Based on the projections, how may climate in Fiji change in the future?

Mean temperature:

Mean rainfall:

Exercise 3: The sectoral impact models — COAST

Introduction: The prototype FIJICLIM model contains two coastal impact models. These models can evaluate changes in shoreline position (shoreline change model) and island inundation (inundation model) in response to climate and sea-level change. These are simple models that can be used to examine a range of climate change scenarios and subsequent impacts on the coastal environment.

Objectives: Explore the potential of the existing models for application to the Viti Levu coastline. The specific aims are:

- To examine changes in shoreline position using different sea, level rise scenarios.
- To explore how changes in storminess can impact on shoreline position.
- To understand the importance of recent (past 100 year) sea•level history and its implications for future response to accelerated sea level rise.
- To gain practical experience in use of the FIJICLIM inundation model.

A. Examining the effects of different sea level rise scenarios on shoreline response

1. Open FIJICLIM.
2. Click on the **'Impact Models'** toolbar.
3. Click on the **wave icon** (left icon) in the Impact Models toolbar to start the coastal models.
4. Select '**Shoreline Change (sand)**' and press **O.K.**
5. In the site sub-menu select '**Site 3 Sigatoka Beach**' in the first open window.
6. Using information provided in Table 1 for Sigatoka Beach insert the parameter values for (-E, 1, h, d and residual) in the site sub-menu.
7. Select the '**SLR Scenario**' sub-menu.
8. In the top window select the **`IPCC 1992a**' emissions scenario.
9. Select the '**Best Guess**' climate sensitivity.
10. Select the '**Storm Parameters**' sub-menu.
11. Insert values for '**Storm cut mean**' and '**Standard deviation**' using the Information provided in Table 1 for the Sigatoka Site.
12. Click on **'Run Simulation'.**

A small spreadsheet is displayed under the 'Results' sub-menu.

13. To plot results — move the cursor to the centre of the spreadsheet and **click the left-hand mouse button.** A small window appears named 'Select Items'.
14. Using the mouse click on '**Equilibrium Shoreline (m)',** then move the cursor to the line stating 'Current Shoreline (m)' hold down the Control key and click on **'Current Shoreline (m)'.** Both the 'Equilibrium Shoreline (m)' and 'Current Shoreline (m)' lines should be highlighted. Click O.K. A line graph *is* displayed that shows the

projected displacement of the equilibrium and actual shoreline using the scenario chosen.

15. By visually reading the graph **record** the amount of retreat (in metres) of the equilibrium shoreline to the year 2100 in the **Results Table** below. Also identify and record the maximum Actual shoreline change in the assessment period.

Repeat the exercise (steps 2-15) for Sigatoka Beach again. However, in this simulation use the **'IPCC 1992e'** emissions scenario and select the **'High Estimate'** climate sensitivity.

Once you have run the simulation and plotted the results, record the amount of shoreline displacement to the year 2100 and maximum actual shoreline retreat in the results table below.

B. Examining the effect of changes in storm magnitude and frequency on shoreline change

Examine how changes in storm frequency and magnitude affect projections of shoreline change at Sigatoka Beach. Repeat steps 2-15 but at steps 10 and 11 use the **'Increased Storminess'** scenario storm parameters for Sigatoka Beach provided in Table 1.

*Remember to record the results for the total change in equilibrium shoreline and maximum change in actual shoreline position in the table below.

C. Explore the differences that might be expected in shoreline response if sea level has been changing over the past 100 years

Repeat steps 2-15 for Sigatoka Beach, Fiji.

Run the simulation 3 times, each time changing the **Residual Sea Level Rise** information in the SLR Scenario sub-menu. The Residual sea level rise values you should use for the simulations are:

0.0 m
+0.2 m
- 0.2 m

After each simulation plot the equilibrium shoreline graph and record-the amount of shoreline displacement in the Results Table.

D. Inundation

Use the follow steps to estimate possible future inundation.

1. In the FIJICLIM menu panel click on the **'Impact Models'** icon.
2. Click on the **wave icon** (left icon) in the Impact Models menu to start the coastal model.

3. Select **`Viti Levu'** from the **'Select Site for Fiji'** panel.
4. Select **'Coastal Inundation'** from the model options menu and click O.K. [the `Select sea level rise scenario window will appear].
5. Change the year in the **'Year'** panel to 2100.
6. Select the **`IPCC 1992a'** emissions scenario and choose the **'Best Guess'** option.
7. Click on the sliding bar at the bottom of the Storm Surge box (below the graph on the bottom left of the window) slide the bar along until the value reads **r =1 in 50.**
8. Alter the curve shape by setting the 1 in 100 year event to **1 in 50.** By doing this you are effectively increasing the frequency of storms.
9. Click on **O.K.** at the bottom of the window. An image of Viti Levu will appear.
10. In the top bar an inundation area is provided for the particular scenario used.
11. Record this value on your exercise sheet.

Table 1: Coastal environmental parameter data required for the FIJICLIM coastal model.

Parameter	**Sigat**	**Increase in**
Parameters for 'Site' Window		
፲— shoreline response time (yrs) for beach recovery.	5.0	
I - closure distance (m):distance from shoreline to base of shoreprofile.	120.0	
h - depth of material exchange (m):	7.0	
d - dune height: height of coastal margin (m) above maximum storm water level.	15.0	
R - residual shoreline movement (m) (i.e. has shoreline been eroding or accreting?).	0.0	
Parameters for 'Site' Window		
μ — mean storm cut (m): mean shoreline erosion in a storm event.	2.0	6.0
S - standard deviation of storminess: controls the occurrence of storms in the model 0 = non stormy.	5.0	15.0

Table 2: RESULTS: Insert results in the available boxes.

	Sigatoka Equilibrium Shoreline Change (m), 2100	**Sigatoka: Max. Actual Shoreline Change (m)**
Shoreline change using — IPCC 1992a Best-Guess		
Shoreline change using — IPCC 1992e High Estimate		
Shoreline change — with altered storm conditions		
Shoreline change in 2100 using 0.0m historical SLR		
Shoreline change in 2100 using +0.2m historical SLR		
Shoreline change in 2100 using —0.2m historical SLR		

Area of Viti Levu inundated (Km^2)	Km^2

1. **What do results from part A of the exercise show about the sensitivity of the shoreline change model?**

2. **What do results of task C reveal about future shoreline change with accelerated sea level rise?**

3. Compare results of parts A and 13 of the exercise:

a. What do results say about increased magnitude and frequency of storms on possible shoreline response?

b. What are the management implications for Fiji?

4. What do the results of tasks A, B and C mean for the future application of FIJICLIM in the Viti Levu coastal environment?

Exercise 4: The sectoral impact models — Water Resources

Introduction: The **flow analysis/flooding model** is used to assess the climate change impact on surface water in high islands with river catchments such as Viti Levu. FIJICLIM contains data for five river systems in Viti Levu.

Objectives: Use FIJICLIM to analyse the possible effects of climate change on river discharge of the Teidamu and Rewa rivers in Viti Levu.

A. Analyse the possible effects of climate change on the river flow of the Teidamu river in Viti Levu

1. Open FIJICLIM.
2. Select the Hydrology (cloud) icon from the Impact Models toolbar.
3. Select Viti Levu from the site list and select the flow analysis / flooding model. Click OK.
4. Select the Teidamu river and check that the scenario is set for 1990.
5. Select the Low Flow analysis. Note river flow in a 1 in 10 year low flow event. Change the return period to 50. Note river flow in a 1 in 50 low flow event.
6. Select the High Flow analysis. Note river flow in a 1 in 10 year flood event. Change the return period to 50. Note river flow in a 1 in 50 flood event.
7. Click on Scenario. Select the year 2100. Select the IS92a emissions scenario. Select the CSIRO GCM. Select the Best Guess estimate climate sensitivity. Click OK.
8. Note the magnitude of the 1 in 10 low flow event and lin 10 flood event.
9. Click on Scenario. Select the year 2100. Select the IS92e emissions scenario. Select the CSIRO GCM. Select the High estimate climate sensitivity. Click OK.
10. Note the magnitude of the 1 in 10 low flow event and lin 10 flood event.

1. **Consider both scenarios and comment on how climate change may affect river flow for the Teidamu river.**

B. Repeat the exercise using the DKRZ GCM pattern

2. Consider this set of results and comment on how climate change may affect river flow for the Teidamu river.

C. Flood potential in the Rewa river system

Use the CSIRO GCM pattern and a selection of emission patterns and values for the climate sensitivity to investigate how climate change may affect, the frequency of severe flooding / flood related damage in the Rewa system? (Assume that flood damage occurs when river flow exceeds 12 000 cubic metres per second.)

3. Record and comment on your results:

Exercise 5: The sectoral impact models - Agriculture

Introduction: The PLANTGRO model in FIJICLIM was developed for application in a Pacific Island context as a means of capturing and expressing local knowledge about plants and how they perform in different environments. There are three important components to PLANTGRO: climate files, soil files and plant files. The climate and soil files provide the basis for examining suitability of specified crops at either specific sites, or over areas. A total of 23 climate and soil factors are considered. There are two key elements to output from PLANTGRO: suitability, which reflects how people perceive plants are suited to their environment; and limitation, which is how plants respond to their environment.

Objective of exercise: Use FIJICLIM to examine the possible effects of climate change on agriculture in Viti Levu.

A. Baseline conditions

Follow the steps below to generate baseline conditions for Taro cultivation in Viti Levu:

1. Go to the main FIJICLIM menu.
2. Select the Plantgro icon on the Impacts menu.
3. Select Viti Levu as the study site.
4. Check scenario option is 1990 (the default Scenario option).
5. From the Plant File menu, select Taro.
6. From the Sowing Month menu, select September.
7. Of the four possible Output Images, leave only the Overall Limitation Rating checked.
8. Run the Model. (This simulation will take a couple of minutes.)
9. Leave the resultant image on the screen.

B. Analysing the effects of climate change

Follow the steps below to analyse impacts on taro using one synthetic scenario of climate change and two scenarios produced by the linked-model approach:

1. Activate the Plantgro menu again.
2. Select the Scenario option and then select Synthetic. Enter 2 in the temperature box (for an increase in average temperature of 2°C) and enter —50 in the rainfall box (for a_decrease in rainfall of 50%). This "synthetic" scenario is comparable to conditions during the 1998 El Nino drought.
3. Select Taro and September.
4. Check only the Overall Limitation Rating.
5. Run the Model and leave the resultant image on the screen.
6. Re-run the above for the IS92a, best guess, CSIRO GCM pattern scenario for 2100.
7. And again for the IS92e, high, CSIRO GCM pattern scenario for 2100.
8. Leave these images on the screen.

Arrange the four images so that you can view them all.

1. How does the drought "anomaly" compare to the 1990 result?

2. What are the relative effects of the two scenarios?

3. If the two scenarios reflect future "average" conditions, what would one expect to see in drought years?

Exercise 6: The sectoral impact models — Human Health

Introduction: The vector-borne disease models relate temperature to epidemic potential. Epidemic potential is an indicator of how easily an epidemic will be triggered and escalate if the disease along with the disease vector were introduced to a susceptible human population. Where epidemic potential is high epidemics will occur more easily, grow faster and smaller vector (mosquito) numbers would be required to sustain the epidemic. Conversely, where epidemic potential is low, epidemics will be less likely to occur, increase more slowly and require a larger vector population to be sustained.

Objective: Use FIJICL1M to examine the possible effects of climate change on the epidemic potential of dengue fever in Viti Levu.

A. Examining changes in epidemic potential of dengue fever in Viti **Levu**

Fiji has experienced several outbreaks of dengue fever in the past, the most recent being in 1998. Assess possible changes in epidemic potential in Viti Levu by following the steps below:

1. Go to the main FIJICLIM menu.
2. Click the Health models icon on the Impacts menu.
3. Select the dengue epidemic potential model and Viti Levu from the site list and click OK.
4. In the scenario generator window set the year to 1990 and click OK.
5. Select all the months of the year. Click OK.
6. Select the box for mean temperature. Click OK. Leave the image on the screen.

7. Repeat steps 2-6 but in step 4 set the year to 2100 and select the IS92a emissions scenario, CSIRO GCM pattern and Best Guess climate sensitivity. Leave the image on the screen.
8. Repeat steps 2-6 using but in step 4 set the year to 2100 and select the 1592e emissions scenario, CSIRO GCM pattern and High climate sensitivity. Leave the image on the screen.
9. Link the images.

1. Describe the changes in epidemic potential of dengue in Viti Levu for the two scenarios compared to the baseline.

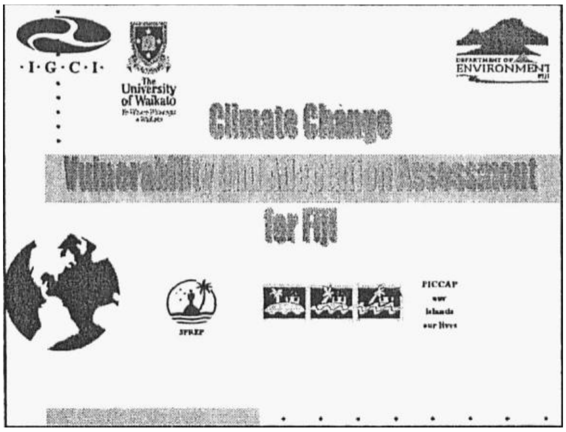
2. What is the epidemic potential in Suva and Nadi for the 1990 baseline, the first scenario and for the second scenario? (Click on the map.)

3. What is the significance of these changes in terms of the future incidence of dengue fever in Viti Levu?

4. Is this analysis useful in determining an appropriate adaptation response? What would constitute an appropriate adaptation to increased transmission efficiency related to climate change?

Annex 4

Powerpoint presentations from National Workshop



Fiji's commitment

- A signatory to the UNFCCC, and thus obliged to provide National Communications
- Fiji's commitment supported by PICCAP
- This commitment extended by the report presented here

Background to the study

- Training in V&A assessment through PICCAP - preparation of a draft V&A report and a national V&A statement
- Support through PICCAP for the development of PACCLIM, a regional scenario generator with example sectoral impact applications for Fiji and Kiribati
- Additional support from the World Bank to complete the V&A report and develop and transfer a FIJICLIM prototype

The present study

- Focussed on Viti Levu as a case study
- Drew on existing baseline information and previously published studies
- Required incorporation of Fiji climate and soils data within PACCLIM, and application of this model system

for selected sectors

Limitations to the study

- Focus on Viti Levu
- While model capabilities are a significant advancement, they are still developmental
- Only four sectors covered - not comprehensively
- Limited time
- A starting point for an on-going process of V&A assessment for Fiji

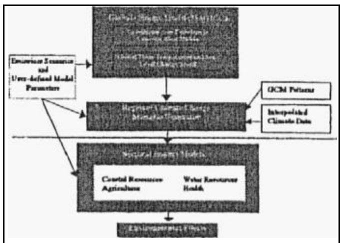
The sectors

- Agriculture
- Coast
- Public health
- Water

Methods

- There were three main tasks
  - Development of climate and sea-level change, as well as non-climatic, scenarios
  - Assessment of impacts
  - Identification of adaptation options

The PACCLIM model system



Viti Levu data in PACCLIM

- Historic temperature and rainfall data, interpolated to a 500 m grid
- Digital elevation data
- Soil attribute data
- River flow data

Sectoral models

- Agriculture - Plantgro, a plant prediction model customised for spatial applications
- Health - A dengue epidemic potential model
- Water - A flow analysis/flooding model, calibrated for 5 sites in Viti Levu
- Coast - Coastal erosion and inundation models (developmental, not used in this study)

Important outcomes

- A completed V&A report
- Development and transfer of a FHICLIM prototype

Climate change scenarios for Fiji V&A study

State: of science

- Unlikely that general circulation models (GCMs) will ever provide accurate information for Fiji, particularly relating to tropical cyclones and ENSO
- Likelihood of increasingly reliable regional information, which can be interpreted based on present climate and its variability

Approach for Fiji

- Used PACCLIM scenario generator
- Selected two GCM patterns
- Used latest GHG emission scenarios recommended by the IPCC

Temperature changes

- GCM model results show temperature increases over Fiji of the order of 0.7°C to 0.9°C per 1.0 °C

Rainfall changes

- Present rainfall patterns strongly influenced by ENSO and positioning of the SPCZ
- GCM results show a more El Nino - like pattern regionally, but positioning of SPCZ varies
- Rainfall changes vary from increases to decreases

Summary of temperature and rainfall scenarios

GCM	Emissions Scenario	2025		2050		2100	
		Temp [°C]	Precip %	Temp [°C]	Precip %	Temp [°C]	Precip %
CSIRO9M2	B2 (mid)	0.5	3.3	0.9	5.7	1.6	9.7
	A2 (high)	0.6	3.7	1.3	8.2	3.3	20.3
DKRZ	B2 (mid)	0.5	-3.3	0.9	-5.7	1.6	-9.7
	A2 (high)	0.6	-3.7	1.3	+8.2	3.3	-20.3

Effects on variability and extremes

- Current information suggests the possibility of an intensification of variability and extremes. For example:
  - — more intense El Nino/La Nina episodes
  - — possibly an increase in cyclone intensity, although this is far from certain
- These changes are consistent with recent experience (sequence of events from 1992 to 1999)

Sea-level rise scenarios

- Global mean projections used for first order assessment

Scenario/Year	2025	2050	2100
B2 (best guess)	11 cm	23 cm	50 cm
A2 (high)	21 cm	43 cm	103 cm

FIJI V&A STUDY

NON-CLIMATIC SCENARIOS

Neil de Wet
I G C I
University of Waikato

Slide

Non-climatic scenarios

- Why?
- Scenario vs prediction
- Enhance assessment of impacts
- Help identify adaptation strategies

Slide 2

Use of scenarios

- Broad and illustrative

rather than

- Quantitative and analytical

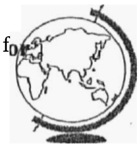
Slide 3

Approach

- Develop a range of scenarios describing a range of development pathways for Fiji

OR

- Develop a best-guess extrapolation of trends **in** order to highlight possible adaptation measures and options for policy intervention



Slide 4

Main components

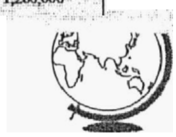
- **Demography**
- **Economy**
- **Infrastructure**
- **Environment**

Slide 5

Population growth

Population projections for Fiji

Projection	2026	2051	2096
High	1,210,000	1,620,000	2,300,000
Medium	1,180,000	1,480,000	1,720,000
Low	1,110,000	1,260,000	1,280,000



Slide 6

Population distribution

- **Presently**
  - — 90% coastal
  - — 60% rural
- **Increased urbanisation /**
- **Increased urban / peri-urban growth**
- **Increased coastal population**

Slide 7

Economy

- **Continued dependence on natural resources and agricultural production**
- **Continued importance of tourism**
- **Continued growth in cash economy but subsistence economies will remain important especially in rural areas**
- **Dependence on foreign aid (droughts cyclones)**

Slide 8

Infrastructure and housing

- **Urban densification**
- **Increase in peri-urban areas / coastal rim**
- **Increase in peri-urban 'informal' housing**
- **Increase in coastal infrastructure / coastal tourism infrastructure**

Slide 9

Environment

- **Fragmentation and degradation of ecosystems**
- **Degradation of land / top-soil loss**
- **Degradation of river catchment areas**
- **Deforestation**
- **Pollution - solid waste, industrial, sewage**
- **Pressure on coastal environment**

Slide 10

Use of scenarios

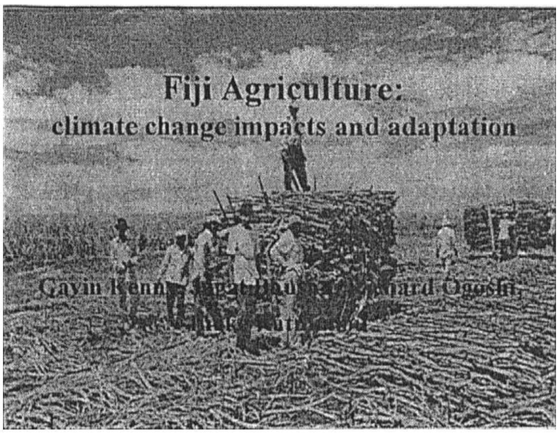
- **Frequently non-quantitative**
- **Assessment of impacts**
- **Identification of adaptation options**

Slide 11

ADAPTATION (or a more optimistic scenario?)

- **Determining a development trajectory for Fiji which would make its ecosystems and Fijian communities MORE RESILIENT to the effects of climate change**

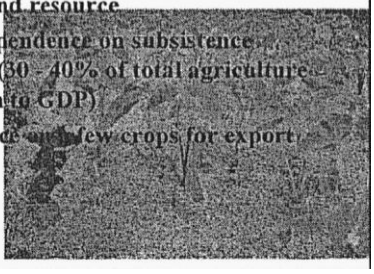
Slide 12



Part 1: Present situation

Slide 2

Characteristics of Agriculture in Fiji



- A limited land resource
- A strong dependence on subsistence agriculture (30 - 40% of total agriculture contribution to GDP)
- A dependence on a few crops for export revenue

Slide 3

Cropping systems

- Subsistence farming (root and fruit crops)
- Semi-commercial farming (some root and fruit crops)
- *Plantation farming (sugarcane and coconut)*

Slide 4

Effects of development on agricultural systems - Fiji

- *Reduction in soil cover*
- *Biodiversity loss*
- *Soil erosion*
- *Land degradation*
- *Downstream effects (e.g. sedimentation)*
- *Problems exacerbated by growing population and pressures of economic development*

Present effects of climate

- ENSO events and tropical cyclones have a strong influence on productivity
- Different places and different crops have varying susceptibilities

Slide 6

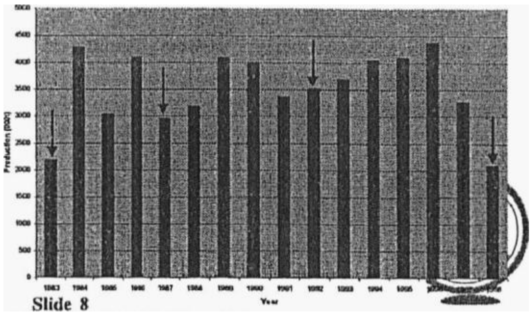
Example - sugarcane

- Requires high temperatures and adequate moisture for early development
- Lower temperatures and drier conditions required near maturation
- Prolonged drought and flooding can cad to crop losses

Slide 7

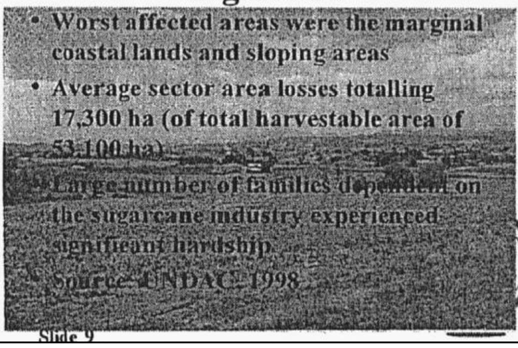
Sugarcane production 1983-1998

Fiji sugarcane production(cane crushed), 1983-1998



Slide 8

The Fiji drought -effects on sugarcane



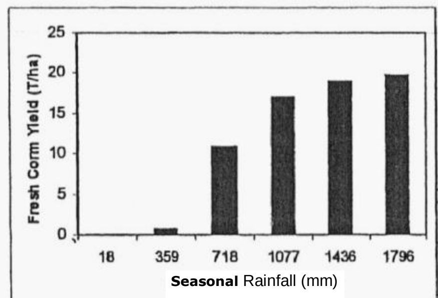
Slide 9

Example - dalo

- Normally planted before onset of rainy season (September)
- Grown in wetter soils
- Rotated with cassava and yam (considered to be more drought tolerant

Slide 10

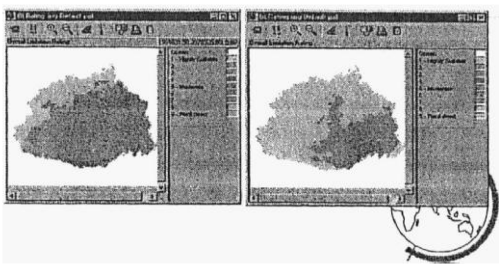
Simulated dale yield response to rainfall in Koronivia



Slide 11

Effect of drought on dale

present +2°C, -50% rainfall



Slide 12

Part 2: Effects of climate change

Slide 13

Impacts of climate change on Fiji agriculture

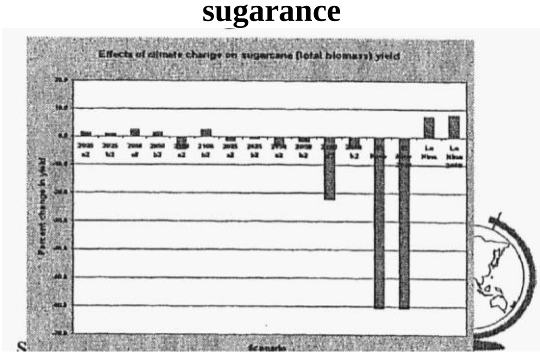
- In general, changes in precipitation (and water balance) and tropical cyclone frequency are likely to have the greatest impact (Nurse *et al.,* 1998)
- Viti Levu case study, using historical data and the Plantgro model in FIJICLIM

Slide 14

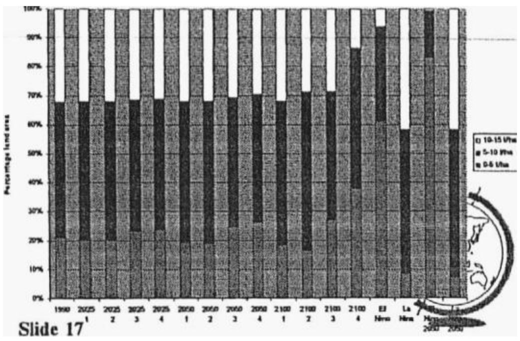
Effects of climate change on sugarcane

- Expected production of 4 million tonnes achieved in 7 of the last 15 years
- Assume intensification of El Nino events in future, e.g. more droughts comparable to 1997/98
- The following might occur in the next 25 to 50 years
  - —47% of years with expected production
  - — 27% of years with half of expected production
  - —26% of years with three quarters of expected production

Effects of climate change on sugarance

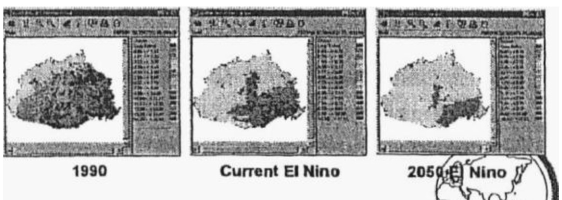


Effects of climate change on dalo in Viti Levu



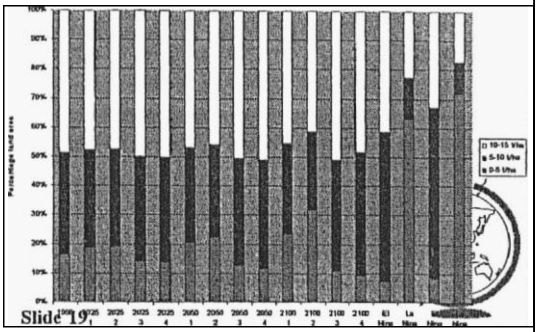
Slide 17

Effects of intensified El Nino drought on dalo



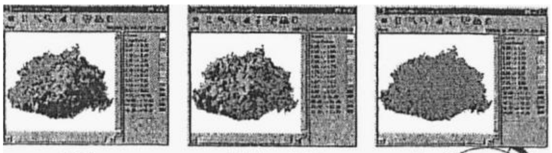
Slide 18

Effects of climate change on yam in Viti Levu



Slide 19

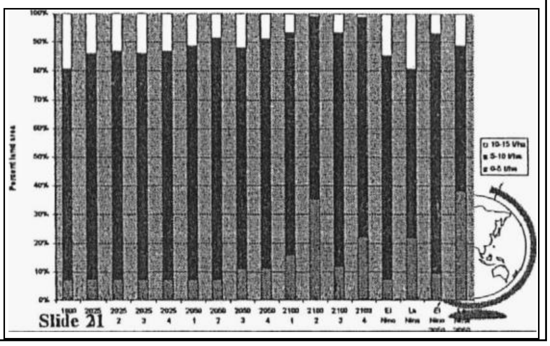
Effects of intensified El Nino & La Nina on yam



1990 El Nino 2050 La Nina 2050

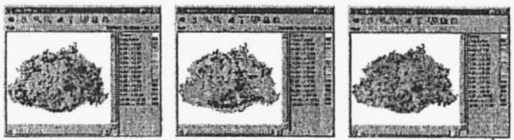
Slide 20

Effects of climate change on cassava in Viti Levu



Slide 21

Effects of intensified El Nino & La Nina on cassava



1990 El Nino 2050 La Nina 2050

Slide 22

Adaptation

- What to do in the face of uncertainty?
- A "no-regrets" approach?
- A greater emphasis on "research and the extension of more flexible farming systems that are tolerant to climatic stresses and variability(FAO, 1999)
- Develop such systems as part of a holistic and integrated, multi-sectoral, approach

Slide 23

More flexible farming systems

- Focus on sustainability
- Crop diversification
- Soil and water conservation practices
- Reduce reliance on imported chemicals and fertiliser
- Farming systems research
- Traditional systems

Slide 24

Some relevant developments in Fiji

- **Draft land use policy - recommendations aimed at sustainable land management**
- **Recent merger of MAFF extension and research divisions-increased opportunity for farming systems research**
- **Landuse Planning Section work on agroforestry etc.**
- **GIS unit, and the transfer of FIJICLIM prototype - matching plants and land**

Slide 25

Some specific measures for Fiji

- **Diversify away from sugarcane in marginal areas**
- **R&D for important subsistence crops**
- **Encourage sustainable farming systems (such as agro-forestry)**
- **Strengthen role of Landuse Planning section in identifying suitable area appropriate land management practices**

Slide 26

Sugarcane

- **Cease production on marginal sloping land**
- **Intensify production in better land areas**
- **Diversify**

Slide 27

Root crops

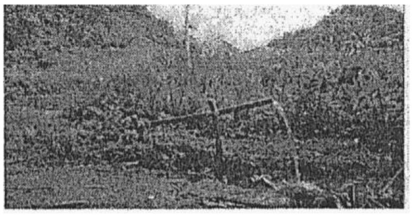
- **Breeding programme for more drought tolerant dalo varieties**
- **Enhance yam breeding programme**
- **Focus on enhancement of traditional farming systems**

Slide 28

The End

Slide 29

FIJI Climate Change V&A Study



HUMAN HEALTH

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Nature of health impacts

- Direct (heat waves, storms, floods)
- Indirect (vector-borne, water-borne, ciguatera, cholera, nutritional disorders etc)
- Diffuse(poverty, inequality, unemployment, migration)

Scoping short list

- **Dengue fever**
- **Malaria**
- **Filariasis**
- **Diarrhoea! diseases**
- **Ciguatera**
- **Nutrition related diseases**

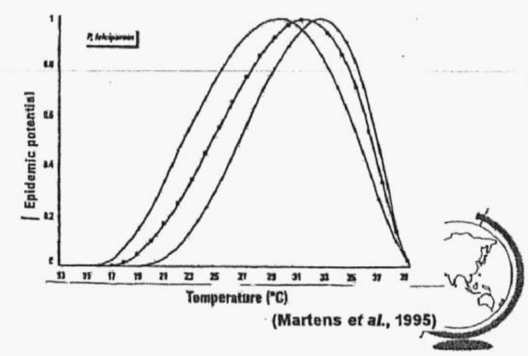
Scoping short list

- **Dengue fever**
- Malaria
- Filariasis
- **Diarrhoea! diseases**
- Ciguatera
- **Nutrition related diseases**

Malaria

- No anopheles mosquitoes in Fiji
- Fiji has remained malaria free
- Change in epidemic risk attributable to climate change is minimal

Falciparum malaria



Filariasis

- **Effective treatment and prevention**
- **Eradication in 10 years (?)**
- **Not relevant to time horizons of climate change**

Ciguatera

- *Data limitations*
- Uncertainty re climate linkages

Scoping short list

- **Dengue fever**
- Malaria
- Filariasis
- **Diarrhoeal diseases**
- **Ciguatera**
- **Nutrition related diseases**

Dengue Fever

- **Classical dengue fever**
- **Dengue Haemorrhagic fever (DHF)**
- **Dengue Shock Syndrome (DSS)**

Dengue vectors in Fiji

- ***Aedes aegypti*** **(container breeding)**
- ***Aedes albopictus***
- ***Aedes polynesiensis***
- ***Aedes pseudoscutellaris***

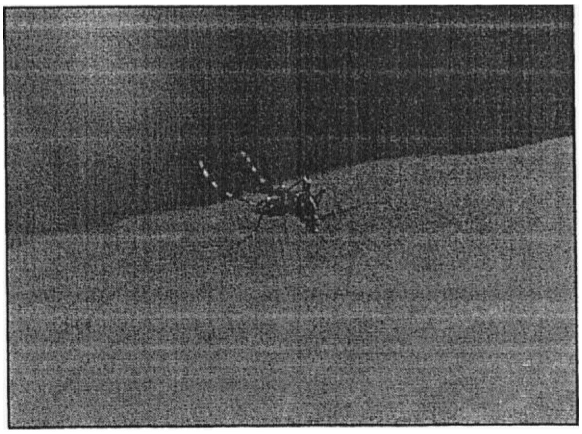


Table 7.1. Historical record of dengue fever epidemics in Fiji

Year	Serotype	Reported number of cases	DHF/DSS	Number of deaths
1885	Unknown	Thousands	None	?
1930	Unknown	Thousands	None	?
1943/4	Unknown	Thousands	None	None
1971/2	Den-2	4000	None	None
1974/5	Den-1	20 000	Yes	12
1980	Den-4	127	?	?
1981	Den-1	Hundreds	Yes	1
1982	Den-2	546+	?	?
1984/6	Unknown	490+	?	?
1989/90	Den-1 and Den-2	3686	Yes	40
1998	Den-2	24000	Yes	13

Adapted from Basu et al, 1999

Climate and vectors

- Rainfall
- Temperature

Rainfall

- Breeding sites
- Rainy season - increased risk

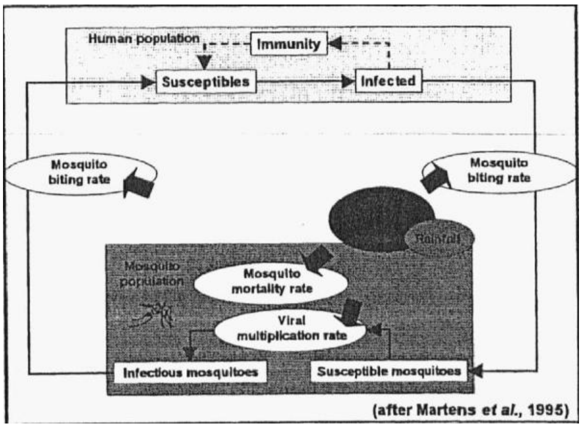
however... ....

Aedes aegypti

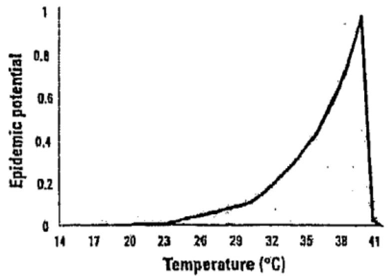
- Prefers urban / domestic environment
- Container breeding
- 1998 Dengue epidemic (water storage drums +)
- Not dependent on rainfall

Temperature

- Powerful determinant of vector distribution
- Influences life cycle, body size
- Influences biting rate
- Mortality



Dengue fever



(Patz *et al.*, 1998)

Two key determinants of dengue risk

- **Ambient temperature**
- **Abundance of breeding sites**

Two key determinants of dengue risk

- **Ambient temperature**

- relates to climate change impact

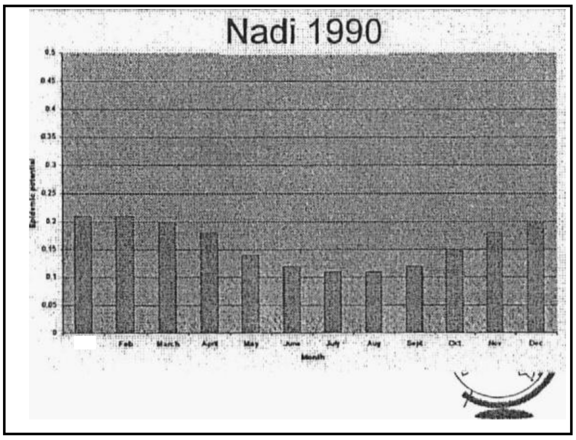
- **Abundance of breeding sites**
  — human factors
  — important in adaptation to climate change

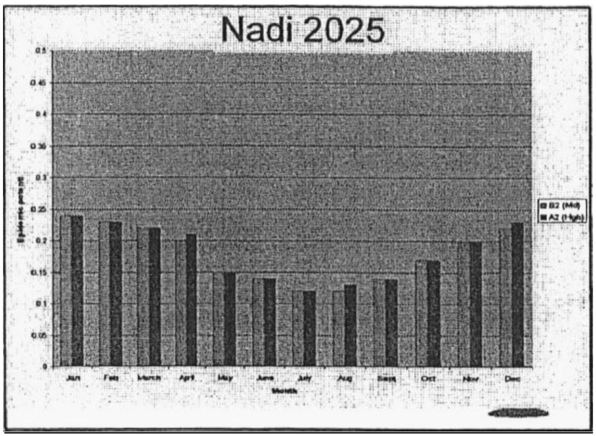
Dengue risk analysis

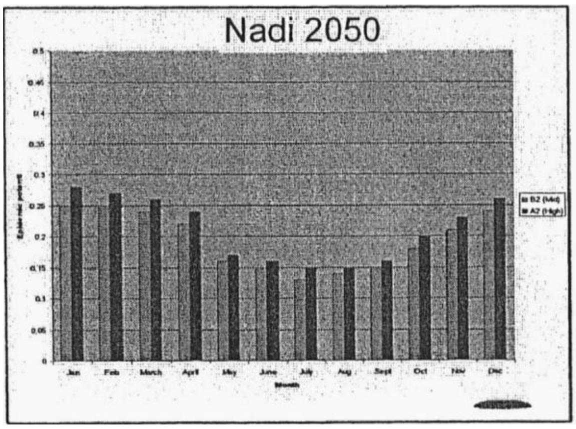
- **Epidemic potential (transmission efficiency)**
- **Changes for Nadi and *Suva (site* analysis)**
- **Spatial changes for Viti Levu**
- **Study scenarios**
  -2025, 2050 and 2100
  -SRES B2 Best Guess and SRES A2 High
  -CSIRO GCM pattern

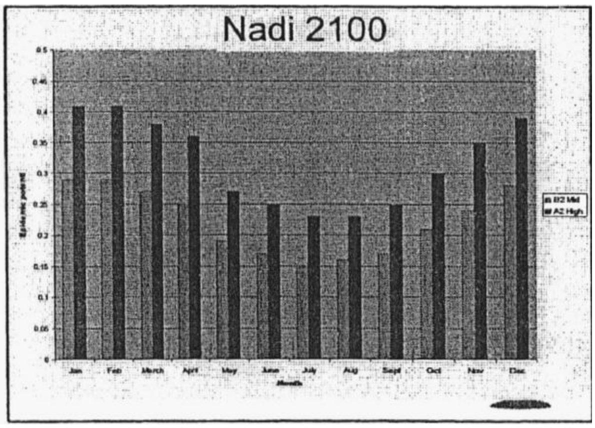
Results

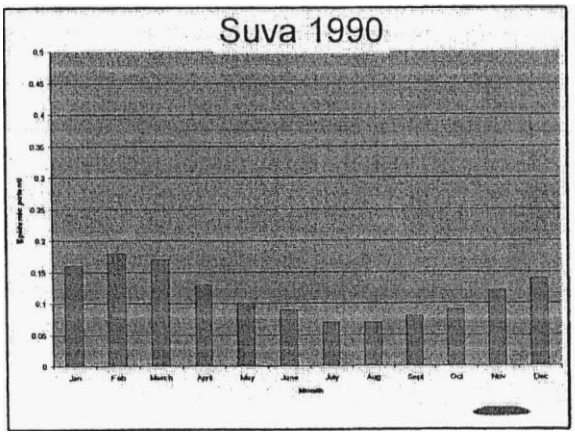
Site analysis

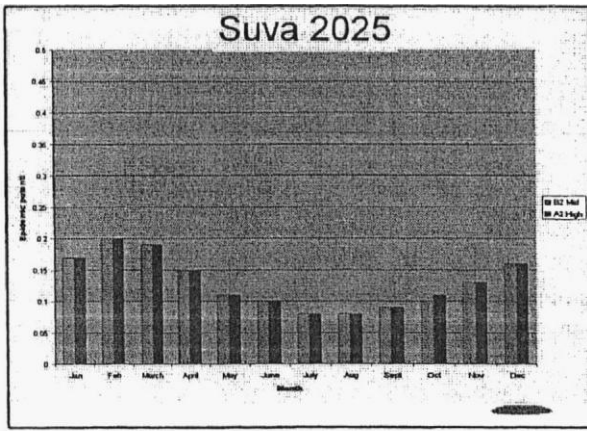

Nadi 1990
Epidemic potential
Month

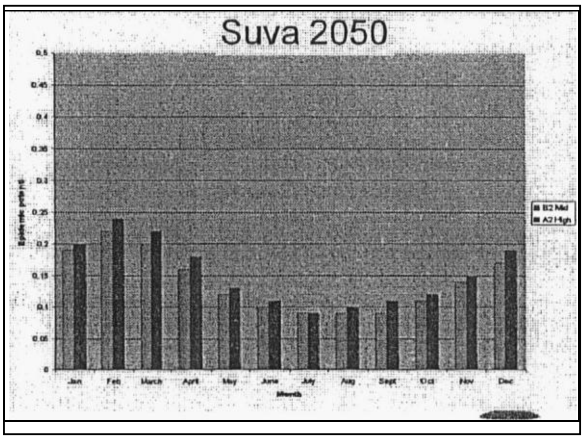

Nadi 2025
Epidemic potential
Month
B2 (Mid)
A2 (High)

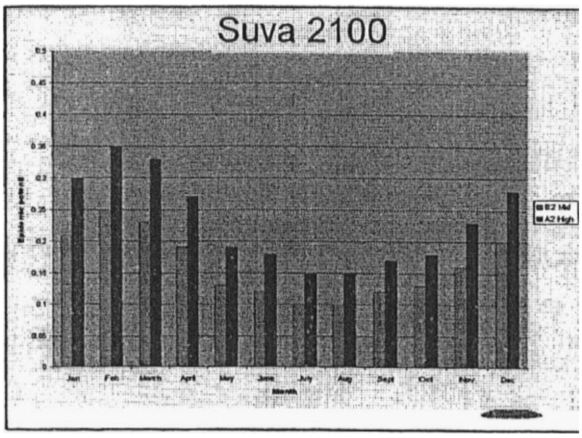

Nadi 2050
Epidemic potential
Month
B2 (Mid)
A2 (High)


Nadi 2100
Epidemic potential
Month
B2 Mid
A2 High

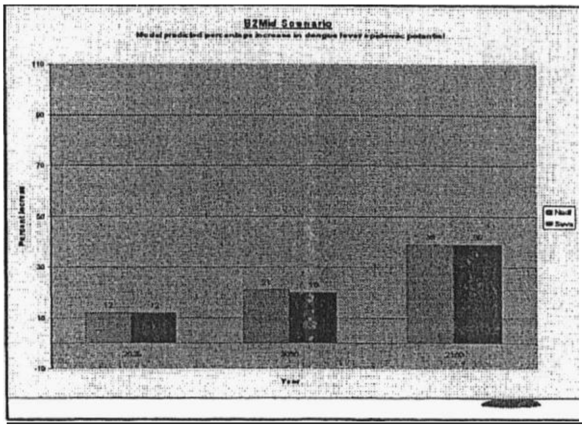

Suva 1990
Epidemic potential
Month

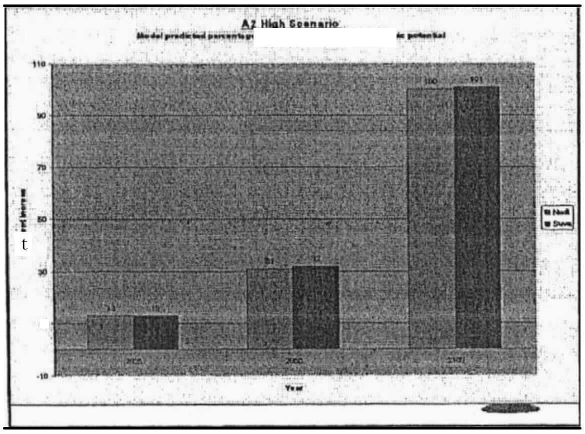

Suva 2025
Epidemic potential
Month
B2 Mid
A2 High



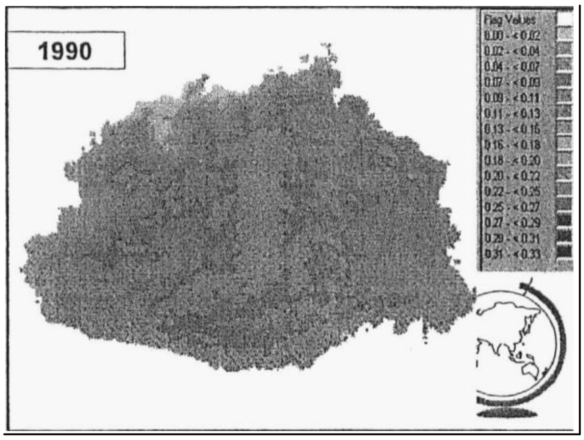


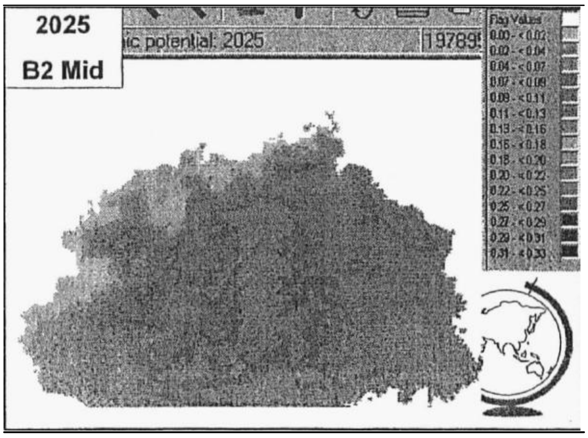
Percentage increase

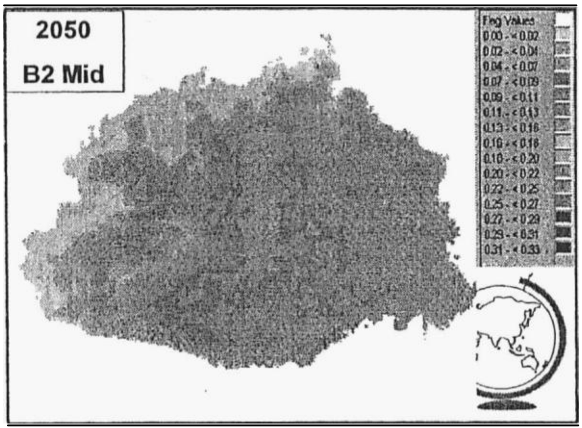


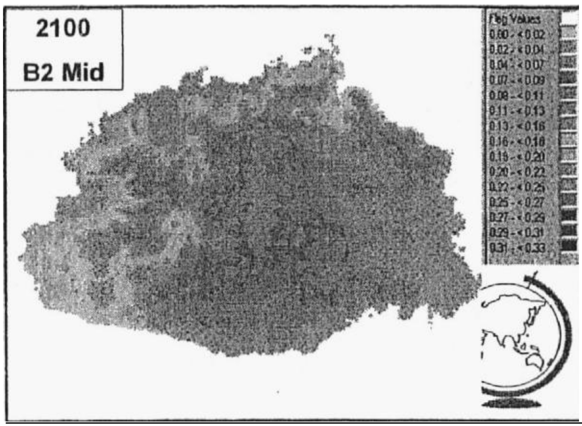


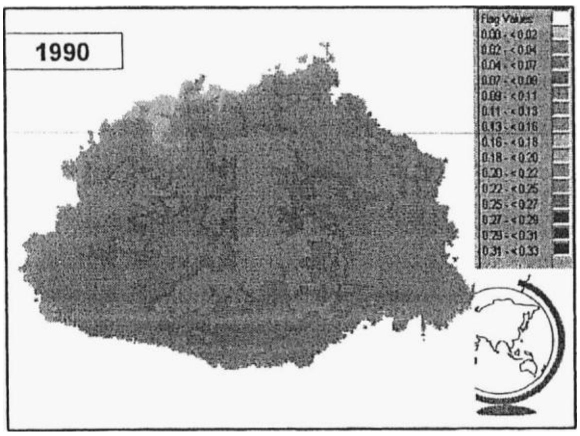
Spatial analysis

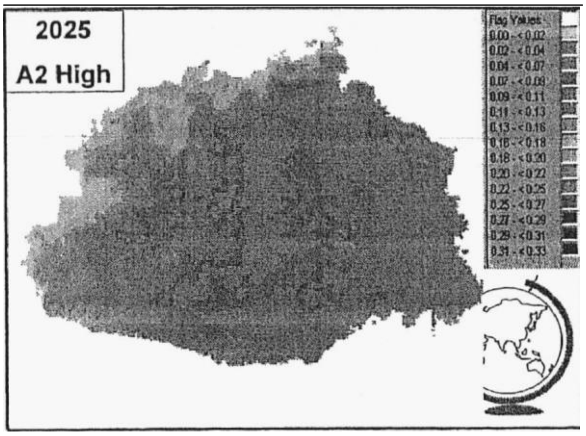

1990
Flag Values
0.00 - < 0.02
0.02 - < 0.04
0.04 - < 0.07
0.07 - < 0.09
0.09 - < 0.11
0.11 - < 0.13
0.13 - < 0.16
0.16 - < 0.18
0.18 - < 0.20
0.20 - < 0.22
0.22 - < 0.25
0.25 - < 0.27
0.27 - < 0.29
0.29 - < 0.31
0.31 - < 0.33

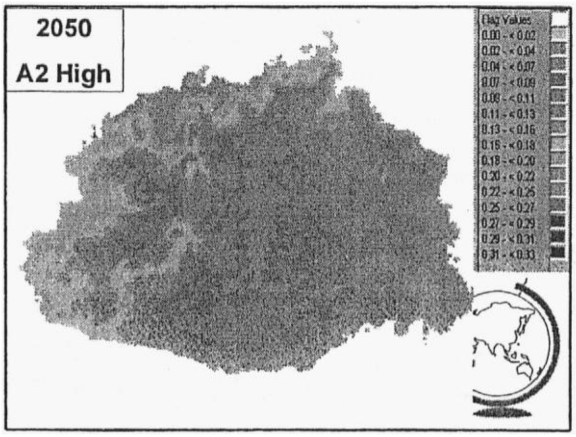

2025
B2 Mid
Flag Values


2050
B2 Mid
Flag Values


2100
B2 Mid
Flag Values


1990
Flag Values


2025
A2 High
Flag Values



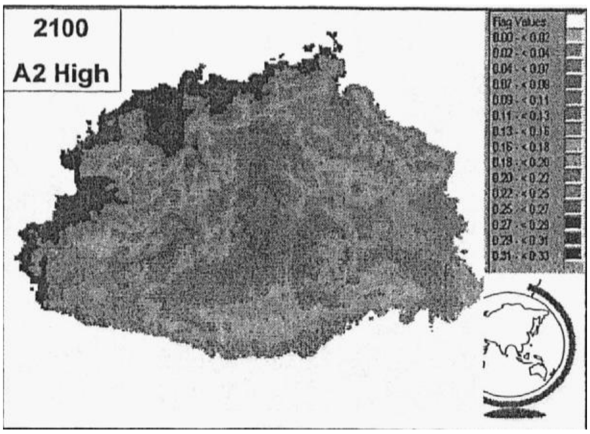
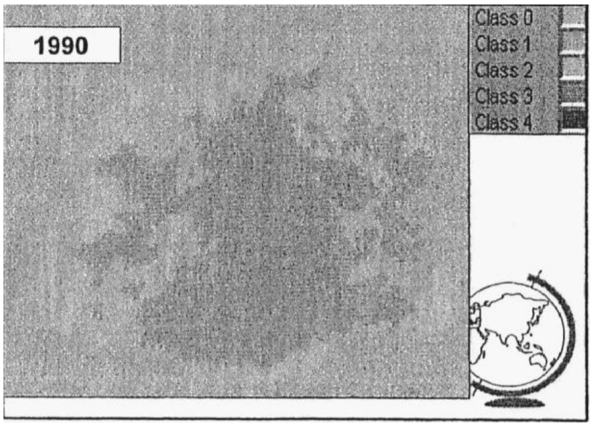
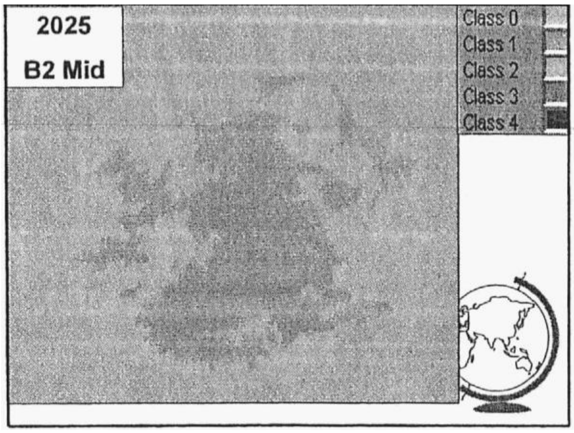
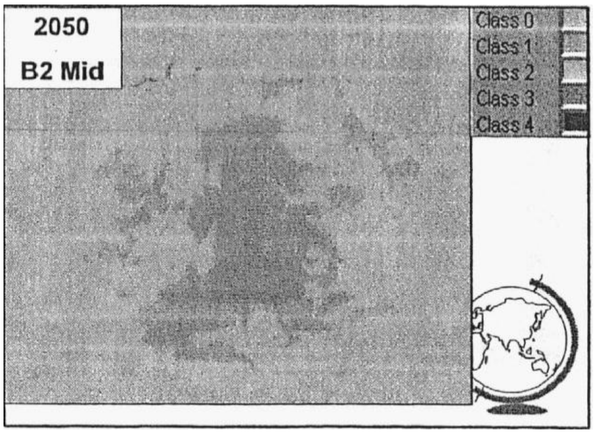


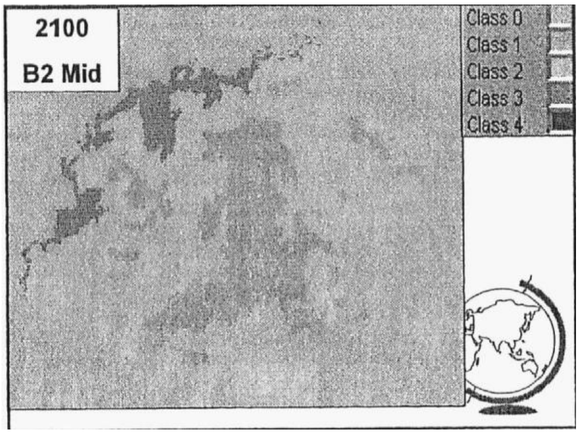
Table 7.4. Assigned risk categories based on model-predicted epidemic potential

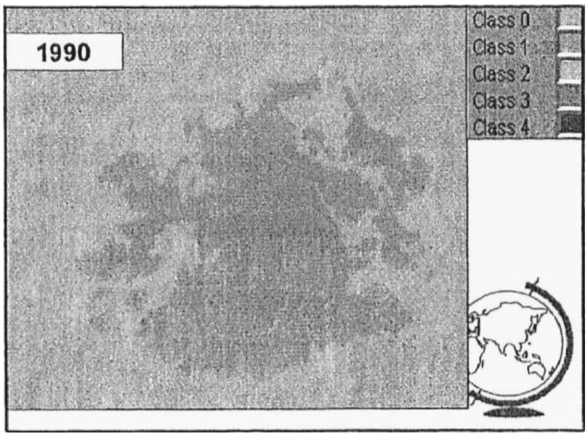
Category	Epidemic Potential	Category description
0	less than 0.01 (or not a land area)	No risk
1	0.01 to just less than 0.1	Low risk
2	0.1 to just less than 0.2	Moderate risk
3	0.2 to just less than 0.3	High risk
4	0.3 to 1.0	Extreme risk

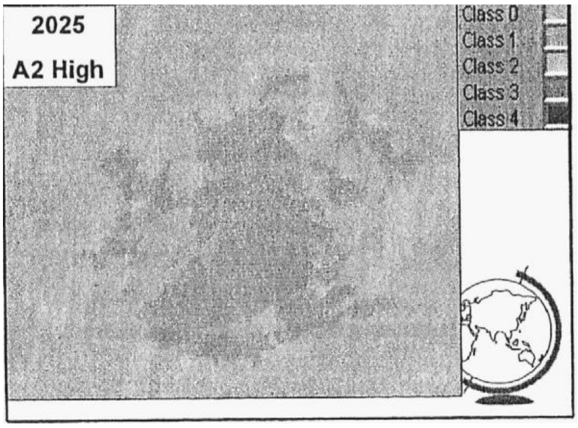


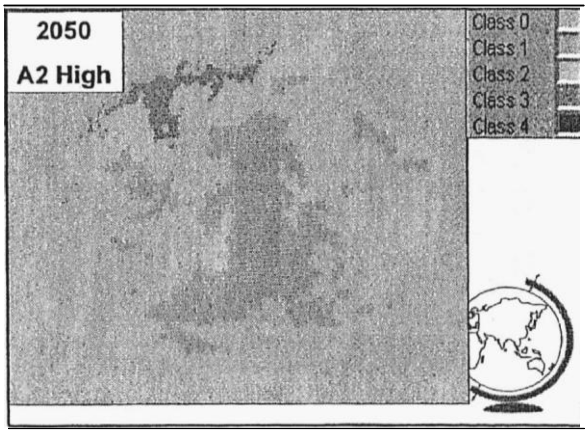


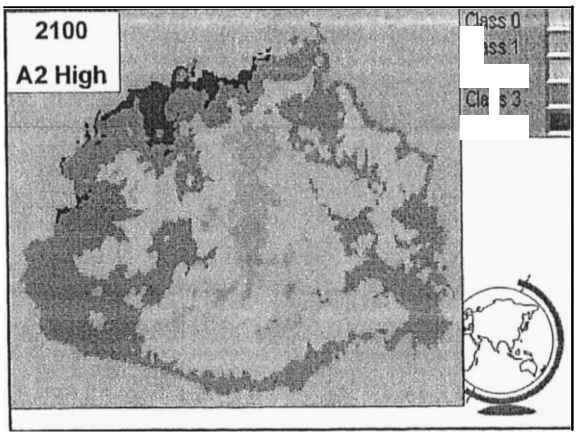


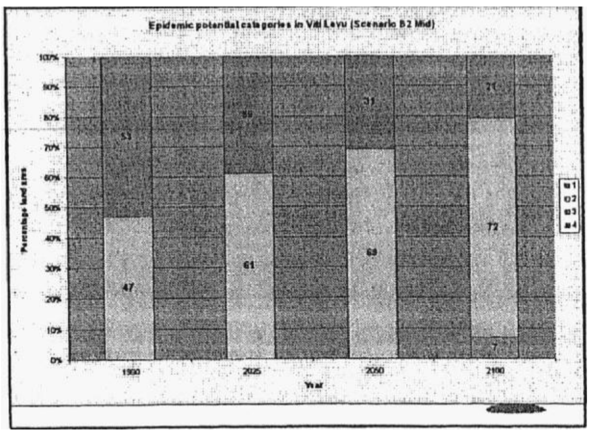

2100
B2 Mid
Class 0
Class 1
Class 2
Class 3
Class 4

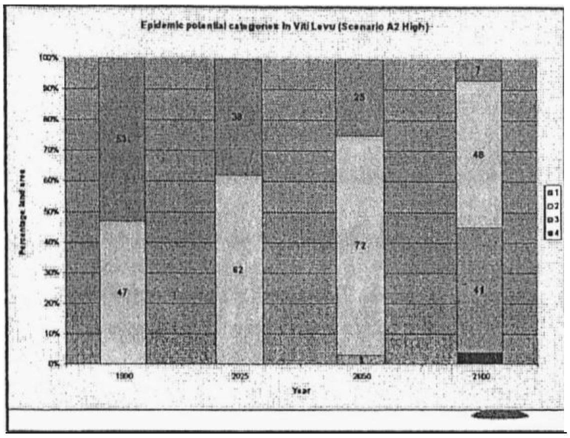

1990
Class 0
Class 1
Class 2
Class 3
Class 4


2025
A2 High
Class 0
Class 1
Class 2
Class 3
Class 4


2050
A2 High
Class 0
Class 1
Class 2
Class 3
Class 4


2100
A2 High
Class 0


Epidemic potential categories in Viti Levu (Scenario B2 Mid)
Percentage land area
Year
1990
2025
2050
2100
53
47
61
31
72
7

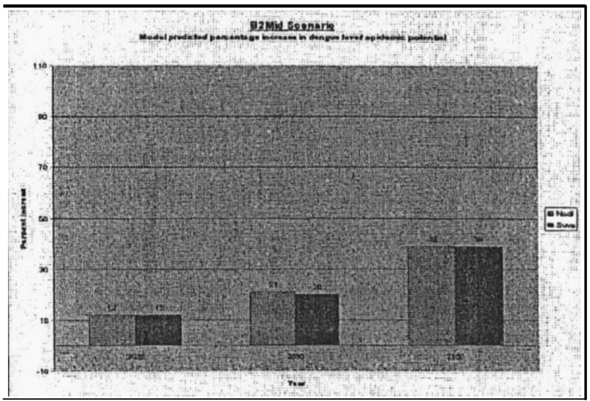


Increased epidemic potential

- **Only one component of risk**
- **Higher epidemic potential**
  - — epidemic will grow faster
  - —produce more cases
  - —require fewer vectors
- **Significance ?**

Possible changes

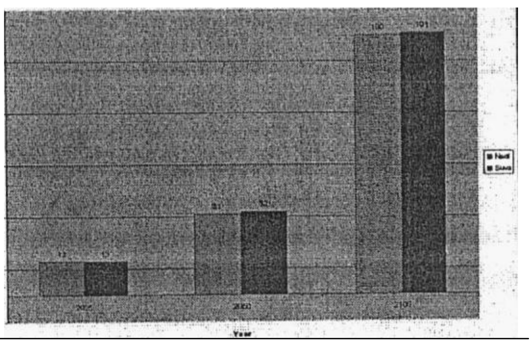
- **Frequency and seasonality of epidemics**
- **Size of epidemics**
- **Endemicity**
- **DI-IF / DSS incidence**
- **Spatial distribution**
- **Estimation of increased ca numbers**



.1111111111118--

A2 High Scenario

Model producted percentage increase in dengue level apldem potential



Diarrhoeal disease

- Variety of pathogens and pathways of exposure
- Water supply and sanitation

Table 7.3. Access to water

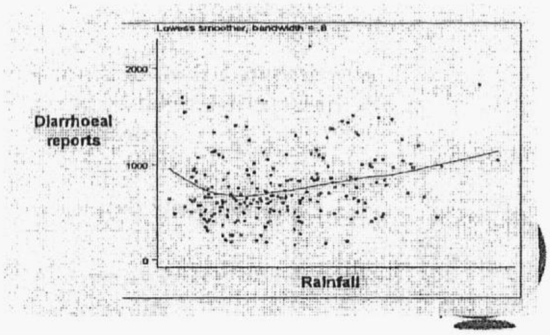
Percentage of population with access to safe water and sanitation (Fiji MoH, 1999*)	
Urban	90
Rural	80
Total	85

- Living Conditions

DD and Climate

- **Multi-factorial**
- **Possible climate** related pathways **of exposure**
  - — Flooding (sanitation, contamination, water quality)
  - — Drought (hygiene, sanitation, nutrition)
  - — Temperature(food spoilage, algal blooms)

Rainfall



Temperature

- Analysis using 1978 -1989 reports
- **Estimated increase of approx. 1000 diarrhoea' cases per degree of warming (based on current population of Fiji)**

Nutrition

- **Downstream impacts**
- **Analogue approach**

1997 / 1998 Drought

- **Protein-energy malnutrition**
- **Iron deficiency anaemia**
- **Vitamin A deficiency**
- **Groups at risk (high nutritional needs)**
  - — under 5 age group
  - — infants being weaned
  - — Pregnant women

Diffuse effects

- **Increased vulnerability**
  - — Poverty
  - — Landlessness
  - — Crowding
  - — Living conditions

Adaptation

Adaptation

- Impacts difficult to quantify - paradoxically more certainty about adaptation
- No regrets approach
- Addressing factors which increase vulnerability

Dengue

- Vector control (source reduction of breeding sites)
- Preventing exposure
- Epidemic preparedness and response
- Primary health care system
- Development trends and policies

Diarrhoeal diseases

- Improved water access and safety
- Improved sanitation
- Drought / flood / cyclone preparedness
- Primary health care
- Living conditions

Nutrition

- Agriculture
- Economy
- Home gardens
- Relief
- Identification of those at risk (PHC)

Diffuse effects?

Adaptation - Common themes

- **Water**
- **Nutrition**
- **Sanitation**
- **Living conditions and housin**
- **Waste disposal**
- **Primary health care**

Following a development trajectory which prioritises:

- Primary health care (rural and peri-urban areas)
- Enhancement of ecological and land productivity
- Adequate and healthy housing
- Safe and adequate water and sanitation
- Management of liquid and solid waste
- Employment and alleviation of poverty

5. Water Resources Sector

Contents

5.1 Overview of sector

Importance of Water

- maintaining physical sustenance
- maintaining socio-economic sustenance

Current water resource - derived mainly from surface water run-off

Focus of study: Viti Levu

West side - leeward, drier

East side - windward, wetter

5.2 Present climate, hydrology and vulnerability

5.2.1 Rainfall

Western side: 1500mm/yr - 2500mm/yr

Data for Nadi Airport and Lautoka presented.

30 year data of average annual rainfall(ram) from 1961-1990

5.2.2 Tropical cyclone

Tropical cyclones are a regular phenomena in Fiji

Cyclones occurring between 1961-1997 tabulated, with briefs on areas affected and damages sustained.

This include:

Hurricane	6.9 Feb,1965
Hurricane Bebe	23-29 Oct, 1972
Hurricane Betty	5-6 April, 1975
Hurricane Bob	4-5 Jan, 1978
Gale Wally	3-5 April, 1980
Hurricane Arthur	13-16 Jan, 1981
Hurricane Oscar	26 Feb-2 Mar, 1983
Hurricane Eric	14-19 Jan, 1985
Hurricane Nigel	16-20 Jan, 1985
Storm GAVIN	3-8 Mar, 1985
Hurricane BOLA	25 Feb-4 Mar, 1988

Storm RAE	- 16-25 Mar, 1990
Hurricane SINA	- 24-30 Nov, 1990
Hurricane JONI	- 6-13 Dec,1992
Hurricane K1NA	- 26 Dec, 1992-5 Jan, 93
Hurricane GAVIN	- 4-11 Mar, 1997
Gale JUNE	- 3-5 May, 1997

5.2.3 Tropical cyclone impacts - Case study of TC Gavin and TC June in 1997

Cyclone Gavin 4-11 March, 1997

- Developed away from -- Fiji-latitude 10°S
- large storm
- travelled quickly - average – 20 km/hr
- no erractic change in speed
- no erratic change in direction
- intensified to hurricane intensity (>63 knots)
- long lifespan – 7 days
- long track – left Fiji waters as a cyclone

Cyclone Gavin 3-5 May, 1997

developed close to latitude 13.5' S

- 'm idget' storm
- travelled slow lyaverage 13 km/hr
- showed erratic acceleration and deceleration
- Showed erratic changes in direction
- Remained mostly at gal intensity(34-47 knots)
- Short lifespan – 3 days
- Short track –decayed I Fiji waters

Features

Cyclone Gavin:

- higher rainfall total - due to longer lifespan
- northwest Viti Levu - most intense precipitation
- more serious flooding - prolonged storm duration
- more serious flooding - also due to stronger hurricane force winds against the shore retarding flood waters out of river estuaries.
- Notable discharge peaks for major rivers in Viti Levu
- Wainibuka and Wainimala rivers produced most of the runoff from the Rewa River catchment. The Waimanu and Waidina were on the leeward side of the cyclone track.

Features: Cyclone June

- developed outside normal cyclone season (Nov-April)
- never formed a visible eye - due to insufficiently favourable environment, e.g. sea temperature
- lower rainfall total - shorter lifespan -less flooding - shorter duration of storm
- most intense for Vanua Levu and Taveuni (Rainfall higher in Vanua Levu and Taveuni than Gavin)
- stream flood levels for Taveuni reported to be highest in living memory.

5.2.4 Tropical cyclones and floods in the Rewa basin

- Rewa river basin - largest in Fiji
- 15 out of 37 tropical cyclones (1970-98) caused overbank floods
- 'flashy' nature of flood hydrograph & rapid response of flow to ppt. is a function of storm intensity & hilly terrain. Ref. TC Kina -eye of the storm passed along northeast coast of Viti Levu.

5.2.5 ENSO and droughts

— Fiji suffered several droughts over recent decades 1978, 1983, 1987, 1992 and 1997-98

— Most recent is the worst drought in the last century

— Causes human suffering & economic hardship

— Most rural communities are reliant on rainwater, streams and shallow wells for domestic use - most vulnerable during these periods.

Climatic and topographic characteristics of Viti Levu: factors for significant drought hazard

(1) Topography

Predominance of south east trade winds and presence of central volcanic ranges results in the north and west being rainshadow areas.
(Lautoka receives only half the rainfall as Suva)

(2) Rainfall seasonality

Fiji's climate has a distinct wet-dry season

Leeward side receives only 20% of total annual rainfall, windward side receives 33%
Therefore rainfall seasonality more pronouced for the dry side of Viti Levu

(3) ENSO

— An inter-annual cycle of disturbance to the Walker atmospheric circulation.

— ENSO affects climatic variability in the Pacific.

— Non-ENSO (normal conditions) - Fiji receives average or above rainfall

— strongly (-) ENSO events (El Ninos) - rainfall failure & drought, associated with equatorward shift in the position of the SPCZ.

5.2.6 Case study of the 1997-98 ENSO and drought in Fiji

-Western Viti Levu recorded the lowest rainfall since records began 100 yrs ago.(1-in-100 year event - by some commentators)

-Rainfall failure across two successive dry seasons and during the intervening wet season.

-Rainfall failure due to the equator shift of the South Pacific Convergence Zone, as a result of strong (-) ENSO.

— Produced the lowest stream baseflows on record.(Though TC Freda & Gavin produced high rainfall in Jan & March, 1997)

— Stream discharge reflects (antecedent) ppt over the whole catctunent. A function of the physiographic, geological & hydrometeorological characteristics of the catchment.

— Two western stream flows case studies showed that stream flow is a better indicator than rainfall amount on the availability of water resources.(Teidamu creek-Lautoka & Nalcauvadra creek-Rakiraki)

— Future management of water resources - should consider effects of stream hydrological behaviour.

5.3 Effects of climate change

5.3.1 Climate change scenarios, floods, and hydrological droughts

Under present climatic conditions, Fiji is prone to two opposite extremes:

(I) river floods - mostly from high intensity & large rainfall during tropical cyclones; and

(2) water shortage due to low stream baseflows (hydrological drought), related to El Nino conditions.

ENSO strongly affects year to year rainfall patterns for Fiji, which influences the location of SPCZ.

-Current GCM models predicts a more El Nino like pattern on a regional basis.

-Thus future rainfall projections vary from:

-annual increases in rainfall - Southwest shill in SPCZ, to

-annual decreases in rainfall - Northeast shift in SPCZ

GCM scenarios

Two different GCM results presented due to uncertainties in future rainfall trends & patterns

The patterns of rainfall change are scaled by global temp. changes from mid & high-case greenhouse emission scenarios, used in the 1PCC assessment.

Predicted future 1-in-10 year max. & min stream flows for Teidamu & Nakauvadra creeks were generated using the PACCLIM water resources impact model.

CSIRO9M2 & DKRZ models were used for the assessment.

Table 5.8 Predicted future 1-in-10 year low and high daily flows for the Teidamu creek, north west Viti Levu

GCM	Emission scenario	[illegible]				[illegible]				[illegible]			
		Temp (°C)	Dprecip %	low flow* m³/s	high flow# m³/s	Temp (°C)	Dprecip %	low flow* m³/s	high flow# m³/s	Temp (°C)	Dprecip %	low flow* m³/s	high flow# m³/s
CSIRO9M2	B1(mid)	0.5	3.3	[illegible]	[illegible]	0.9	5.7	[illegible]	[illegible]	1.6	[illegible]	0.112	[illegible]
	A2(high)	0.6	3.7	[illegible]	[illegible]	1.3	[illegible]	[illegible]	[illegible]	3.3	[illegible]	[illegible]	[illegible]
DKRZ	B1(mid)	0.5	-3.1	[illegible]	[illegible]	[illegible]	-5.7	[illegible]	[illegible]	1.6	[illegible]	[illegible]	[illegible]
	A2(high)	0.6	-3.7	[illegible]	[illegible]	1.3	[illegible]	[illegible]	[illegible]	3.3	[illegible]	[illegible]	[illegible]

current high flow = 50.44 m³/s
current low flow = 0.102 m³/s based on 1981-1996 streamflow data

Table 5.9. Predicted future 1-in-10 year low and high daily flows for the Nalesavadra creek, north west Viti Levu

GCM	Emission scenario	2025				2050				2100			
		Temp (°C)	Precip %	low flow m^3/s	high flow m^3/s	Temp (°C)	Precip %	low flow m^3/s	high flow m^3/s	Temp (°C)	Precip %	low flow m^3/s	high flow m^3/s
CSIRO9M2	B2 (mid)	0.5	3.3	0.080	132.423	0.9	5.7	0.082	135.449	1.6	9.7	0.085	141.627
	A2 (high)	0.6	3.7	0.080	132.986	1.3	8.2	0.084	138.704	3.3	20.3	[illegible]	154.215
DKRZ	B2 (mid)	0.5	-3.3	0.084	121.972	0.9	-5.7	0.082	120.885	1.6	-9.7	0.078	115.738
	A2 (high)	0.6	-3.7	0.084	121.449	1.3	-8.2	[illegible]	[illegible]	3.3	-20.3	[illegible]	[illegible]

current high flow = 128.192 m^3/s
current low flow = 0.087 m^3/s, based on 1979-1996 stream flow data

5.3.2 Maximum flows - flood potential

CSIRO9M2 model projected an increase of up to 10% by 2050 and 20% by 2100

Due to similar climate, topography, geology and landuse in the west of Viti Levu, possibility of transferring such results to the Nadi & Ba rivers.

Therefore increase of 10-20% flood volume due to climate change needs to be addressed, particularly if channel aggradation continues as a result of sediment delivery from current intensive sugarcane land use.

5.3.3 Minimum flows - water shortage potential

The DKRZ model suggested a decrease of up to 10% by 2050 and 20% by 2100 in low flows for both catchments.

- For small streams water resource may become significantly scarce within 50 years.
- For larger rivers- salt intntsion, due to low flows may become a problem, especially to agricultural production.

Difficult to determine which projection to apply.Therefore, best approach is to adopt the worst combination of change, i.e. both increased flood & hydrological drought magnitude.

5.4 Meeting future water demand-case study Lautoka-Nadi area

Study: broad scale nature to indicate estimate of possible impacts rather than in-depth analysis.

Sources: Vaturu Dam - 45ML/day

Lautoka (3 sources) - 14.5ML/day

Combined sustainable yield: 98ML/day (1996 PNG Consultant report - 1 to 10 yr drought.

NLRWS: covers some of the driest region of Fiji & major tourist developments & infrastructure.

5.4.3 Population and water consumption

1995 Supply information

14ML/d -Nadi area

I9ML/d - Lautoka area

13ML/d - leakage & unauthorised connections

i.e. 29%

Total pop. served: 123,000

Capita demand: 330L/d(1996)(ref.1998 JICA Wished Report) (Commercial & domestic sectors not differentiated)

5.4.4 Future projections of water demand for Lautoka-Nadi case study

Conservative estimates used for projections

Pop.growth rate: national average

Per capita demand: 300L/d

Losses: 25%

Analysis: (based on 98ML/d safe yield)

Demand exceeds supply in 2051 & 2041, for mid & high-range pop. growth scenarios respectively.

Demand would not exceed potential supply for low growth pop. scenario.

Approximation of projected sustainable yield of NLRWS

-Effects of CC-relatively insignificant in the year 2025, but contribute to shortages by 2050.

-Low pop. Scenario- CC not significant except high scenario for 2100.

-Current amount of water loss (estimated at 29%) is greater than potential changes in sustainable yield attributed to CC-even for the most extreme scenario.

5.5 Adaptation

Summary of options for mitigation of floods & droughts on Viti Levu

•Structural measures

-Catchment management (holistic approach)

Catchment management-more appropriate for Viti Levu, *as* it is compatible with adaptation measures deemed appropriate in the other sectors addressed.

5.5.1 Direct hazard mitigation

Flood control
Structural control measures are:
-diversion channels
-weir and retarding basin
-cut-off channel and retarding basin
-flood control dam
River improvement -a) river channel widening
b) dike construction
e) river bed excavation

Flood control dams-most beneficial option: used for both water storage to alleviate droughts & also controls floods.

Drought alleviation

I. Water resources management: improve overall management of supply and reduce unnecessary losses such as leakages.(ultimate target for maximum losses for Nadi-Lautoka area should be 5%)

2, Water legislation - review of current laws to addressed current water management issues and possible impacts on the sector by climate change.

3. Development of alternative water resources.

Government to commit to further development of ground water *as* an alternative source to relieve pressure on surface supply during droughts.

4. Consumer payment - raise price to alleviate the high rate of abuse and misuse across the community.

5.5.2 Catchment management

1. Maintaining & improving the water retention & storage function of watersheds by:

-increasing (natural) forest area; -regulating land development;

-protecting land uses that retard flow, e.g. natural wetlands; and

-maintaining river flow capacity, e.g. through soil conservation to prevent siltation.

2. Reducing the flood damage potential by:

–limiting development & urbanisation in low-lying flood-prone areas; and

-promoting flood-proof house design where necessary.--

3. Improving social infrastructure & resilience through:

- education programmes to raise community awareness of land & water conservation;
- better forecasting & communication of impending flood & drought hazards; and,
- continued support of existing disaster reduction programmes.

5.5.3 Institutional development facilitating adaptation

Catchment Authorities

Promotes institutional development & devolution of policy and decision-making to a regional level.

e.g Ba Catchment Authority

Water Authority

Currently water management is divided between different Government departments.

Establish a single "Water authority" with divisions for hydrology (river monitoring) and engineering (control structures, irrigation and drainage) and supply.

Economic Implications of Climate Change in Two Pacific Island Country Locations

Case Illustration for Viti Levu, Fiji

Dr. Robert S. Raucher
Stratus Consulting Inc.
Boulder, Colorado, USA
March 2000

Overview

- Background on Study
  - Sponsorship
  - Objectives
- Sector-by-Sector Review
  - Physical impacts from V&A
  - Economic valuation
  - Strengths, limitations, and implications
- Implications and Next Steps

Study Background

- Sponsored by World Bank
  - Part of Regional Economic Review (RER) for 2000
  - One of two integrated efforts funded by the Bank: Physical impacts (V&A) update, plus our economics report
- Relied on Extensive Cooperation and Assistance by Fijian Country Studies Team
  - Providing the foundation of knowledge and insight
  - Accommodating the World Bank's ambitious schedule

RER Implications

- Good Intentions
  - Raise climate issues before national leaders in economics and finance
  - Intended target audience broader and more varied than typical for climate issues
  - Need to portray issues in economic and policy-relevant context

RER Implications (cont.)

- Unfortunate Limitations
  - Insufficient time or budget (for all parties involved)
  - Excessive expectations (especially given limitations in data and knowledge, need to work more closely with in-country professionals, needs and sensitivities)

Objectives of Economics Report

- Estimate Potential Economic Damages from Changing Climate
  - Built upon climate change, physical impacts, and adaptation scenarios developed in V&A report
  - Provide sector-by-sector evaluation of damages (costs of climate change)
  - Examine adaptation benefits (avoided damages) and costs

Objectives of Economics Report (cont.)

- Economic Output Useful for
  - Understanding the $ magnitude of climate Implications
  - Inform and guide sectoral policies and general economic planning priorities(e. g. for adaptation, contingencies)

Water Resources Sector (and extreme events)

- Models Predict Either Increase or Decrease in Annual Average Precipitation
  - Decrease implies more drought-like situations
  - Increase may be beneficial or damaging (intensity versus annual average
  - Increased rainfall intensity may be most important feature (damaging)

Water Resources Sector (and extreme events) (cont.)

- The Drought of 1997/1998 as an Illustration
  - Total accounting of damages: over F$300 million
  - What if this became a 1 in 5 or 1 in 20 year event?

Insert slide 1 of suvaport.ppt

Water Resources

- Other Impacts of Potentially Lower Annual Precipitation (nonextreme events)
  - Urban water supplies inadequate to meet demand
  - NLRWS supply deficit doubled in 2100 (but still less than 29% unaccounted for water)
  - Lower water quality, and associated potential health impacts
  - Potential agricultural, tourism, and other impacts

Water Resources (cont.)

- Flooding: Cyclone Events May Be More (or less) Severe
  - Flooding damages in coastal areas (average F$44 million over 8 recent events)
  - Flooding-related deaths and injuries
- Other Cyclone-Related Damages
  - Sedimentation (F$1 million per year for Rewa River)
  - Wind damages, and elevated sea levels/storm surge

Water Resources (cont.)

- Impacts from Increased Precipitation and Intensity (nonextreme)
  - Reduced agricultural yields (dab)
  - Hydrological short-circuiting
- Climate Change Impacts (c. 2050)
  - 20% change in cyclone damages (+ or-)
  - El Nino-droughts (1998 event return period of 20 years)

Water Resources(cont.)

Adaptations

- Water diversion projects (structural, benefits only under wet scenario)
- Water storage and diversion (structural, benefits for either wet or dry)
- Leak detection and repair for public water supplies
- Rainwater collection systems
- Afforestation, upland conservation, and land management (multiple benefits)

Coastal Resources

- Mangroves and Coral Reefs Provide Many Valuable Goods and Services
  - Many are nonmarket, but still quite valuable
  - Climate change may reduce quantity and/or quality of their resources
  - Damage estimates based on assumed levels of mangrove and reef loss
- Infrastructure and Other Resources
  - Population and infrastructure concentrated in coastal lands
  - Potential damages from sea level rise, storm surge

Insert slides 2-4 from suvaport.ppt

Agricultural Resources

- Sugarcane
  - Dominant sector
  - Vulnerable to climate (especially drought) and world markets (pricing)

Agricultural Resources (cont.)

- V&A Approach for Sugarcane (absent reliable applicable model)
  - 47% of years have 1990 level production (4 million tonnes)
  - 33% with 50% yield reduction ('98 drought with 3 year return period)
  - 20% with 25% yield reduction (cyclones, drought residuals)

Agricultural Resources (cont.)

- Root Crops
  - Crop-specific response to alternative precipitation projections
  - Dalo declines in drier scenarios; improves in wetter scenarios
  - Yams show reverse of dalo trends (better in drier scenario)
  - Cassava reduced in either precipitation context
- On Net, Root Crops Show Decline in Value of Output Regardless of the Climate Change Scenario Applied

exhibit 7-5, exhibit 7-7

- (slides 5-6 of suvaport.ppt.)

Agricultural Resources (cont.)

- Macroeconomic Consequences
  - CGE model of Fijian economy, Ministry of National Planning
    - Model runs and analysis kindly provided by Mrs. Radrodro, Senior Economic Planning Officer
  - Results for various sugarcane scenarios show modest macro-level impacts

Agricultural Resources (cont.)

- CGE-Type Models May Understate Sectoral Disruptions
  - May miss transition period dislocation costs (moving labor and capital resources across sectors to find new employment)

exhibits 7-6; 7-8

- (slides 7-8 of suvaport.ppt.)

Public Health

- Extreme Climate Events
  - Cyclone-related fatalities: increase or decrease 1 to 2 cases per year, on average
  - Fatalities avoided valued using "Value of a Statistical Life" concept (VSL)
  - Adds F$5 to F$10 million to cyclone damage change estimates

Public Health (cont.)

- Issues with Using VSL Estimates
  - NOT the "value of a life — it is the value of small changes in risk
  - Observed values for people choosing whether to accept various risks
  - Based on data for US and UK, converted to Fijian economic context

Public Health (cont.)

- Dengue Fever Outbreaks
  - Currently, every 3.75 to 10 years
  - Increased epidemic frequency: 20% and 40% in V&A Report (for 2050, and 2100, respectively)
- Valuation
  - Method 1: Medical costs plus lost productivity (adjusted Cuban estimate) plus increased fatality risk, based on 1998 outbreak
  - Method 2: Bottom up approach with lost productivity, medical costs, restricted activity day (RAD) values, and fatality risk

insert 8-8

- (insert slide 9 of suvaport.ppt.)

exhibit 9-1 (updated) and 9-2

- slides 10-11 of suvaport.ppt

Major Drought-Related Damages and Expenditures for the Drought of 1997-1998, Fiji (F$ 1998 * 1000)

Item	Cost
Sugarcane crop losses	$125,000
Sugarcane crop rehabilitation programme	$43,700
Food and water rations	$33,000[a]
Weaning foods	$3,600[b]
Food crop losses	$15,000[c]
Crop re-establishment needs	$410
Welfare payments & lost income	$75,000[d]
School children funding	$625[e]
School water tanks and gardens	$1,500
Draft animals grass-starved	$2,400[f]
Milk production decline (50%)	$10,890[g]
Farm drains and creeks	$260[h]
Irrigation to re-establish sugarcane	$40
Boreholes for water supply	$630[i]
Commercial forest	$80[j]
Health and nutrition	$1,800[k]
Macro impacts	+[l]
Fire damage (up to 10% of forest areas)	+
Tourism	+
Total	**F$313,935+**

a. Ten months at $3.3 million per month.
b. F$360,000 per month times 10 months.
c. Estimate of revenue losses from failed new plantings, by Director of Ag Extension.
d. F$2,000 per family times 15,000 farm families, covering 6 months of recovery, prorated to also include 9 months of zero income.
e. 10,000 children missed school because of hardship. F$500K was fundraising target to reach 8,000 still in need.
f. Molasses block feeding program to restore work animals to work condition.
g. F$39,600 loss per day, for 275 days (75% of a year).
h. One year of 2 year grant program to clean up drains.
i. 675 families served by boreholes, at F$937 per family.
j. Re-establish dead plants only, only for mahogany plantation.
k. Foreign aid food assistance received.
l. Budget deficit of 2.4% GDP; negative GDP growth of 4.0% rather than anticipated 3.0% positive growth. Cost to government is 30% of budget (or 3 times the revenue loss).

Source: UNDAC, 1998, supplemented with original analysis.

Major Drought-Related Damages and Expenditures for the Drought of 1997-1998, Fiji
(F$ 1998 * 1000)

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Source: UNDAC, 1998, supplemented with original analysis.

Summary of Coastal Resource Values for Viti Levu and Potential Impacts from Climate Change			
Category	**Good or Service**	**Annual Values (millions of 1998 F$)**	**Estimated Annual Damages from Climate Change (millions of 1998 F$)**
Mangroves	Subsistence fisheries	19.9-29.8	1.9-6
	Commercial fisheries	18.8-28.2	1.8-5.6
	Recreation	14.5-46.2	1.5-2.9
	Medicinal plants	30-45	3-9
	Habitat	7.2	.7-1.4
	Raw materials	8.2	.8-1.6
	Coastal protection	68.1-86.2	6.8-13.6
	Biodiversity (other than medicinal plants)	+	+
	Nonuse (existence and bequest) values	+	+
	Ornamental fish	+	+
	Fuelwood	+	+
	Nonwood products	+	+
	Importance to marine ecosystems	+	+
	Importance to marine recreation	+	+
	Importance to inland groundwater	+	+
Coral Reefs	Subsistence fisheries	7.4	.7-3
	Commercial fisheries	7	.7-2.8
	Recreational fishing	8.3	.8-3.3
	Tourism	188	18.8-75.2
	Habitat	9.3	.9-3.7
	Coastal protection	206.5-638	20.7-255.2
	Ornamental fish		
	Biodiversity	+	+
	Nonuse values	+	+
Infrastructure	Road maintenance costs	na	.6
	Other maintenance and repair costs increases	na	+
Seagrasses	Habitat for fisheries	+	+
	Other seagrass services	+	+
Total		**> 593.2-1108.8**	**>59.7-383.9**

Omissions, Biases, and Uncertainties and Their Effect on the Estimates of Climate Change Damages to Viti Levu		
Impact	**Likely Impact on Damage Estimate[a]**	**Comment**
Mangroves fuelwood omitted from estimates	+	Local gathering of deadwood for fuel from mangrove areas may be of significant value to local residents.
Nonwood products from mangroves	+	Nonwood products omitted from this analysis may provide appreciable subsistence, cultural, or commercial values to local users.
Mangrove effects to marine ecosystems	+	Reducing sedimentation and maintaining habitat for marine species enhances biodiversity and ecologic health.
Mangrove effects to marine recreation	+	Reduced sedimentation of coral reefs and seagrasses increases current and potential future recreational uses of the coastal area.
Mangrove effects to inland groundwater use	+	Protecting groundwater from salinization preserves these freshwater supplies for current and potential future uses for domestic, agricultural, and/or industrial purposes.
Biodiversity (other than medicinal plants)	+	Apart from local use of medicinal plants, no values are assigned in this analysis to other use or nonuse motives associated with maintaining biodiversity in mangrove and coral reef areas.
Nonuse (existence, bequest, and intrinsic) values	+	Preservation of coastal mangroves and coral reefs, and associated protection of marine, mangrove and reef ecosystems, is likely to generate existence, bequest, and intrinsic values.
Aquarium and curio trade	+	Income from sales and export of ornamental fish and curio were not estimated.
Infrastructure maintenance, repair, and replacement costs	+	These public and private costs are likely to increase because of sea level rise and increased occurrence of storm surges and tsunamis.
Loss of seagrasses	+	Climate change-induced loss of seagrasses and their services were not estimated.
Research value	+	It is difficult to value the benefits of gaining academic knowledge through mangrove and reef research. Biomedical research can increase the range of commercial products available and helps in combating disease, and research on corals can be used for environmental and climate change monitoring (Spurgeon, 1992).
Educational value	+	Social and financial benefits are experienced: financial benefits arise through education programme expenditures. These can be valued, but are possibly accounted for when valuing tourism and research revenues.

Omissions, Biases, and Uncertainties and Their Effect on the Estimates of Climate Change Damages to Viti Levu (cont.)

Impact	Likely Impact on Damage Estimate[a]	Comment
Social value	+	Local communities living nearby and utilizing reefs and mangroves gain additional esoteric benefits. These include cultural and heritage values which represent the benefit to communities of traditions and customs which have evolved based on associations with reefs and mangroves (Spurgeon, 1992).
Reef value for coastal zone extensions	+	The third United Nations Convention on the Law of the Sea (UNCLOS III, 1982) gives rise to a new, potentially massive value for some coral reefs. The law specifies several different types of coastal zone, including Exclusive Economic Zones, Territorial Waters and Archipelagic Waters, over which coastal states have certain rights concerning resource use. Baselines may be drawn from fringing reefs around islands, and thus can be responsible for significant economic benefits (Spurgeon, 1992).
Coral. mining	-	Income from coral extraction for use as aggregate is not included. Sustainable use is not typical, so foregone income stream is limited.
Navigational costs	-	Indirect costs related to navigation around reefs will decrease with reef loss.
Coral coastal protection services	U/+	This analysis does not apply higher $/ha estimates that are available in the literature.
Subsistence fishing	U	It is unknown whether the available 1983 estimates are reflective of current levels or values of subsistence fishing.
Mangrove-related fishing	U	It is uncertain if current fisheries in Fiji are 40-60% dependent upon their mangroves. Mangroves may support more or less than this range.
Mangrove losses assumed at 10% to 20%	U	Absent alternative scientific information, the assumed climate change scenarios will entail mangrove losses between 10 and 20%. This range is given for illustrative purposes. If climate causes mangrove losses of 40%, damages of F$50 million annually would occur in addition to the stated losses associated with a 20% loss of mangroves.
Coral reef losses assumed at 10% to 40%	U	It is uncertain whether the assumed climate change scenarios will entail coral reef losses between 10 and 40%. This range is given for illustrative purposes, and further research is necessary.

[a] Direction and magnitude of effect on damages from climate change:
+ = likely to increase losses, if factor were included in the monetized analysis
- = likely to decrease losses.
U = uncertain, could be + or - .

Summary of Estimated Acreage Suitability Changes for Fijian Root Crops under Climate Change

Scenarios[a]	Yield Class	Share of Cropping Area		
		Dalo (taro)	Yam	Cassava
Base(1990)	10-15 t/ha	32%	48%	19%
	5-10 t/ha	46%	35%	74%
	0-5 t/ha	22%	17%	7%
	w.avg t/ha[b]	8.0	9.0	8.1
	value(1000s F$)°	F$2,000	F$3,900	F$5,200
		Absolute Change from Baseline in 2100		
1	10-15 t/ha	0%	-3%	-12%
	5-10 t/ha	+4%	-3%	+3%
	0-5 t/ha	-4%	+6%	+9%
	w.avg t/ha	82	8.6	7.1
	% change	+2.5%	-4.4%	-12.3%
	change in value (1000s F$)	+F$50	-F$172	-F$640
2	10-15 t/ha	-4%	-6%	-18%
	5-10 t/ha	+9%	-9%	-10%
	0-5 t/ha	-5%	+15%	+28%
	w.avg t/ha	8.1	8.0	5.8
	% change	+1.2%	-11%	-28%
	change in value (1000s F$)	+F$24	. -F$429	-F$1,460
3	10-15 t/ha	-4%	+3%	-13%
	5-10 t/ha	-1%	+3%	+8%
	0-5 t/ha	+5%	-6%	+5%
	w.avg t/ha	7.6	9.5	7.2
	% change	-5%	+5.5%	-11%
	change in value (1000s F$)	-F$100	+F$215	-F$572
4	10-15 t/ha	-18%	-1%	-17%
	5-10 t/ha	+3%	+9%	+2%
	0-5 t/ha	+15%	-8%	+15%
	w.avg t/ha	6.3	9.4	6.5
	% change	-21%	+4.4%	-20%
	change in value (1000s F$)	-F$420	+F$172	-F$1,040

a. Scenarios for 2100:
   Warmer wetter
   1: CSIRO9M2 GCM and the B2 (mid) emissions scenario; +1.6°C +9.7%P.
   2: CSIRO9M2 GCM and the A2 (high) emissions scenario; +3.3°C +20.3%P.
   Warmer drier
   3: DKRZ GCM and the B2 (mid) emissions scenario; +1.6°C -9.7%P.
   4: DKRZ GCM and the A2 (high) emissions scenario. +3.3°C -20.3%P.

b. Weighted average yields are based on assuming midpoints of the yield class (e.g., 10-15 t/ha as 12.5 t/ha) weighting by share of land in each class.

c. Value of production numbers are based on FAOSTAT data as shown in Exhibit 7-1.

Summary of the Value of Agricultural Impacts by Crop and Scenario (F$1000s)

	Scenario'				
	A[b]	1	2	3	4
sugarcane	-48,100				
Dalo		+50	+24.	-100	-420
Yam		-172	-429	+215	+172
Cassava		-640	-1,460	-572	-1,040
Totals: Not including sugarcane Including sugarcane[c]		-762 -48,862	-1,865 -49,965	-457 -48,557	-1,288 -49,388

a. Scenarios for 2100

Warmer wetter

1: CSIRO9M2 GCM and the B2 (mid) emissions "scenario; +1.6°C +9.7%P.

2: CSIRO9M2 GCM and the A2 (high) emissions scenario; 4-3.3°C +20.3%P.

Warmer drier

3: DKRZ GCM and the B2 (mid) emissions scenario; +1.6°C —9.7%P.

4: DKRZ GCM and the A2 (high) emissions scenario. +3.3°C -20.3%P.

b. Scenario A, the sugarcane scenario, is based the following assumptions: 47% of years with expected production of four million tonnes, 33% of years with half of expected production, and 20% of years with three-quarters of expected production (due to effects of cyclones and residual effects of drought periods).

c. The totals with sugarcane assume that the average sugarcane losses occur in each of the alternative climate scenarios given for the root crops, as no data were available to estimate separate temperature and precipitation sensitivities for sugarcane.

Simulation Results - Pessimistic and Optimistic Scenarios for Sugarcane Production - Using 1997 Datasets

Variables	Pessimistic Scenarios: Using 1997 World Prices			Optimistic Scenarios:		Multiple Scenarios
	10% Reduction $million	20% Reduction $million	30% Reduction $million	5% Increase $million	10% Increase $million	20% Reduction 10% Decline in World Prices
1. Private savings	-2.027	-4.474	-7.055	0.768	1.354	-10.671
2. Private Consumption Expenditure	-12.573	-27.747	-43.755	4.765	8.393	-66.178
3. Total Government Transfers	-0.062	-0.143	-0.23	0.021	0.035	-0.344
4 . Net Capital Inflows	1.648	3.569	5.623	-0.691	-1.297	12,262
5. Net Private receipts of investment income from abroad	0.745	1.327	1.802	-0.419	-0.839	2.89
6 . Total Government tax revenue	-4.030	-8.556	-13.192	1.700	3.155	-18.380
7 . Total Government consumption expenditure	-3.497	-7.460	-11.496	1.435	2.614	-13043
8. Total Government investment expenditure	-0.361	-0.787	-1.228	0.141	0.252	-1.498
9 . Total Government savings	-0.107	-0.164 .	-0.236	0.102	0.253	-3.493
1 0 . Total imports in domestic currency	-4.478	-9.677	-15.082	1.802	, 3.266	-19.396
11. Total exports in domestic currency	-7.081	-15.048	-23.261	2.982	5.515	-35:402
1 2 . Private investment expenditure	-0.487	-1.070	-1.668	0.180	0.310	-1.902
13. Consumer Price index						
1 4 . Aggregate demand for iriformal unskilled labor	-0.136	-0.023	0.206	0.202	0.504	0.726
15. Private Disposable income	-14.538	-32.078	-50.58	5.512	9.713	-76.504
16. Income Tax revenue	-1.142	-2.407	-3.677	0.482	0.888	-3.831
17. Company Tax revenue	-0.751	-1.502	-2.245	0.376	0.754	-4.485
18. Production Tax revenue	-0.338	-0.738	-1.157	0.134	0.242	-1.73
19. Tariff revenue	-0.506	-1.087	-1.689	0.207	0.378	-2.059
20. Vat revenue	-1.019	-2.228	-3.492	0.395	0.703	-4.909
21. GDP	-19.522	-42.437	-66.327	7.703	13.819	-98.628
2 2 . Real GDP	-0.005%	-0.009%	-0.013%	0.003%	0.005%	-0.011%
2 3 . Nominal Consumption check	-12.569	-27.731	-43.716	4.765	8.396	-66.095
2 4 . Real Consumption	0.003%	-0.007%	-0.011%	0.001%	0.002%	-0.017%
2 5 . National Welfare	-18.777	-41.109	-64.524	7.283	12.979	-95.737
2 6 . Real National Welfare	-0.003%	-0.006%	-0.010%	0.001%	0.002%	-0.015%

Omissions, Biases, and Uncertainties		
Element	**Direction of Bias**	Comment
Sugarcane Production	?	Absence of data on yield changes for sugarcane under climate change is a significant uncertainty in the assessment. The magnitude and the direction of the potential bias are uncertain but potentially significant.
Sugarcane Marketing	++	Sugarcane marketing under the Lome Convention is a major uncertainty. Continued special treatment of sugar is uncertain, and changes could be of greater significance than climate changes. Reductions in the subsidy would alter land use, possibly replacing sugarcane with more climate tolerant crops, thus reducing vulnerability.
Coconut (copra)	?? (possibly -)	Coconut is second to sugarcane in terms of production values (though only about 20% of the value of sugarcane). Its omission from the biophysical assessment limits the scope of the assessment. The direction and the magnitude of the omission on vulnerability are difficult to assess without understanding whether the performance of coconut is diminished or enhanced by climate change. Increased extreme events, however, are likely to reduce production.
Yaciona (kava)	slight	The V&A Report noted that yaqona yields were not significantly affected by climate changes. It is possible that areas planted with yaqona might increase because of its tolerance, if markets for its products can be developed. That would produce a positive effect after adaptation. Increased extreme events, however, might limit its production potential.
Ginger	??	Ginger is a growing source of export earnings in Fiji. Though its importance may continue to grow, we cannot assess how it will perform under climate change without further study.

Omissions, Biases, and Uncertainties and Their Effect on the Economic Analysis of the Impacts of Climate Change on Human Health

Impact (benefit category)	Likely Impact on Estimated	Comment
Cyclones		
Future change in cyclone frequency	U	No projections are available for potential changes in frequency.
Changes in population distribution	+	Population is likely to become more densely settled in urban coastal areas, thus increasing the probability of deaths and extensive property damage. No data are available to demographic shift
Lost productivity due to (e.g., injury, illness,	+	No data are available to quantify the number of days of productivity due to storm events.
Drought		
Direct impacts of drought	U	No data are available on the direct impacts of drought, so they must be inferred indirectly through other health impacts (drought, diarrhea cases). (Other drought impacts are described elsewhere, in Chapter 5.)
Dengue Fever -		
Change in population distribution ’	+	Population is likely to increase in density, thus increasing the number of breeding sites and increasing the ease of transmission. No are available to quantify this increased risk. It is uncertain how the availability of funding for vector control may change in the future; currently it *is* very limited. No data are available to estimate individual willingness to pay to avoid contracting dengue.
Funding availability for control	U	
Individuals' values for not contracting dengue fever	+	
Change in number of more severe forms of (DHF)	+/U	The proportion of the number of cases of DHF to the number of cases of regular dengue fever *is* likely to increase due to climate change, although the extent is uncertain (Feresi et al., 1999). Increased numbers of DHF cases would increase the number of deaths and the costs of vector control efforts.
Diarrhea Cases		
Days of lost productivity	U	Data for the number of days of lost productivity were not available, so a range of 2 to 5 days was assumed.
Deaths due to diarrheal diseases,	+	No data were available on the number of deaths caused by diarrheal diseases, so this impact was not included.
Nutrition-Related illnesses		
Cost and economic impact of these illnesses	+/U	The health impacts of nutrition-related illnesses are indirect, and few data exist to quantify their economic impacts. Thus no cost estimate was made for these illnesses, although their economic impact could be substantial and will probably increase with future climate change.

Key: U: Uncertain, +: Damages likely to be higher than estimated, -: Damages likely to be lower than estimated.

Summary of Estimated Economic Damages for Fiji		
Damage Category	**Annual Value ($F millions)**	**Comments**
Cyclone severity change	-2.9 to 2.9	Model projects either decrease or increase in severity; estimates net of economic development or population growth.
El Nino-related droughts	14.3 to 78.5	Increased frequency and/or severity, based on 1997-1998 event recurring more frequently (or current frequency but higher severity).
Loss of mangroves & related services	16.5 to 40.1	Assuming 10% to 20% loss; omits several important mangrove services (see below).
Loss of coral reef & related services	21.9 to 88.0	Assuming 10% to 40% loss; omits several key services, including coastal area protection (shown in row below).
Coastal infrastructure protection	20.7 to 255.2	Based on Costanza et al. (1997) values linked to coral reefs; uncertain validity of per hectare estimate for this application.
Agricultural output change due to temp. or rainfall changes	48.6 to 50.0	Dominated by sugar cane losses, but root crops show net decline regardless of precipitation change (increase or decrease).
Public safety (change in cyclone fatalities)	-5.5 to 5.5	Cyclone severity projected to either decrease or increase, based on average cyclone-related fatalities over past years.
Increased incidence of dengue fever	7.0 to 45.6	Includes lost productivity, medical costs, and willingness to pay to reduce the risk of a typical case or a fatal case of dengue fever.
Increased incidence of diarrhea	0.6 to 1.4	Based on observed incidence in periods of both drought and extreme rainfall events, omits childhood fatalities.
Total Monetizable Damages	**121.2 to 1,066.7**	
Change in annual average precipitation	+	Precipitation may increase or decrease, damages likely > 0.
Loss of nonmonetized mangrove services	+	Biodiversity, fuelwood, nonwood products, nonuse values (bequest and existence values), and other goods and services.
Loss of nonmonetized coral reef goods and services	+	Biodiversity, ornamental fish, nonuse (existence and bequest) values, and other goods and services.
Loss of coastal lands	+	Cultural values and other losses apart from loss of infrastructure.
Agricultural output loss apart from changes in rain or temp.	+	Agricultural declines as may arise due to soil erosion, increased pest infestations, or other consequences of climate change.
Potential increase in fatal dengue fever cases	+	The proportion of the more severe and potentially fatal form, dengue fever (DEW), is expected to increase.
Infant mortality due to diarrhea	+	Diarrhea can be fatal for infants and young children.
Total Damages	**121.2 to >1,066.7**	

Adaptation Screening Matrix

Adaptations/ Criteria	High Effective-ness[a]	Low Economic Cost[b]	Feasibility	Low Environ-mental Impact	No Regrets	Must be Anticipatory
Sea Level						
Protection	X		X[c]			X
Retreat	X?			X		
Accommodation	?	X	?	X	X	X
Agriculture						
Shift crops	X	?	X	?		
Traditional crops	?		X	X		
R&D on new crops			X	X	X	X
Reduce sugar subsidy		X		X		
Water Resource						
Afforestation		X	X	X	X	
Multipurpose reservoir	X		X		X?	X
Flood control dikes			X		X?	X
Human Health						
Improve health care system	X		X	?[d]	X	X
Enhance disease monitoring	X		X	X	X	X
Enhance disease vector control	X		X		X	X

a. Considers effectiveness under a wide range of climate change scenarios, e.g., wet vs. dry.

b. Does not consider opportunity costs of adaptation.

c. Assuming outside funding is available. If it is not, this option is not feasible given Fiji's limited financial resources.

d. This could have substantial adverse environmental effects depending on how the health care system in improved. For example, measures to reduce the spread of disease carrying insects or animals can harm the environment.