Pacific Adaptation Strategy Assistance Program

The Vulnerability of Groundwater Resources to Climate Change in Timor-Leste

A report to the Australian Government
Department of Climate Change and Energy Efficiency

December 2011

Australian Government

International CLIMATE CHANGE ADAPTATION Initiative

Australian AID

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by

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Executive Summary

This report is part of a two part study of the vulnerability of Timor-Leste's ground water resources, and those who use them, to predicted climate change.

In this part of the study by Charles Darwin University (CDU) we focus on potential impact and adaptive capacity to address the vulnerability of Districts to water availability, and provide recommendations for water management. The second part of the study, by Geosciences Australia and presented separately, investigates the biophysical vulnerability of Timor Leste (of the aquifers) to climate change.

This report uses a mixed methods approach including:

- Review of current climate change predictions
- Review of information about aquifer characteristics, provided by the GA study
- Assessment of exposure of aquifers to pressure by groundwater users, by reviewing population distribution and growth
- Evaluation of adaptive capacity of groundwater users, using census data on indicators of wealth, and field interviews about use and management of water resources.

Using these methods we identify priority areas for action in water management and current and potential adaptation options. These options link readily to the National Adaptation Programmes of Action for Timor-Leste (NAPA), and we have also ranked them broadly in terms of predicted cost of implementation.

Timor-Leste is a small island developing state, located in the eastern part of the lesser Sunda Islands archipelago. Topography is rugged, with the central mountains of the island reaching altitudes of almost 3000m. The climate is monsoonal, and annual rainfall varies with elevation and aspect, from less than 1000mm in some coastal areas to over 2500mm in the wettest high altitude areas. Timor-Leste has a complex geology and much of the bedrock is sedimentary calcareous rock with shallow soils of low water holding capacity, high alkalinity and low nutrient content.

According to the national census, in 2010 Timor-Leste had a population of 1.07 million. Population growth is high (2.4%), fertility rate is high (5.7 births for each fertile aged woman) and the population is relatively young (41% under 14 years, 54% between 15-66 years, and about 5% over 65 years).

Already, water insecurity is widespread in Timor-Leste and is a major limitation of food security and livelihoods. Low-input agriculture is the main economic activity in Timor-Leste, with over 86% of households involved in subsistence farming. The main staple crops are rice, maize and cassava, with the limited rice production on the coastal plains fed by gravity irrigation and maize widely grown on the uplands.

Geoscience Australia has classified aquifer types in Timor-Leste according to geology and "prospectivity", i.e. potential flow rates or yields. The major aquifer types in Timor-Leste are:

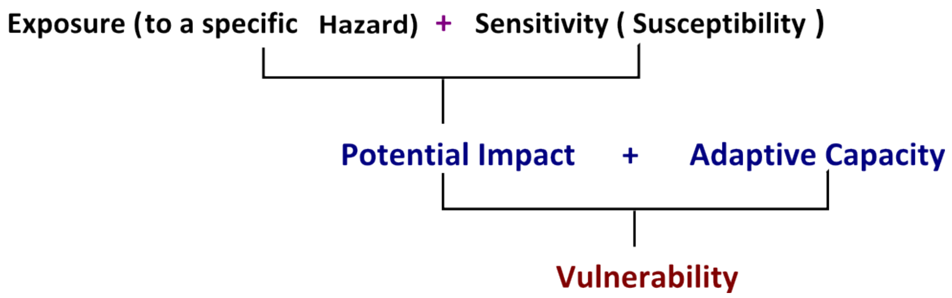
- Sedimentary aquifers with intergranular porosity, which have potential to hold large amounts of groundwater. Alluvial sedimentary aquifers have potential to be high yielding aquifers, with higher yield associated with greater porosity where sediments are more well-sorted (e.g. Dili).
- Limestone karstic aquifers with fissured porosity are associated with many springs fed by groundwater and are sensitive to rainfall. In limestone areas, groundwater recharge, storage and yield are affected by the age of the system which determines whether fissures and channels have formed (e.g. in and around Baucau).
- Fractured rock aquifers with localised porosity are low yielding and usually only sufficient for household use and animal watering. There is little or no porosity and groundwater is stored in existing fractures, with new channels not becoming larger with time (e.g. Lequidoe in Aileu District).

A substantial proportion (about 33%) of the population live on high yielding sedimentary aquifers, particularly on the coast, such as in Dili District, however, most of the population (44%) live on localised aquifers in the highlands (approximately equally on high yielding karst and low yielding localised fractured rock aquifers aquifers).
Uncertainty in climate change projections for Timor-Leste is relatively high because Timor-Leste is a similar in size to the grid cells of the models used for projections, has variable topography and little climatic data with which to test the validity of the models that underpin the projections.

The most recent climate projections for Timor-Leste have been published by the Pacific Climate Change Science Program (www.pacificclimatechangescience.org). These projections include:

- warming of average air and sea temperatures (by 0.4-1.0^{o}C by 2030 under a high emissions scenario);
- decrease in dry season and increase in wet season rainfall;
- extreme rainfall events to occur more frequently;
- decrease in frequency and increase in high intensity cyclones;
- sea level rise will continue (by 6-15cm by 2030 under a high emissions scenario)
- ocean acidification will continue.

Impacts of climate change are discussed within the following framework:



Exposure of groundwater resources to climate change were derived from prospectivity of aquifers as determined by Geoscience Australia. Sensitivity of groundwater resources was mapped by overlaying relative aquifer yield and modelled annual rainfall. Areas along the central northern coast and in Oecussi are expected to be particularly sensitive. Sensitivity was also considered in terms of population pressures, both density and rate of change.

Potential impacts of climate change were a function of expected exposure to climate change and sensitivity to those changes. High potential impact was identified in several areas on low yielding, localised aquifers: Liquica District, with low rainfall west of Dili; the Districts of Ainaro, Aileu, Bobonaro, and Ermera, with high and rapidly growing populations; Oecussi District, with high population growth and low rainfall. The major towns of Dili and Baucau can also be considered sites of high potential impacts because of high population densities and high population growth rates. This is despite having relatively high yielding aquifers: high yielding sedimentary aquifer in the case of Dili and high yielding fissured aquifer in the case of Baucau. In addition, the surrounding hills are underlain by low yielding fractured rock aquifers.

Vulnerability to climate change is a product of potential impacts and adaptive capacity.
High adaptive capacity can minimise the vulnerability of a community or nation in the face of high potential impacts. Adaptive capacity is influenced by many factors, including poverty, education, health and social capital. We derived some possible indicators of adaptive capacity using data from the national census and Demographic and Health Survey, and from field surveys at sites representing the main aquifer types. This investigation indicated higher vulnerability due to potentially low adaptive capacity in some Districts. Dili is wealthy compared with other Districts and this may represent relatively high capacity for adaptation. Other factors, such as implementation of some health programs and evidence of community management bodies, suggest high adaptive capacity in other Districts. Current adaptation

strategies in some sites included cooperative management of water resources, moving temporarily when water sources became unavailable, carrying water, and collecting rainwater.

In summary, the following adaptation options are recommended:

1. Documentation and monitoring of ground water resources – to improve understanding of water availability;
2. Integrated water harvesting and storage, and irrigation maintenance – to build local resilience and adaptive capacity;
3. Agricultural diversification - to build resilience and adaptive capacity;
4. Improving governance (policy and regulation) – to reduce waste and over use, to secure availability and access, and to increase adaptive capacity.

The people of Timor-Leste face substantial challenges in coping with the variability of the current climate, and further challenges regarding the expected changes to climate and water availability. Options for adaptations to climate change should be considered in the context of food security and sustainable agriculture and natural resource management practices at community, landscape and national scales. The need for this broader framework is stipulated in the National Adaptation Programmes of Action for Timor-Leste (NAPA).

Sumáriu Eksekutivu

Relatóriu ne'e hanesan parte ida husi parte rua estudu ne'e nian kona-bá vulnerabilidade Timor-Leste nia rekursu bee-rai-okos, no ema sira ne'ebé uza bee, hodi prevee mudansa klima..

Iha parte estudu ida ne'e husi Universidade Charles Darwin (UCD) ami konsentra kona-bá impaktu potensiál no kapasidade halo adaptasaun hodi responde ba vulnerabilidade distritu sira nian ba disponibilidade bee, no fornese rekomendasaun ba jestaun bee. Parte seluk husi estudu ne'e halo husi Geosciences Australia (GA) no aprezenta ketak ona, ne'ebé investiga vulnerabilidade biofízika Timor-Leste nian (husi aquíferu) ba mudansa klima.

Relatóriu ne'e uza aprosimasaun métodu kahur inkluindu:

- Revizaun ba previzaun atuál mudansa klima
- Revizaun ba informasaun kona-bá karakterístika aquíferu, forñesida husi estudu GA
- Avaliasaun ba espozisaun aquíferu kona-bá presaun husi ema ne'ebé uza bee-rai-okos, liu-hosi halo revizaun ba distribuisaun no kresementu populasaun, no
- Avaliasaun ba kapasidade adaptasaun husi ema ne'ebé uza bee-rai-okos, uza dadus husi sensu kona-bá indikasaun rikusoin, no intervista iha terenu kona-bá uzu no jestaun rekursu bee.

Uza métodu hirak ne'e, ami identifika area prioridade ba asaun iha jestaun bee nian no opsaun adaptasaun atuál no potensiál. Opsaun hirak ne'e liga fasilmente ho Programa Asaun Adaptasaun Nasionál (PAAN) ba Timor-Leste nomós jeralmente ami klasifika ona ein termu estimatizasaun kustu ba implementasaun.

Timor-Leste hanesan rai ki'ik ho estadu sub-dezenvolvidu, lokalizadu iha parte Oriental illa arkipelagu Sunda. Topografia hanesan ruguzu, ho foho iha rai-klaran aas to'o altitude besik metru 3000. Klima hanesan monsaun,no udan tinan varia ho elevasaun no aspetu, komesa husi kiik-liu 1000 mm iha area tasi-ibun balun to'o aas-liu 2500 mm iha area udan maka'as liu ho altitude aas. Timor-Leste iha jeolojia ne'ebé komplikadu no alizerse barak-liu mak sedimentariu kalkáriu (sendimen berkapur) ho rai-fohon mihis no kbiit atu kaer bee ki'ikoan, alkalinidade aas no konteúdu nutriente ki'ik.

Bazea ba sensu nasionál, iha 2010 Timor-Leste iha populasaun hamutuk miliaun 1.07. Kresimentu populasaun sa'e aas (2.4%), no taxa fertilidade mós aas (5.7 moris ba kada feto idade fértil) no populasaun relativamente foin-sa'e (41% iha tinan 14 mai-okos, 54% tinan entre 15-66, no maizumenus 5% tinan aas-liu 65).

Ita hatene katak, in-seguransa bee iha fatin-fatin iha Timor-Leste no ida ne'e hanesan limitasaun signifikante ba seguransa ai-han no meiu-de-subsistensia. Agrikultura ki'ik hanesan atividade ekonomia importante iha Timor-Leste, ho 86% resin família involve iha agrikultura subsistensia. Aihan importante kuda iha Timor-Leste maka hare, batar, no aifarina, ho produsaun hare oitoan iha parte tasi-ibun ne'ebé fornese ho udan been ka irigasaun gravidade no ai-han batar kuda barak liu iha rai lolon ka foho-leten

Geoscience Australia klasifika ona tipu de aquíferu iha Timor-Leste bazeia ba jeolojia no "prospektividade", i.e. taxa potensiu fluxu rendimentu. Maioria aquíferu iha Timor-Leste hanesan:

- Aquíferu Sedimentariu ho porosidade intergranula ne'ebé iha potensiu atu kaer no/ka rai montante bee-rai-okos barak. Aluviál aquíferu sedimentariu iha potensiu maka'as atu hetan rendimentu aquíferu ne'ebé barak, ne'ebé asosiadu ho porosidade ne'ebé sedimentu klasifikadu di'ak liu (e.g. Dili).
- Aquíferu Kalkariu Karstiku ho fizurada porosidade mak asosiadu ho bee-matan hirak ne'ebé hetan bee mai husi bee-rai-okos nomós sensitivu ba udan-been. Iha area kalkariu, bee-rai-okos priénse hikas (rekarga), estorasaun no rendimentu afetadu husi idade sistema ne'ebé mak determina tantu fizurada no kanál bee formadu tiha ona (e.g. iha no besik parte Baucau)

- Aquíferu Fatuk Fraturadu ho porosidade lokalizadu ne'ebé mak hetan rekursu bee oitoan-liu no dala barak natoon de'it atu uza ba uma-kain nia nesisidade nomós fó hemu ba animal. Iha ne'ebá oitoan ka la iha porosidade, no bee-rai-okos halibur-hamutuk iha fratura, ho kanál foun la sai luan no/ka boot ho/ka tuir tempu (e.g. Lequidoe iha Distritu Aileu).

Proporsaun substansiál (besik 33%) husi populasaun hela iha rendimentu sedimentariu aquíferu ne'ebé boot, barak liu hetan iha tasi ibun, hanesan iha Distritu Dili, maibé populasaun barak liu (44%) hela iha aquíferu lokalizadu iha alevasaun aas (aprosimasaun hanesan iha rendimentu maka'as karstiku no rendimentu ki'ik iha aquíferu fatuk frakturad).

Projeksaun mudansa klima ne'ebé la klaru ba Timor-Leste foti relativamente aas tanba Timor-Leste hanesan tamañu ho selula grade husi modelu hirak ne'ebé uza iha projeksaun, iha variabilidade topográfia no dadus klima ne'ebé limita atu koko validade modelu hirak ne'e hodi tulun halo projeksaun.

Projeksaun mudansa klima ba Timor-Leste ikus liu páblika ona husi Programa Siencia Mudansa Pasífiku (www.pacificclimatechangescience.org). Projeksaun sira hare iha pontu tuir mai:

- Temperatura atmosfera mediu no nivel tasi-been sa'e (ho 0.4-1.0^{o}C molok 2030 ho senáriu emisaun ne'ebé aas)

- Tempu (periodu) bain loron menus, maibé periodu udan-tau sa'e
- Iventu udan maka'as sei akontese i nia frekuensia sei aumenta
- Frekuensia udan menus maibé intensidade siklonu sa'e
- Nivel tasi-been sae no sei sei kontinua (ho 6-15 cm antes 2030 ho sénariu emisaun ne'ebé aas)
- Asidifikasaun tasi-been sei kontinua

Impaktu mudansa klima bele diskuti husi enkudramentu tuir mai:

Ekspozisaun (ba ameasa espesífiku) + Sensitividade

Impaktu poténsiál + Kapasidade adaptasaun

Vulnerabilidade

Expozisaun rekursus bee-rai-okos ba mudansa klima derivadu husi prospektividade aquíferu ne'ebé determinadu husi Geoscience Australia. Sensitividade rekursu bee-rai-okos hahú ho mapea liu husi sobrepozisaun rendimentu aquíferu relativu no modela udan-tinan nian. Area iha parte sentru kosta norte no iha Oecussi ekspekta hanesan sensitivu liu. Sensitividade ne'e mós iha konsiderasaun mai husi presaun populasaun inkluindu densidade no alterasaun taxa.

Impaktu poténsiál mudansa klima mak hanesan funsaun ekspozisaun hahe'in ba mudansa klima no sensitividade ba mudansa hirak seluk tan. Fatin ne'ebé mak iha impktu poténsiál aas ou maka'as inkluidu fatin hirak iha rendimentu ki'ik, Aquíferu lokalizadu: Distritu Liquica, ho udan been ki'ik iha parte oeste Dili, Distritu seluk hanesan Ainaro, Aileu, Bobonaro, no Ermera, ho populasaun ne'ebé mak ma'e lalais no aas; Distritu Oecussi, ho populasaun sae maka'as no udan-been ki'ik. Iha mós impaktu poténsiál aas ba maioria sidade Dili no Baucau tanba densidade populasaun nomós taxa kresimentu populasaun aas. Maske iha fatin rua ne'e rendimentu aquíferu aas: rendimentu aquíferu sedementariu hanesan hetan iha Dili no rendimentu aquíferu fizurada hanesan hetan iha Baucau. Aumenta tan, foho hot-hotu ne'ebé sirkula kauza rendimentu ki'ik iha aquíferu fatuk fraturadu

Vulnerabilidade ba mudansa klima foti hanesan produtu impaktu poténsiál no kapasidade adaptasaun. Kapasidade adaptasaun ne'ebé aas bele minimiza vulnerabilidade ne'ebé populasaun ka nasaun hasoru ho impaktu potensiál aas. Kapasidade adaptasaun influensiadu ho fatóres barak, inkluindu ki'ak, edukasaun, saúde no kapitál sosiál. Ami foti posibilidade indikatores balun ba kapasidade adaptasaun utiliza dadus husi sensu nasionál no survei demografia no saúde, no husi estudu iha kampu, iha fatin hirak ne'e reprezenta ona tipu aquíferu prinsipál. Investigasaun hatudu katak vulnerabilidade aas liu iha distritu balun akontese tanba potensiu kapasidade adaptasaun ki'ik. Dili riku kompara ho distritu selu-seluk no ida ne'e bele reprezenta relativamente kapasidade adaptasaun ne'ebé aas. Fatores seluk, hanesan implementasaun ba programa de saúde balun no provas orgaun jestaun komunidade, sujere kapasidade adaptasaun ne'ebé aas iha distritu selu-seluk. Estrategia adaptasaun ne'ebé iha agora, iha fatin balun inkluindu jestaun koperativa ba rekursu bee, muda temporario wainhira existencia bee uza bai-bain maran (ka la iha), lori bee, i rekollia udan been.

Iha sumáriu, opsaun adaptasaun iha pontu rekomendasun hirak tuir mai:

1. Dokumentasaun no monitoramentu ba rekursu bee-rai-okos atu hadia koñesimentu ba disponibilidade bee
2. Investigasaun armajein bee-rai– atu hadia disponibilidade
3. Integrasaun koileta bee no manutensaun irigasaun – atu konstrui resil'ensia no kapasidade adaptasaun
4. Diversifikasaun agrikultura – atu konstrui resilénsia kapasidade adaptasaun
5. Hadia governasaun (polítika i regulamentu) - atu hamenus ou uza liu lixu, atu garantia disponibilidade no asesu, i atu hasae kapasidade adaptasaun

Povu Timor-Leste hasoru desafíu substánsiál atu rezolve variabilidade klima oras ne'e, no dezafíu hirak seluk tan iha relasaun ho ekspektativa mudansa klima no disponibilidade bee. Opsaun adaptasaun ba mudansa klima tenki konsidera iha kontestu seguransa alimentar no agrikultura susténtavel no prátika jestaun rekursu naturais iha komunidade sira-nia leet, iha skala paizajein no Nasionál. Nesesidade ba engudramentu ida ne'ebé estipuladu iha Programa Asaun Adaptasaun Nasionál ba Timor-Leste.

Glossary of acronyms and foreign language terms

Term or abbreviation	**Meaning**
ADB	Asian Development Bank
aldeia	Hamlet
bee nain	Traditional human and spiritual custodians of water
CDU	Charles Darwin University
ENSO	El Niño Southern Oscillation
FAO/WFP	Food and Agriculture Organisation/World Food Program
GA	Geosciences Australia
HDI	Human Development Index
IPCC	Intergovernmental Panel on Climate Change
kusin	Rainwater collecting container
MDG	Millennium Development Goals
NAPA	National Adaptation Programmes of Action for Timor-Leste
PCA	Principal components analysis
RWSSP	Rural Water Supply and Sanitation Project
RWASH	Rural Water Sanitation and Hygiene
SPLOM	Scatter plot matrices
suco	Village
uma-lulik	Sacred houses
UNDP	United Nations Development Program

Contents

1. Introduction

1.1 Definitions of terms

> Vulnerability to climate change is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (IPCC 2007).
>
> "Vulnerability assessments entail ... considering one or more of the following: exposure to climate risk, susceptibility to damage, and capacity to recover" (Barnett *et al*. 2007).

Vulnerability is the product of the potential impact of climate change and the capacity to adapt to climate change (Fig. 1). Potential impact, positive or negative, is the product of exposure and sensitivity. The adaptive capacity of a system, region or sector refers to its capacity to respond in a way that makes it better equipped to deal with external influences via either autonomous or planned adaptation (Allen Consulting Group 2005; Nelson *et al*. 2010)

Exposure is influenced by a combination of the probability and magnitude of climate change, examples of which include projections of changes in temperature and rainfall (total and seasonality). Sensitivity reflects the responsiveness of systems to climatic influences: the threshold points at which effects will be exhibited, whether changes will occur in trends or steps, and whether the changes will be reversible. For example, determining changes in aquifer yield as a function of rainfall amount and intensity would be a measure of sensitivity.

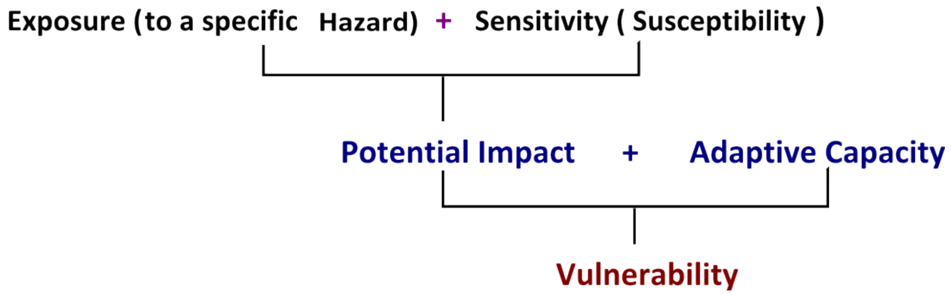


Figure 1. Factors determining vulnerability
From (Allen Consulting Group 2005) adapted from (Schroter 2004)

This type of analysis is usually used to investigate biophysical systems but it may be applied to impacts on human enterprises and the consequent vulnerability of human livelihoods and human health.

This study by Charles Darwin University (CDU) and the study by Geoscience Australia (GA) comprise two parts of a project investigating ground water resources and climate change in Timor-Leste. The project is titled: 'Assessment of Impacts of Climate Change on Groundwater in Timor-Leste'. In complementary studies, GA has investigated biophysical vulnerability (of the aquifers) and CDU has investigated socioeconomic vulnerability (of the people).

In the GA study, 'exposure' refers to aquifers subjected to hazards caused by climate change, such as changes in rainfall and sea level, and 'sensitivity' is related to characteristics of the aquifer types, such as changes in aquifer yields when exposed to the climate change hazards. The potential impacts considered in the GA study are primarily changes to aquifer yields due to changes in rainfall and seawater intrusion into freshwater aquifers in response to sea level rise.

The CDU study is a broader consideration of vulnerability with respect to changes in water resources and how these impact on livelihoods. In the CDU study, exposure includes changes in water resources (mainly changes in aquifer yield and rainfall) and sensitivity includes population pressures (mainly overall national population growth, increasing urbanisation, and other demographic changes). Adaptive capacity is the capacity of people, communities and government agencies to adapt to potential impacts of climate change, and could include a shift towards more irrigated and intensive agriculture, for example.

Adaptive capacity can be influenced by a range of factors, including social, institutional, political, and technological factors. We have compared some possible indicators for adaptive capacity using data from the 2010 census (UNFPA 2011) and the Demographic and Health Survey (National Statistics Directorate 2010). The correlations between these indicators were investigated to determine the extent to which a few indicators could be used as a proxy for others. In our study, poverty and 17 other parameters related to wealth, education and health were used as potential indicators of adaptive capacity.

Vulnerability of livelihoods due to impacts of climate change on groundwater resources is directly related to the potential impacts and inversely related to adaptive capacity of the households and communities.

It is acknowledged that many factors will influence water resources and livelihoods in Timor-Leste, and, in some cases, climate changes impacts will be minor compared with other impacts such as demographic changes and land management practices. This study considers vulnerability to climate change impacts on water resources in the context of other expected influences in Timor-Leste.

1.2 Data sources and methods of analysis

Climate change projections for Timor-Leste have been drawn primarily from existing reports (Acil 2010; Barnett *et al*. 2007; Kirono 2010) and the outputs of the Pacific Climate Change Science Program (PCCSP). For small mountainous islands such as Timor-Leste, climate projections, and consequently predicted impacts, are uncertain because global climate models are coarse (100-500 km resolution) relative to the scale of landscape variability. For Timor-Leste, the paucity of long term data records is a further limitation.

Assessments of sensitivity and exposure in this report have been based on the following:

- analysis of groundwater yield or availability (and indicative recharge/availability) conducted by Geoscience Australia;
- desktop analyses of current water use and trends in demands for access to water in Timor-Leste;
- national census data for 2004 and 2010; and
- primary data collected in the field.

Case study sites for primary data collection in this study were selected to represent the major aquifer types:

- sedimentary aquifer in Dili District, including; Becora, Tasitolu, Comoro, Caicoli, Formosa, Bemori, Vila Verde, Pantai Kelapa, Cristo Rei, and the peri-urban areas towards Hera, and Dare, and the upper coastal section of the Comoro River;
- localised, fractured rock aquifer at Laleia and Vemasse in Manatuto District, and Lequidoe in Aileu District; and
- fissured aquifer in Baucau District, including Kota Lama, Kota Baru, Triloka – Darusala.

Primary social data were obtained from interviews with key informants and householders, and focus group discussions (Appendix II). These were then related to other data sources (including from GA and national census).

Spatial analyses included overlaying census data, rainfall, hydrogeology, infrastructure, administrative boundaries and topography. National trends were investigated with resolution to the Sub-District level, overlaying census data from 2004 and 2010, and field case studies with resolution to suco level.

2. Context of Timor-Leste

Timor-Leste is located in the eastern end of the lesser Sunda Islands archipelago which extends from Java towards northern Australia (Fig. 2.1). The island of Timor is divided into Indonesian administered West Timor, and the nation of Timor-Leste in the eastern part. Timor-Leste also includes the enclave of Oecussi and the island of Atauro. Timor-Leste is one of the world's newest[1] and poorest nations, becoming a sovereign state on 20 May 2002, and is now a parliamentary democracy with a President as Head of State. The nation is divided into 13 Districts (Fig. 2.2), 62 Sub-Districts, 442 sucos (villages) and 2,336 aldeias (hamlets). As a fragile post-conflict nation, Timor-Leste has had nearly ten years of alternating peace and violence. The situation has been peaceful since 2008, and there has been significant progress in establishing institutions of state. However there are many challenges including fragile security characterised by weakened social cohesion; high unemployment (particularly in urban areas and amongst young people); limited public and private sector capacity; and limited non-oil economic development opportunities. A sluggish economy and a high unemployment rate amongst youth is a security risk which threatens the process of democratisation and construction of a viable state.

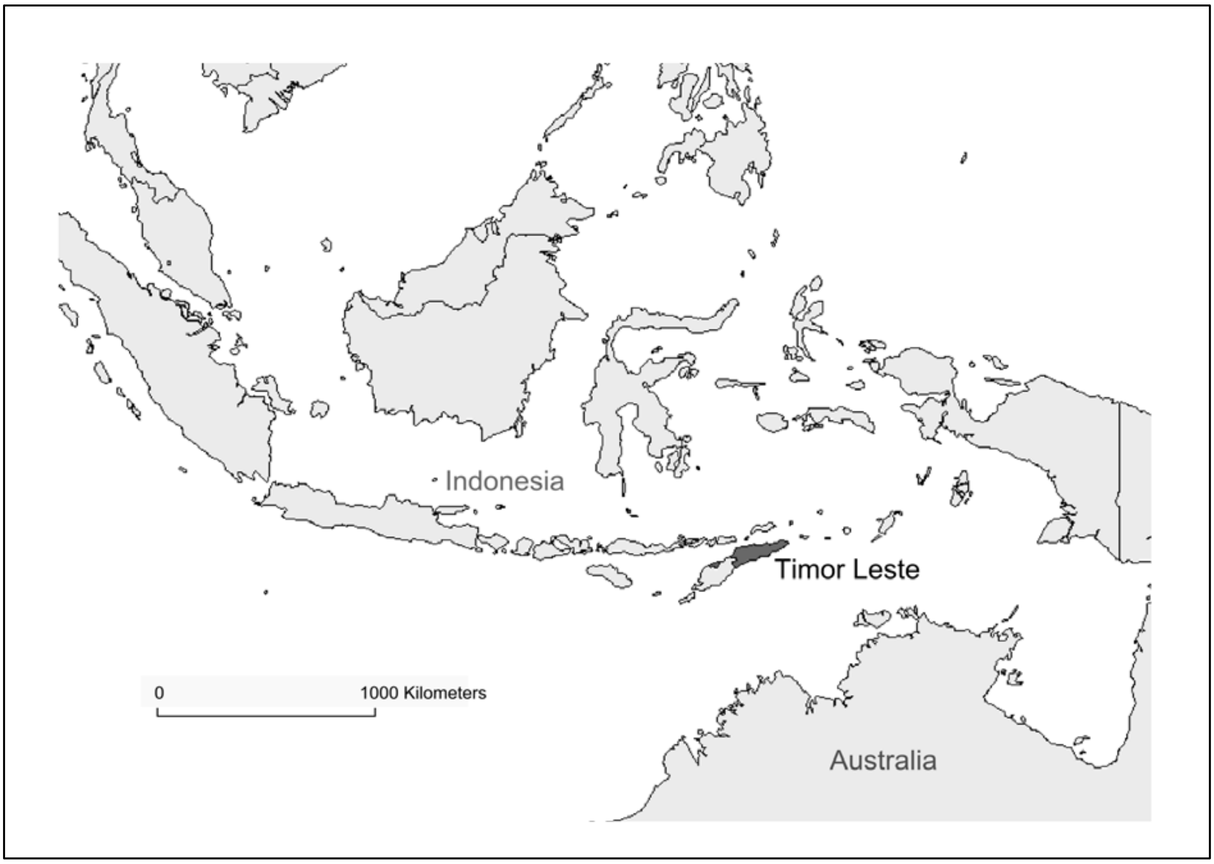


Figure 2.1 Location of Timor-Leste

[1] Timor Leste achieved full independence in international law on May 20th 2002 but remained under the guidance of the UN.

2.1 Environment & Climate

Geologically, the island of Timor is considered to be part of the Banda arc, and forms a structural fold and thrust belt on the outer edge of the Australian continental margin, and is one of the most geologically and geographically complicated islands in the archipelago (ESCAP 2003). The bedrock is predominantly sedimentary calcareous rock, generally with thin soils of low water holding capacity, high alkalinity and low nutrient content (Monk *et al.*1997).

Timor-Leste has a monsoonal climate with two distinct rainfall patterns: a northern mono-modal pattern with a 4-6 month wet season starting in December and a southern bimodal rainfall pattern with 7-9 month wet season with two rainfall peaks starting in December and May (Table 2.1). Rainfall is comparatively low on the north coast (<1000mm pa), moderate in central and elevated areas (1500-2000 mm pa), and highest (>2500 mm pa) in high altitude areas (Fig. 2.2).

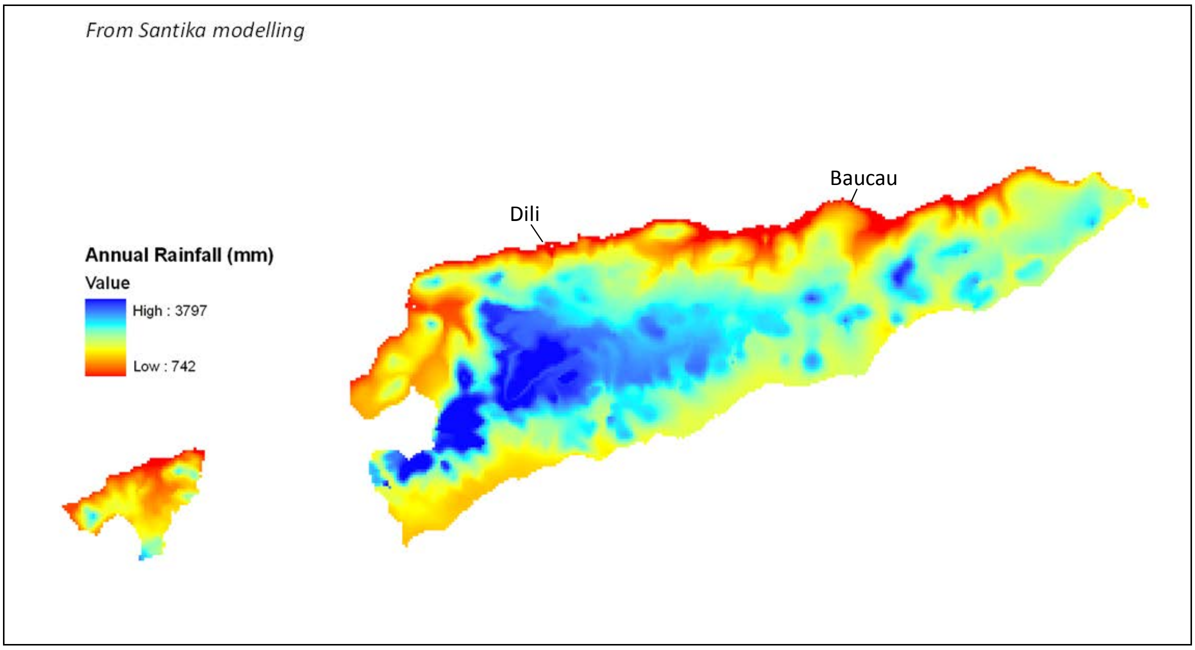


Figure 2.2 Average annual rainfall distribution, derived from model (Winarto 2004)

When ENSO[2] occurs, rainfall is reduced in January to March in Timor-Leste and the start of the rainy season is generally delayed. ENSO is associated with drier conditions and later on set of the wet season particularly in the northern part of Timor-Leste (BMRC 2003). The Timor group are the only islands in the Indonesian archipelago that are subject to tropical cyclones.

[2] ENSO is the El Niño Southern Oscillation, during which the surface of the tropical eastern Pacific Ocean is relatively warm and there are high air surface pressure in the west Pacific.

Table 2.1 Timor-Leste can be divided into six agroclimatic zones.

Zone	Feature	Altitude (m)	Rainfall (mm)	Months of rain
Mono-modal rainfall pattern (NW monsoon)				
Northern Lowlands	10%, coastal lands	<100	<1000	4-5 months Nov to March
Northern Slopes	Land in northern hills 23%	100-500	1000 – 1500	5 – 6 months Oct – March
Northern Highlands	Hills and mountains in the north 20%	>500	>1500	6 – 7 months Oct – April
Bi modal rainfall pattern (NW monsoon & SE trades)				
Southern Highlands	Hills and mountains in south 15%	>500	>2000	9 months Nov- April May - July
Southern Slopes	Hill lands in the south 21%	100-500	1500- 2000	8 months Nov – March May – July
Southern lowlands	Coastal land in the south 11%	<100	approx 1000	7-8 months Nov – March May – July

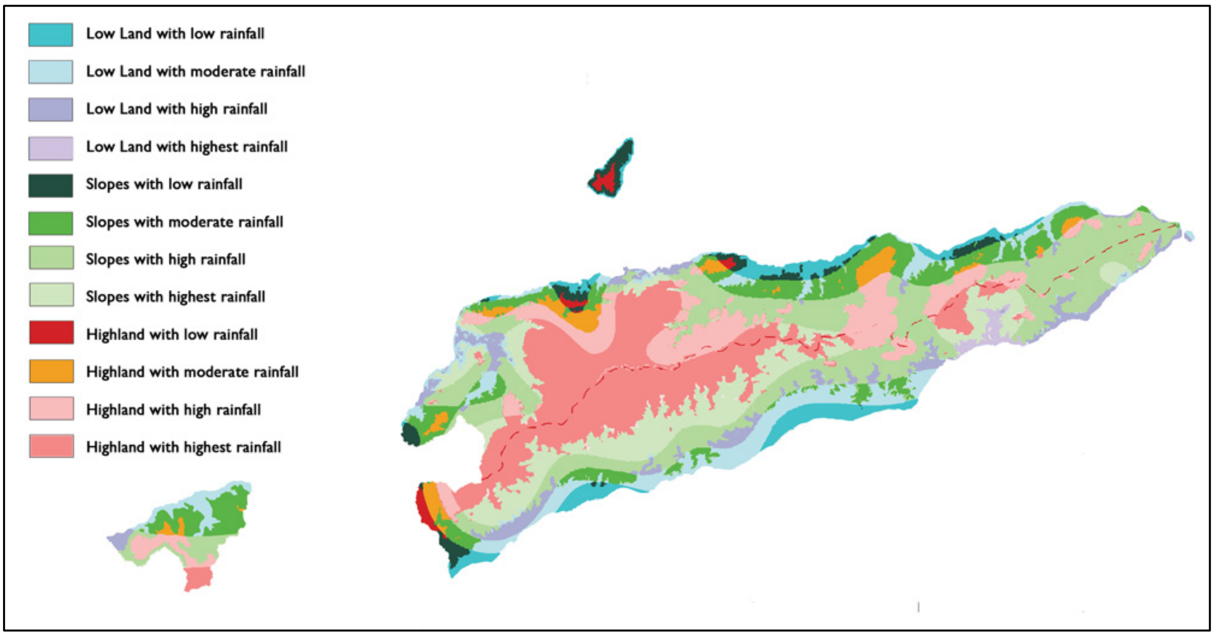


Figure 2.3 Agroclimatic zones in Timor-Leste (adapted from ARAPET 1996)

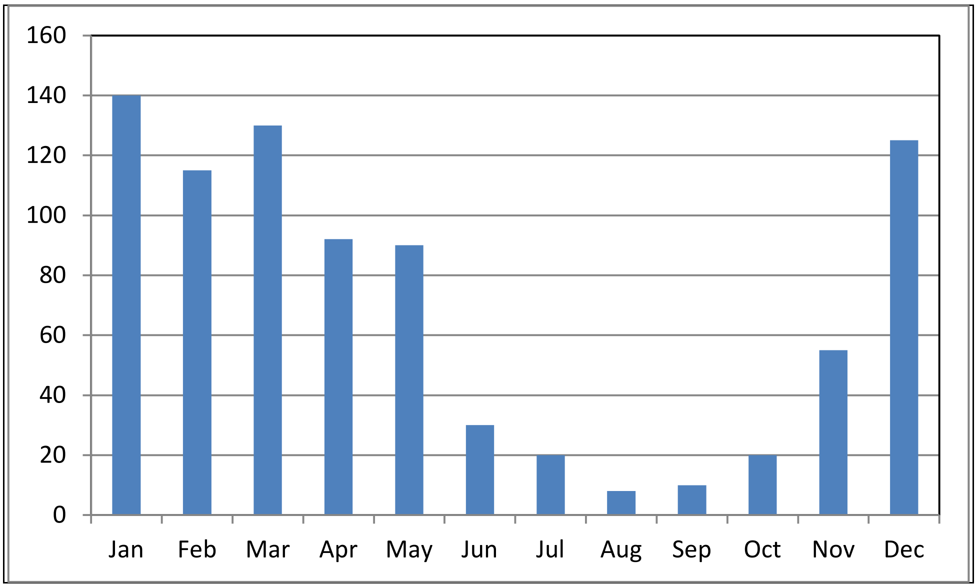


Figure 2.4 Average monthly rainfall (mm) in Dili (data from 1950-present, with gaps around 1975 and 2000)

The natural resource base of Timor-Leste is depleted and fragile. Forest cover has declined due to shifting cultivation and increasing demand for fuel wood. Past Indonesian and Portuguese administrations have also contributed to depletion of forest resources (McWilliam 2003). Associated soil depletion in upland areas is substantial and widespread. The island consists of a rugged central mountain range with surrounding coastal plains. About 44% of the land area is on slopes of 40% or more (Sandlund 2001). Slash and burn agriculture is widely practiced and there is pressure on remaining forests as population grows and more arable land is required.

Agriculture is largely limited by low rainfall and uncertainty in timing of the start of the wet season, sufficient to support crops. Food shortages occur in both relatively dry and relatively wet years, with frequent, intense rainfall events resulting in flooding, landslides and destruction of crops and houses (Min Econ & Dev 2008).

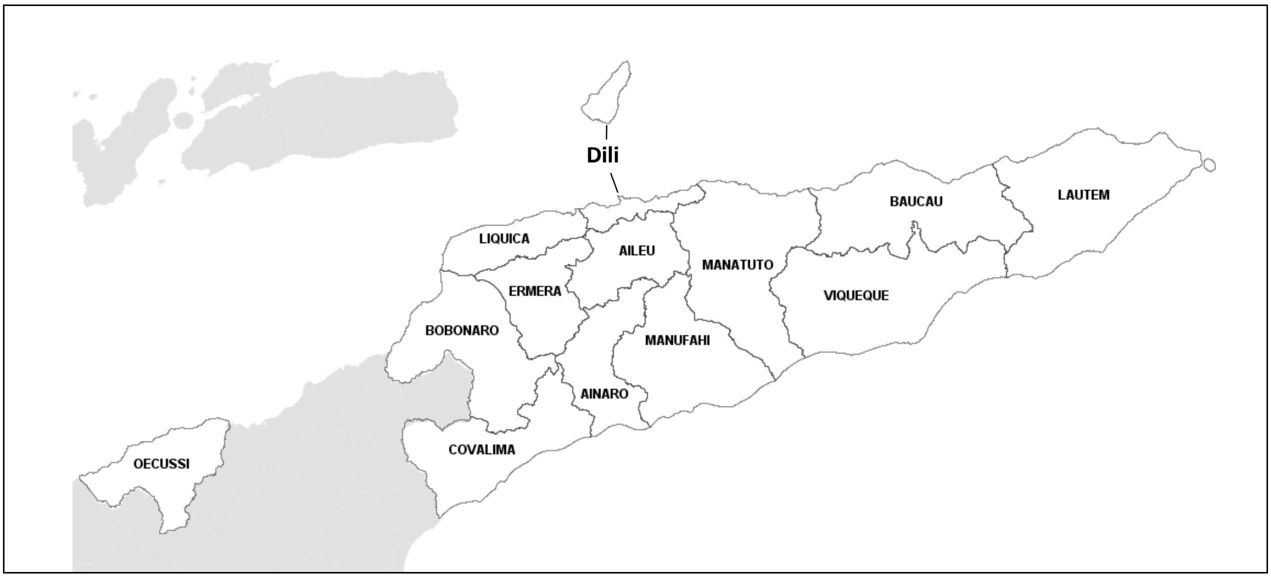
2.2 Population

In 2010 the population of Timor-Leste was 1.07 million and population growth was high (2.4%; NSF & UNFPA 2011). The high fertility rate of 5.7 births for each fertile aged woman (NSD 2010) indicates future challenges for infrastructure, planning and development in Timor-Leste. The population is balanced between male and female, however it is skewed towards the young, with 41% under 14 years, 54% between 15-66 years, and around 5% at 65+ years (NSF & UNFPA 2011). The population is predominantly Catholic (97%), with about 2% Protestant and a small Islamic community of less than 1%.

The population is concentrated in the capital, Dili (Fig. 2.5). The 2010 Census shows that 29.6% of the population live in the urban[3] areas: 18% of the population living in the capital city, Dili, and about 10% in each of Ermera and Baucau Districts. With an overall population density of 71/km^2, the density in urban areas (352/km^2) is almost an order of magnitude greater than that in rural areas (53/km^2). The population growth from 2004 to 2010 shows an increase of 33% in Dili District and 12% in Baucau District and the urban areas of Ermera District (Fig. 2.6).

[3] The definition of urban in the Timor-Leste Census Report is all District capitals and areas where (a) population >2000, (b) <50% population are employed in agriculture & remainder employed in modern sector, (c) have electricity and piped water, and (d) there is access to schools, medical care & recreational facilities.

(a)



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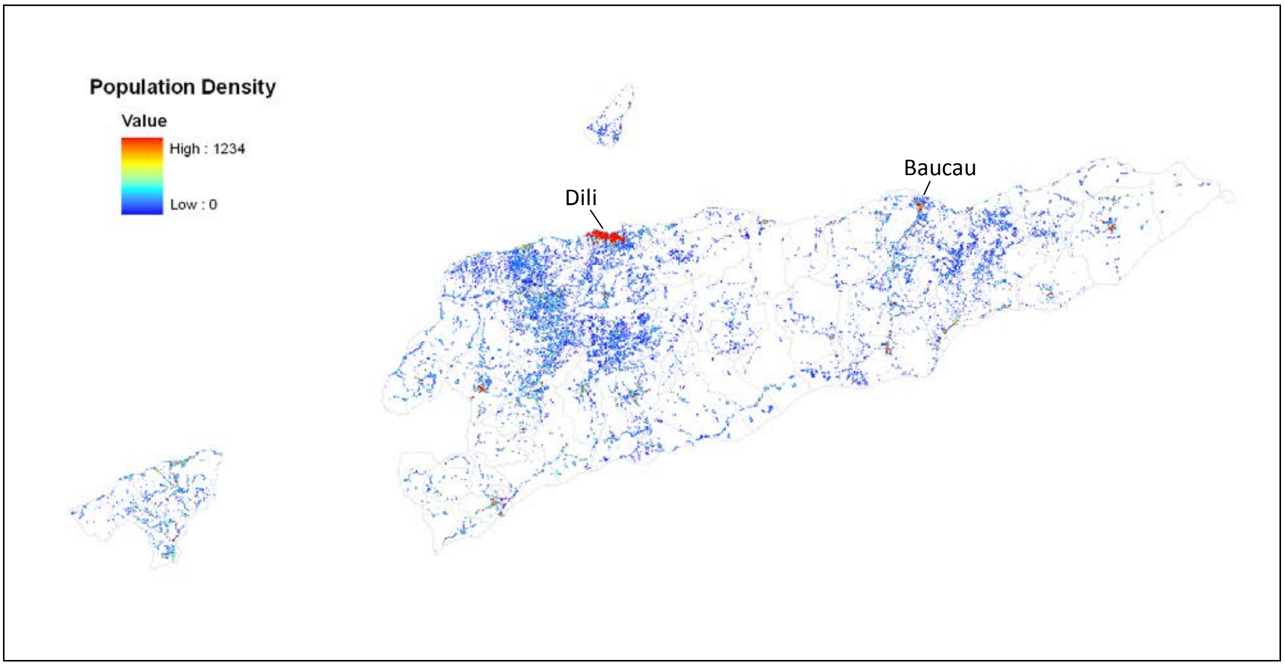
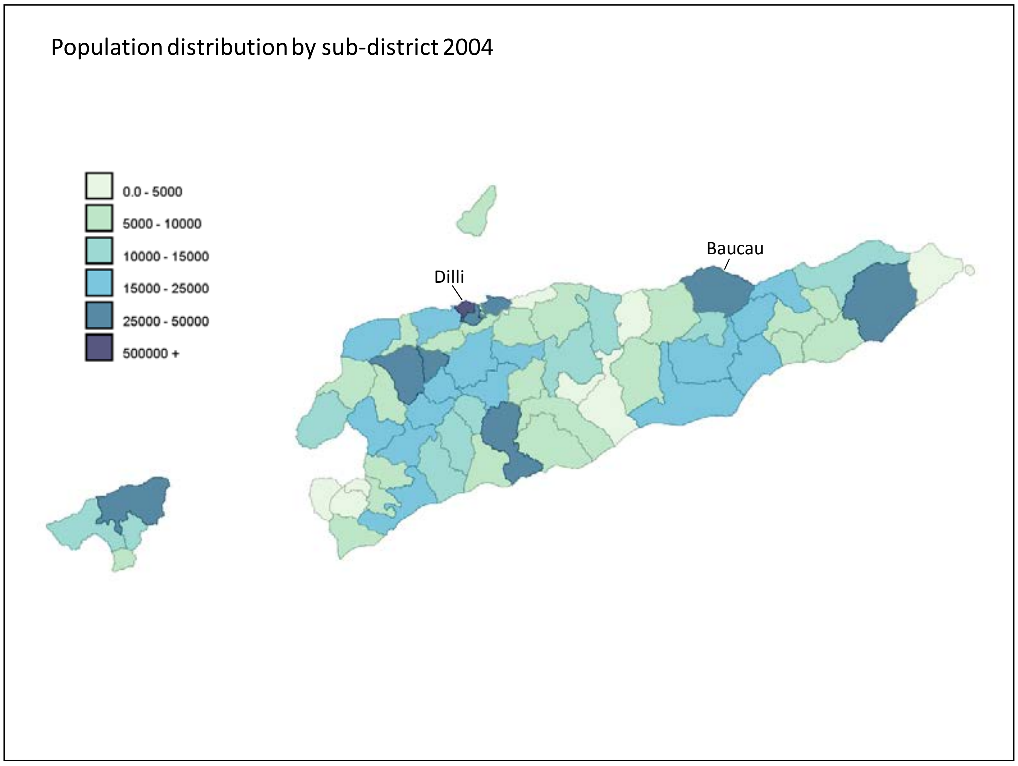


Figure 2.5 (a) Districts of Timor-Leste and (b) their population density (numbers of people/0.25 km^2) in 2004.
Household population data from the 2004 Census and averaged for grid size of 500mx500m**.**

(a)



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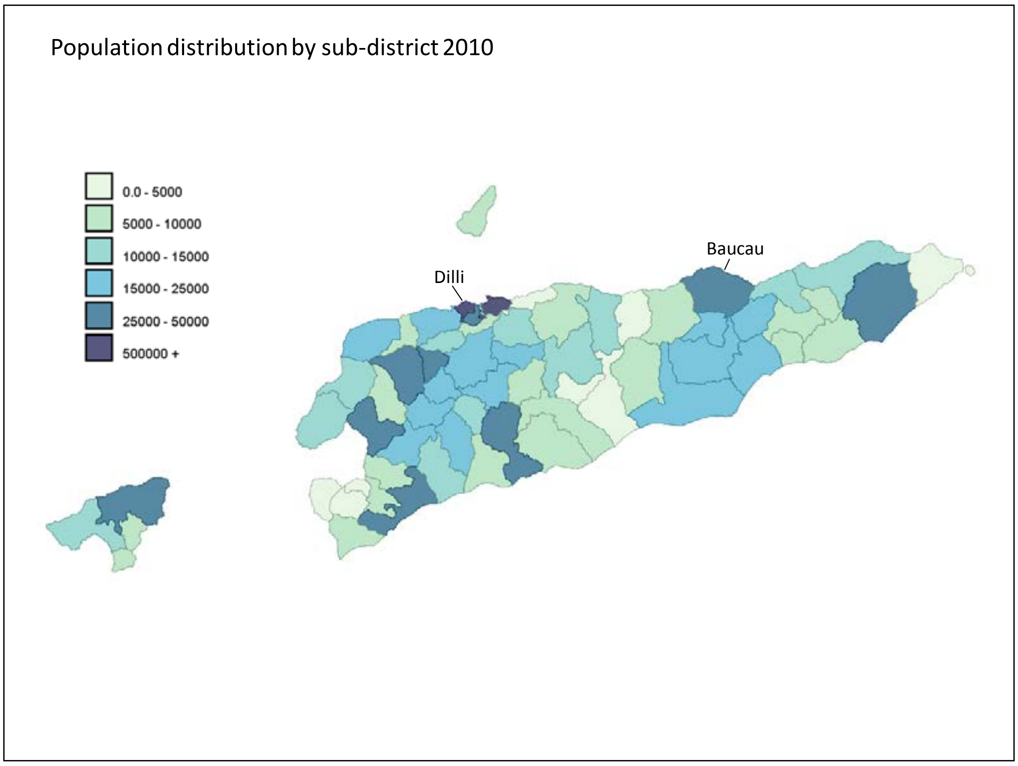
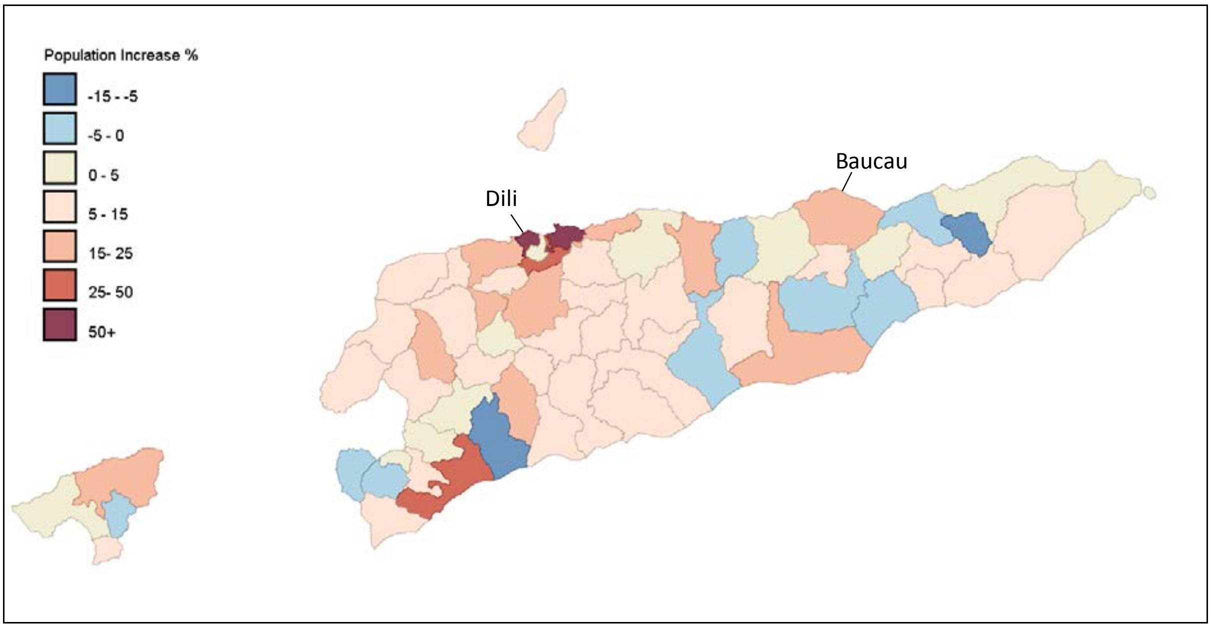


Figure 2.6. Population of Sub-Districts in (a) 2004 and (b) 2010

(a)



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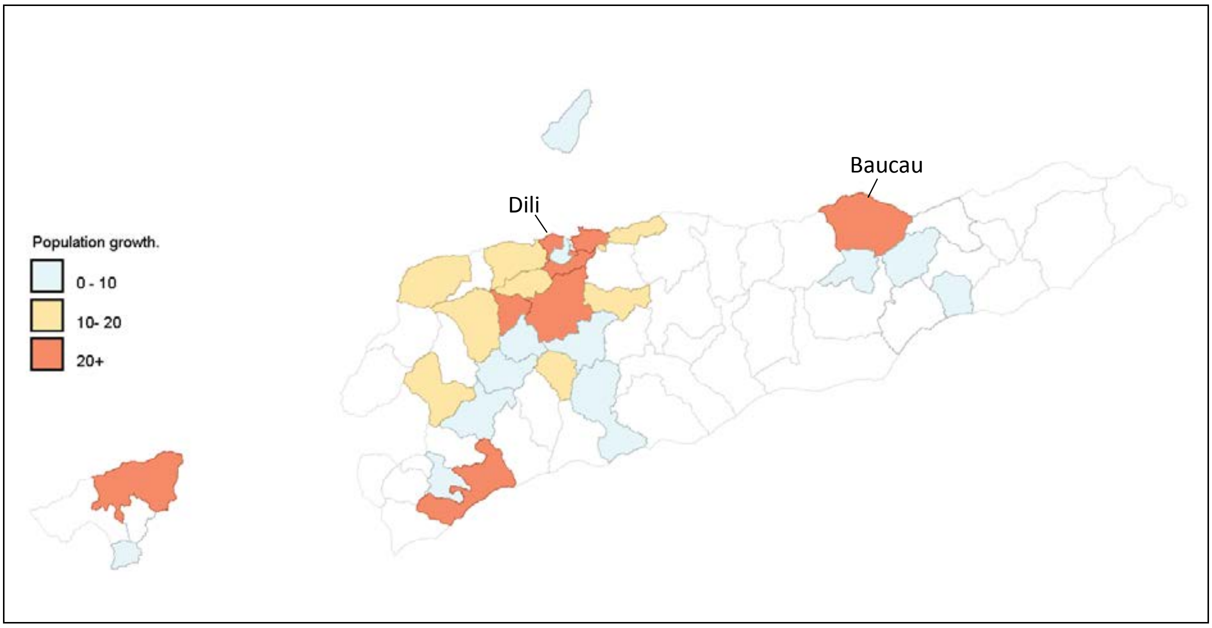


Figure 2.7 Change in population by Sub-Districts from 2004 to 2010.
Data from the national census in 2004 and 2010, (a) as percentage change for all Sub-Districts and (b) as percentage change for Sub-Districts with population densities greater than 50 people/km^2.

2.3 Socio-economic conditions

According to the United Nations, Timor-Leste is one of the world's 50 "least developed countries" (LDCs) and is also a Small Island Developing State (SIDS). Just over 30% of the nation's GDP is generated from the export of mineral oil, which creates an economy which is subject to volatile and slow non-oil GDP growth. The 2008 State of the Nation report gives a non-oil per capita GDP of USD364 in 2007 which has stagnated since 2002, leaving Timor-Leste as one of the poorest nations in Asia (UNDP 2009a). The World Bank characterises Timor-Leste as a lower middle income country with a gross national income (GNI) in 2007 of USD1500, however without oil revenue GNI is USD400.

The poverty line is nationally determined at USD 0.88 per capita per day, and the 2010 census shows that 41% of the population fell below that line. Poverty is more severe in the central Districts (58%) and western Districts (55%), compared with the eastern Districts (27%). This situation reportedly improved during 2009 as economic activity remained strong due to government spending. Food insecurity is widespread throughout the country and affects over 64% of the population, with most of these households facing an annual "hungry season" of up to three months without sufficient rice or maize. Food insecurity is most pronounced in the upland areas. Chronic malnutrition affects 47% of the entire population, with a quarter of all women and a half of all children malnourished. Low crop productivity, high on-farm grain storage losses, lack of infrastructure, and rapid population growth are major contributors to food insecurity. Timor-Leste is a net importer of food, importing 60% of its rice needs imported (FAO/WFP 2007).

Underemployment is very high in rural areas with very low incomes, and agricultural incomes have remained stagnant since 2002. Non-rural farm employment is only available through public works projects such as bridge and road building (UNDP 2009a). Urbanisation is an accelerating process, partly as a result of young people leaving rural communities and agricultural production for the apparent opportunities of Dili. Youth unemployment and associated unrest remain major social issues in Dili, however local systems of authority and landownership based on ritualised ancestral rights in relation to sacred houses (*uma lulik*) remain strong, in many rural areas.

Low-input agriculture is the main economic activity in Timor-Leste, with over 86% of households involved in subsistence farming. The main staple crops are rice, maize and cassava, with the limited rice production on the coastal plains fed by gravity irrigation and maize widely grown on the uplands. Tuber crops are valuable supplements that can be harvested during lean times to replace rice or maize (Seeds of Life 2009).

The UNDP currently ranks Timor-Leste low on the Human Development Index (HDI) at 120 out of 169 countries, up from the previous assessment, but still below the regional average. Literacy rates are low, with an estimated 50% of the population unable to read or write. The status of women is generally low, with only around 50% of the female population having received some education, and the rates of maternal and neonatal mortality are alarmingly high with approximately 30% of women lacking access to any ante-natal care. Recent indications are that while progress has been made, Timor-Leste is not on track to achieve its Millennium Development Goals (MDG) by 2015. It will be difficult for Timor-Leste to achieve (MDG) target 7a - "to halve the number of people without access to safe drinking water and basic sanitation" - although there has been a trend towards this goal (UNDP 2009b).

3. Livelihoods & water resources

3.1 Water resources

In hydrological terms, water scarcity is measured by the population overlaid with water availability, and the universal threshold is 1,700 cubic metres per person per annum for meeting the basic requirements for agriculture, industry, energy and the environment. Availability below 1000 cubic metres is characterised as scarcity, and below 500 as absolute scarcity (Watkins 2006). Water shortages are experienced frequently in Timor-Leste; during regular dry seasons and during drier than average years (ADB 2004; Yance 2004; Costin and Powell 2006).

According to the World Health Organisation and UNICEF, the minimum daily water requirement for drinking and basic personal hygiene is 20 litres per day per person from a source within 1km of the household. Availability of less than 20 litres per day impacts negatively on the ability of people to maintain their physical health and dignity. If bathing and laundry washing are included, then the personal threshold increases to about 50 litres per day (Watkins 2006). In Timor-Leste most communities outside the established urban areas are below this threshold. In the case study site at Lequidoe, most people survive on 6-7 litres per day and so can be considered to be water insecure in the current climate.

Availability

Currently groundwater levels show large variation both with season and with total wet season rainfall. This indicates that, in general, groundwater relies on annual recharge and is likely to be sensitive over a short time frame to changes in rainfall (Wallace 2011a).

GA have classified aquifer types in Timor-Leste according to geology and “prospectivity”, i.e. potential flow rates or yields from aquifers. The major aquifer types in Timor-Leste are:

- Sedimentary aquifers with intergranular porosity have potential to hold large amounts of groundwater. Alluvial sedimentary aquifers have potential to be high yielding aquifers, with higher yield associated with greater porosity where sediments are more well-sorted sediments (e.g. Dili).
- Limestone karstic aquifers with fissured porosity are associated with many springs fed by groundwater and sensitive to rainfall. In limestone areas, groundwater recharge, storage and yield are affected by the age of the system and whether fissures and channels have formed (e.g. in and around Baucau).
- Fractured rock aquifers with localised porosity are low yielding and usually only sufficient for household use and animal watering. There is little or no porosity and groundwater is stored in existing fractures, with new channels not becoming larger with time. (e.g. Lequidoe in Aileu District).

A substantial proportion (about 33%) of the population live on high yielding sedimentary aquifers, particularly on the coast, (e.g. Dili), however, most of the population (44%) live on localised aquifers in the highlands (Wallace 2011a) (approximately equally on high and low yielding localised aquifers) (Fig.3.1).

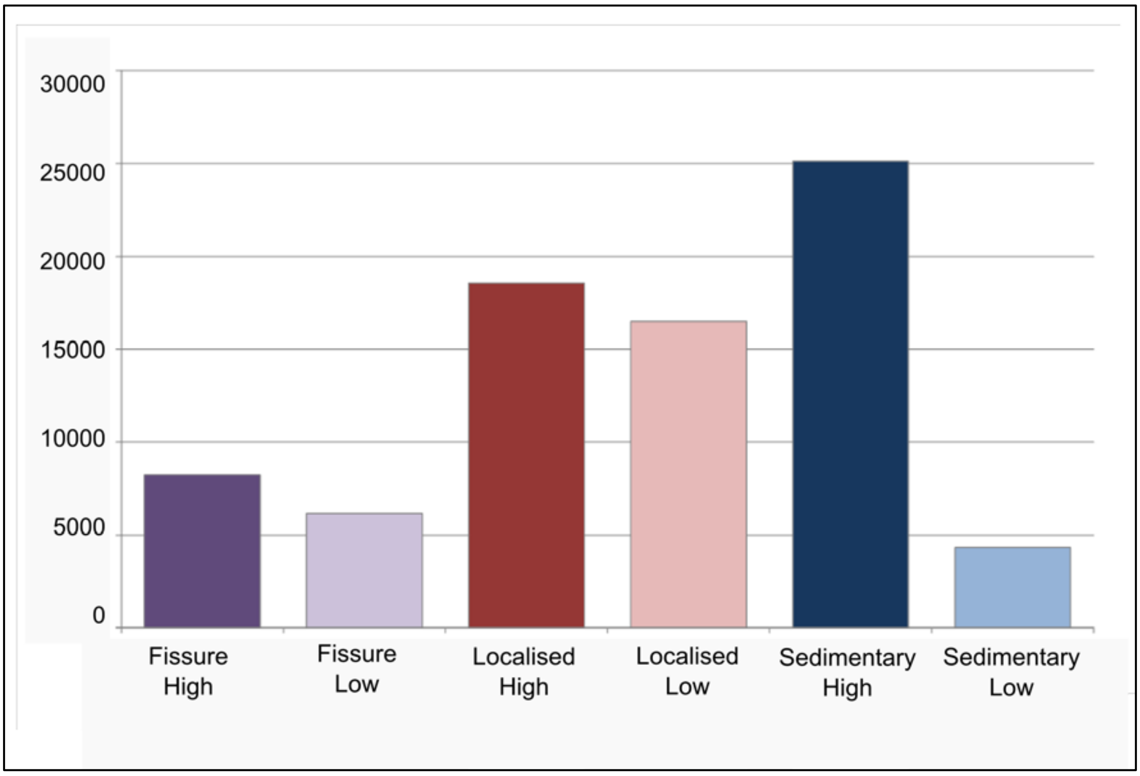


Figure 3.1 Population living on each of the major aquifer types.
Derived from 2004 census data.

Sources

The people of Timor-Leste access water from a range of surface (springs and rivers) and groundwater (wells and bores) sources. Surface water flows are closely linked to groundwater storage and flows (Wallace 2011a), so that, directly and indirectly, there is a heavy reliance on groundwater in Timor-Leste. Field studies were conducted at sites representing the main aquifer types (Fig. 3.2) and confirmed that there is a heavy reliance on groundwater, particularly shallow and deep sedimentary aquifers under Dili, and springs in areas with fissured and fractured rock aquifers (Table 3.1).

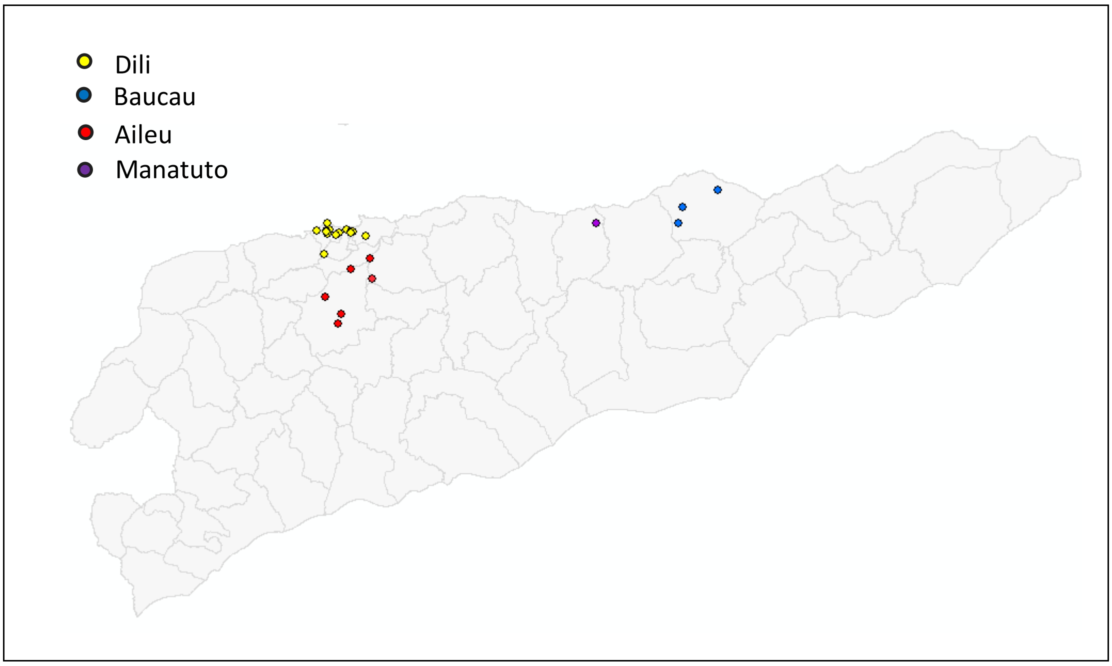


Figure 3.2 Location of field study sites.

Table 3.1 The main sources of household water reported by respondents in the field study sites.
Note: key informants included in interviewee numbers.

District	Aquifer type and yield	Setting	Household water sources
Dili	**Aquifer**: Intergranular (alluvial) **Yield**: High potential	Commercial users – hotels (15 interviewees)	• Piped water from deep aquifer, high quality water, chlorinated at pump site • Treated and filtered water from the Comoro and Bemori rivers delivered through municipal infrastructure • Bores into deep aquifer • Some shallow tube wells • Water Vendors to supplement supply from groundwater and piped treated water • Purchased bottled water for drinking • Several have large swimming pools filled with groundwater either from bores or supplied by water vendors. • Some have holding tanks for groundwater.
		Central urban areas (8 households)	• Piped water from deep aquifer, high quality water, chlorinated at pump site • Treated and filtered water from the Comoro and Bemori rivers delivered through municipal infrastructure • Tube wells into shallow aquifer, low quality. • Some households buy in drinking water • Bores into deep aquifer
		Peri-urban semi-permanent dwellings (10 households)	• Tube wells into shallow aquifer • Unprotected springs in the hillsides where people come to bathe, do laundry and collect water in small plastic jerry cans. • Some unreliable intermittent piped water using old infrastructure
		Peri-urban area (8 households)	• Shallow tube wells with salty water • Unprotected springs in the hillsides where people come to bathe, do laundry and collect water in small plastic jerry cans. • Some piped water using old infrastructure Some deep bores

		Peri-urban to rural (3 households)	• River – diverted and/or hand collected • Unprotected springs high up on ridges for other families at higher elevations.
Baucau	**Aquifer:** Fissured porosity (Karst) **Yield:** High potential	Urban (Old Town) (6 interviewees)	• Protected springs, piped water, unprotected springs, sometimes water vendors.
		Urban (New Town) (6 interviewees)	• Some piped water, water vendors, public taps, bores and springs.
		Rural (7 households, 15 interviewees)	• Newly installed public taps piped from local spring and under community management. • Previously collected from spring 1km distant, then moving to Osstiku spring approx 6-7 km distant in dry season, some rainwater collection, many houses have small concrete tanks.
Manatuto	**Aquifer**: Intergranular porosity (Sedimentary) **Yield:** High potential	Rural township (4 households, 4 interviewees)	• Piped water supply to main town, but frequently reliant on low quality river water dug from riverbed for extended periods of several months due to pumping station not working. • Many people of the opinion that rainwater causes illness if used for bathing or drinking. • Some households with drums to collect rainwater
Aileu	**Aquifer**: Localised (Fractured) **Yield**: Low potential	Rural (30 households, 25 interviewees)	• Limited piped water directly from unprotected springs in fractured rock. • Hand carrying from lower elevation springs as higher springs dry out in dry season. • River water. • Pipe system old with limited to no flow further along ridgelines, no water in dry season from pipes. People move to follow the springs down the mountains when those at higher elevations dry up • Very limited rainwater collection, but strong interest in all groups. From about August water becomes very scarce in this area.
Ermera	**Aquifer**: Localised (Fractured) **Yield**: Low potential	Rural (10 interviewees)	• Community reliant on small spring • Hand carry water from the river in the dry season when the spring dries up • Reported during 2009 the spring did not run, and had to collect water from the river.

3.2 Drinking water

Most rural households obtain drinking water from unimproved sources (Table 3.2). Whilst over 90% of urban households obtain drinking water from "improved" sources, this includes some sources for which quality and seasonal reliability are not guaranteed. The quality of bore water can be poor and vary with season. Intense rainfall events are associated with increased sediment flow and pollution, and in some areas water becomes temporarily unsuitable for drinking (Costin and Powell 2006). During our field study interviews, many communities reported that springs and groundwater sources they used became discoloured and dirty during the wet season. In coastal areas salt water intrusion can lead to salinisation of water sources (wells) and also to contamination of groundwater by sewage (Wallace 2011a).

Collection and use of rainwater is not widespread, and attitudes vary with some communities interested to try (e.g. Lequidoe and Kota Baru in Baucau) and others averse to the concept because of fears that drinking or washing in rainwater will cause illness (e.g. Laleia, Manatuto) (Table 3.2). Collection of rainwater is discussed in relation to adaptation options in section 8.

Table 3.2. Percentage of households with drinking water from improved or unimproved water sources.

Sources of drinking water	National average for Timor-Leste	Rural areas	Urban areas
Improved	66	57	91
Not improved	34	43	9

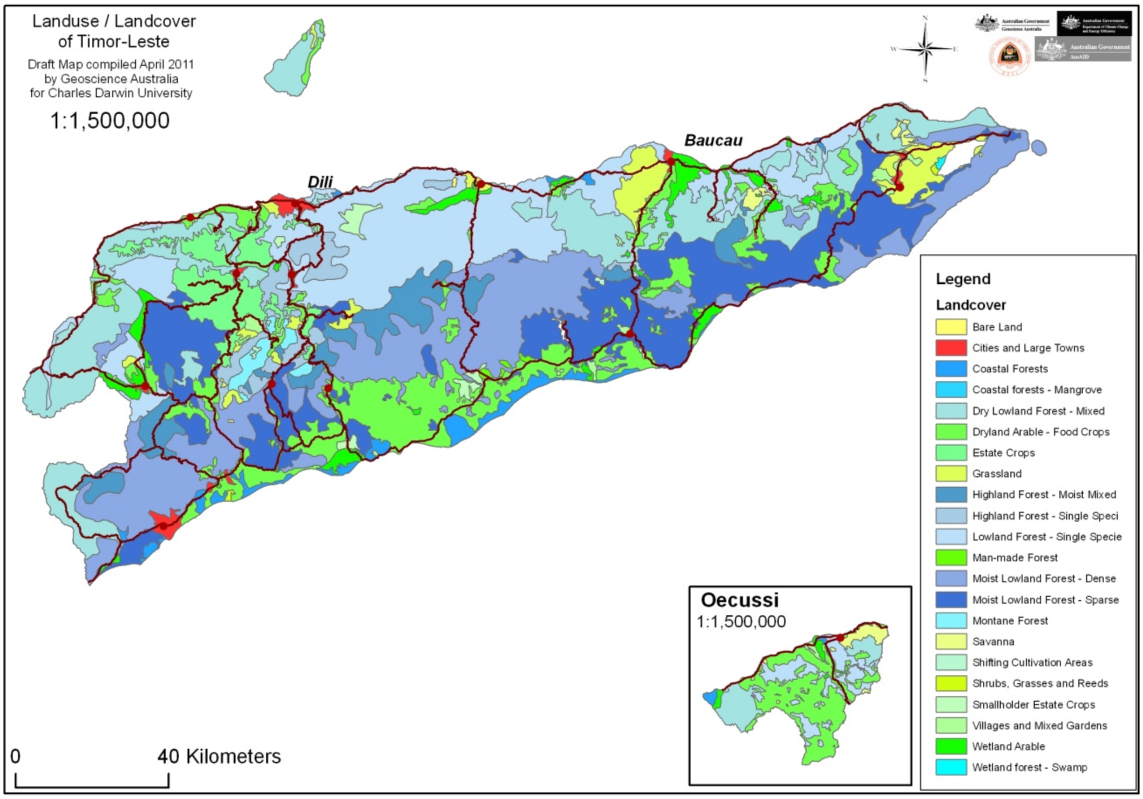
Data from National Census 2010. Improved sources include public tap, pipe or pump outdoors, protected spring or well. Not improved sources include unprotected spring or well or river.

3.3 Agriculture

Rain-fed subsistence agriculture is the primary livelihood for over 85% of households in Timor-Leste. The productivity of rain-fed agriculture directly affects food security. The productive capacity (yield per hectare) of farm land is affected by rainfall, soil fertility, weed burden, crop variety and slope. Ninety eight percent of farm land in Oecussi and ninety three percent in Covalima is reliant solely on rainfall, and this is indicative of the strong reliance on rain of most upland and dryland farming systems in Timor-Leste. Most households that are severely and moderately food insecure farm either rain-fed flat land, or rain-fed moderately sloping land, and few farm irrigated land (Oxfam Australia 2007) (Fig. 3.3). Rainfall and its distribution closely determine agricultural production, because irrigation systems are currently underutilised and used exclusively for rice production.

An FAO and WFP report (FAO/WFP 2007)indicated that 7% of land area is irrigated land. However the actual area irrigated with groundwater is estimated to be 2–3% of the total land area with irrigation infrastructure (de sa Benevides 2003; ALGIS 2001; FAO 2010). In 2004, total water withdrawal was estimated at 1,172 million m^3, of which 91.4 % was for agriculture, 8.4 % for municipalities, and 0.2 % for industry (FAO 2010). Further investigations are required to determine the effects of groundwater levels on dryland agriculture in Timor-Leste and the effects of agricultural land use on groundwater recharge.

(a)



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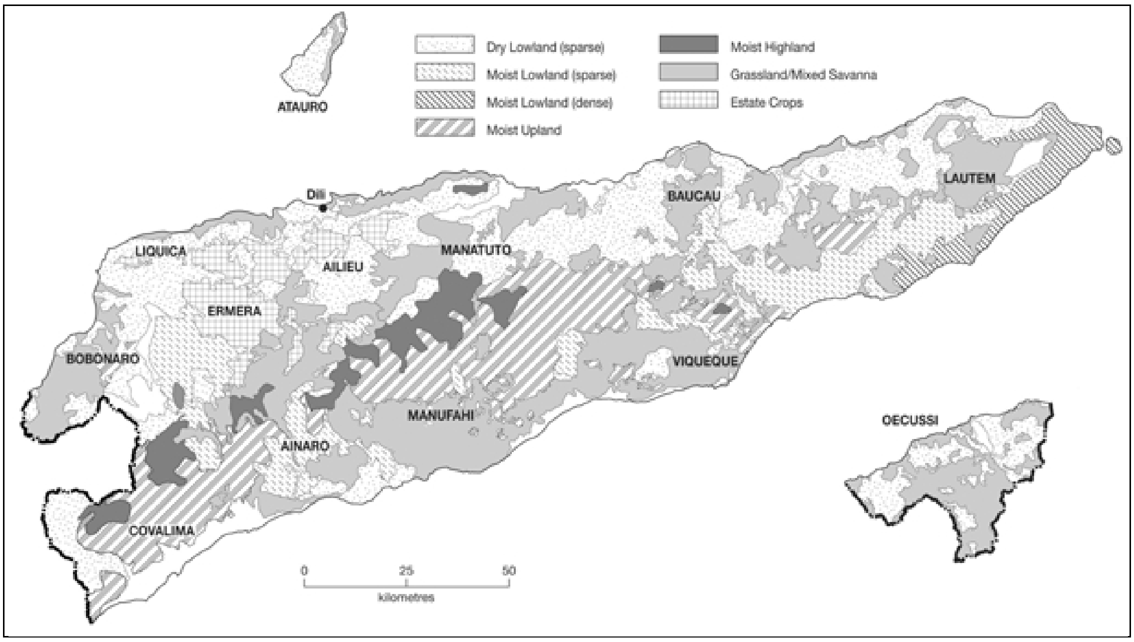

Figure 3.3 (a) Land use and land cover in Timor-Leste, (b) Major land use categories in Timor-Leste. (a) Compiled by GA; (b) Cited in McWilliam, 2003; adapted from map produced by the GIS Unit, Ministry of Agriculture and Fisheries, Dili,East Timor 2001.

3.4 Hydroelectricity

Hydroelectricity schemes in Timor-Leste have been investigated and some are operational, with one mini hydro-electric plant constructed to date at Gariuai (Dec 2011), and several more regional hydro-electric projects planned for the near future. The Iralalaru Hydro-electric project that was proposed for the Lautem District in the far eastern end of the island was rejected due to community concerns raised over the potential impact that the large Iralalaru project would have on water flows to local communities in the area and wider scale environmental impacts.

The Gariuai Mini Hydro system was opened in November 2008 and provides power to the city of Baucau. Situated in the small community of Gariuia between Baucau and Venilale, it is in a groundwater-fed karstic limestone catchment (Hoeiseth &Klei 2007). In 2009, Gariuai was closed due to a large landslip that damaged and exposed the piping infrastructure. The cause of the sudden sinkage is under investigation by geologists. At the time of writing, the Gariuai system was scheduled to be reopened within the month (DNGRA pers comm). The Gariuai hydroelectric plant “borrows” the water at the downstream side of a rice paddy field area situated on the edge of the elevated Baucau plateau. The water is released at the powerhouse outlet on the upstream side of a large, low level farmland area. In between the intakes and the outlet there is a small cultivated area that has access to irrigation water from a small spring not affected by the hydroelectric plant.

In early 2011, feasibility studies for two more hydro-electric power projects were analysed by the Council of Ministers and slated for future investment. These are planned for the Bulobo River in Maliana and the Magapu River in Atsabe. Hydrological measurement and assessment has also been undertaken for a potential new hydroelectric power project in Aiasa, Bobonaro District (HydroTimor).

4. Water management

4.1 National governance of water supply

Supply of potable water in Timor-Leste is the responsibility of the Ministry of Infrastructure and enunciated in the government's commitments under Infrastructure and Improving Living Conditions: "to provide potable water to its people, the government plans to legislate upon water usage, rehabilitate existing water treatment and sanitation facilities, perform maintenance on such facilities, and develop hydrologic studies aimed at the construction of multiple usage dams" (Timor-Leste 2011). Currently extraction of water is largely unregulated. As described in the previous section, many communities in Timor-Leste could be characterised as water insecure, particularly those on the low yielding fractured rock aquifers (such as Lequidoe), those on coastal plains with brackish aquifers (such as Tasitolu suco in Dili District), and where supply of water is intermittent because of extended power outages (such as Laleia town in Manatuto District).

4.2 Water governance in urban and peri-urban Dili

Dili is divided into 10 areas for the purposes of water management and supply, and the government water supply is sourced from a deep aquifer and in some areas mixed with treated and filtered river water collected in a weir in the hills behind Dili. The weir delivers water from the Comoro and Bemori rivers, where it is treated and filtered to reduce turbidity. Water is pumped from shallow aquifers that are subject to contamination by sewage and chemical intrusions. People pumping from the shallow aquifer with tube wells or 'dragon pumps' reported that the water is of low quality. Those accessing the deep aquifer through the government-provided network all reported good quality, clear water throughout the year. Most of the large hotels in Dili reported that they have deep bores and also buy water, delivered in trucks by water vendors. Our enquiries indicated that there are three suppliers in Dili, including one main private provider and one government provider, the National Directorate of Water and Sanitation (SAS). These suppliers provide water to hotels, restaurants and the community. They occasionally supply water to the upland areas near Dili, usually when there is a wedding or festival. The exact rate of extraction from the aquifer is not known, but the combined estimate from respondents to the field survey was about 570,000- 670,000L per week[4]. This is likely to be an under-estimate due to some under-reporting. Water vending businesses also operate from Baucau's Kota Lama (Old Town) and supply similar clientele, such as businesses in the city and some deliveries to the hinterland.

Some households in Dili already have water meters installed on their household pumps, and the installation of water meters is currently being implemented on a wider scale in Dili. At present there is no charge for the water. However many households are expecting to be billed for water use in the future and believe that this is the purpose of the meters.

4.3 Water governance in rural areas and communities

In October 2011, USAID launched a clean water project aiming to provide community tap stands to 70% of the rural population through the RWASH program. This program aims to set up District level water committees and train communities to build, manage and maintain water and sanitation systems and protect their water sources (USAID 2011).

In some areas, such as Darusala *aldeia* in Baucau District, there is strong local governance of water through a local water committee. In this area communities have traditional human and spiritual custodians *(bee nain*) of their water resources and its connection to the water flowing through the Old Town in Baucau via the karst system (Palmer 2010). The local committee in Darusala has recently installed new community taps that are funded through a tariff paid by local families. There is some concern about whether this will be sustainable, as some families may not be able to afford the tariff payments and will not make their contribution, with the follow on effect of other families unwilling to pay when others have free access.

Whilst some other communities also have a local committee in charge of water management, these are not always functional. During field interviews, several respondents reported that community members had attended training in Dili sponsored by aid projects, on water management and maintenance, but after the

[4] The estimate of water supply by water vendors in Dili to large businesses is derived from total reports of 114 -134 trucks per week, with each truck carrying 5000L.

training no one had taken on the responsibilities of maintaining water systems or managing the water in their community.

During field interviews, we expected to find traditional belief systems and stronger community management of local water resources in the areas that appeared to be water insecure. However this was not the case. In Baucau, where there was plentiful water supply, the traditional management and belief systems survived. However in water insecure areas (e.g. Lequidoe) we found little evidence of traditional community water management. This situation may relate to the capacity of local communities with good water supplies to develop higher levels of social capital around the resource, while in those areas where water is scarce, the level of competition is high and each household looks after its own interests (Feldman & Assaf 1999).

4.4 Reliability of water supply

Respondents from the peri-urban areas of Dili are at present somewhat water insecure with problems accessing potable water at times. One group from Becora have a pipe running to their households, but piped water often ceased flowing for weeks at a time. There were no problems with water supply during Indonesian times, but now no maintenance is carried out and the piped water is dirty and unreliable. Sewage is channelled into a hole in the ground near the houses. As an alternative to piped water, this group reported that they collect water from a small river nearby or from a local spring.

An evaluation of the ADB-funded Water Supply and Sanitation Rehabilitation Project (ADB 2004) concluded that maintenance was a major issue, especially for urban water supplies, and that community management systems had been unsuccessful due to a poor understanding of the social factors underlying the establishment of these systems.

Most households outside central urban areas hand collect water from unimproved sources, and some receive water piped from springs (Photo 4.3 & 4.4). In all of the case study sites in rural and peri-urban areas where people are reliant on piped water, the pipework was not maintained, had significant head loss due to off-takes and damage further up the line, or piping was not functioning at all. During our field interviews, some respondents reported significant leakage and loss of water through old pipes, and a lack of maintenance of infrastructure such as holding tanks around the water sources and springs leading to loss of valuable water. Common problems were taps on tanks that were broken soon after installation and never repaired or replaced.

In Lequidoe (Aileu District), a water-insecure site, piped water supplies the community until the spring runs dry in July to August each year. Most respondents in Lequidoe described carrying water by hand from springs at lower elevations after the higher springs become dry each year, with some people walking for 2 -3 hours on steep slopes. In the Kota Baru area of Baucau, many respondents hand carry water from springs and use water from bores and wells. Around the Triloka area of Baucau District people reported hand carrying water from as far as 5 km in the dry season, though recently installed community tap stands should alleviate this problem. “Collecting water is everyone’s work”, according to one respondent in Darusala *aldeia* (e.g. Photo 4.1). Respondents from all field study sites indicated that there is no demarcation along age or gender for this task. With the introduction of the government pension for seniors, a small economy has developed with the elderly paying others to fetch water now that the elderly can afford to pay for this help.

Photo 4.1 Girls with jerrycans carring water from spring to house

Communities on localised, fractured rock aquifers largely rely on springs, many of which stop flowing during the dry season. This was the case for communities interviewed in Lequidoe Sub-District and some respondents from Samalete and other sucos in Railaco Sub-District in Ermera District. One of the NGO's reported that there had been water infrastructure installed in several of the sucos in the Sub-District, but that maintenance was an unresolved and ongoing problem. Some of the systems were installed in 1994 under the Indonesian administration and they have not worked since 2004. One group interviewed in Samalete reported that they rely on two water sources: river water (a long way below the ridge top) and a small spring that stops flowing in the dry season. During 2009 the spring had no water at all and people had to rely entirely on river water.

4.5 Collection and use of rain water

We focus specifically on rainwater supply here as it appears to be an under-utilised resource, which has the potential to ameliorate some of the supply problems outlined above. Field interviews indicated rainwater is not widely collected and used, and attitudes to this varied among the field study sites.

In Lequidoe, a water insecure site described above, a few households had rainwater collecting containers (*kusin,* Photo 4.2), some supplied through World Vision or other NGOs and some made in Lequidoe. People reported that they were not sure why some households had these and not others, but all respondents in Lequidoe were keen to try rainwater harvesting. Most people were aware of the problems associated with water storage such as breeding mosquito larva and said that they knew to cover their drums, or to empty out their tanks after three days to prevent the insects from completing their lifecycle. However this is not a useful strategy for storing water for longer periods. Some houses have bamboo tubes to drain rainwater onto vegetable gardens. Households that have a *kusin* reported that it was not sufficient for their household needs, and all were very interested in building a bigger tank to hold more water. One respondent mentioned that families on Atauro Island have 600L tanks for rainwater collection and thought that would be ideal for Lequidoe. Households without *kusin* reported using buckets to collect rainwater in the wet. All household respondents in peri-urban areas were interested in rain water harvesting and were interested in ways of increasing storage capacity through to the dry season. Respondents from Baucau- Darusala and Kota Lama were all open to the idea of rainwater harvesting and some houses in Darusala, Triloka have small, square concrete tanks with metal piping from the roof (Photo 4.3).

In contrast, respondents in Laleia, in Manatuto District, were all firmly against rainwater harvesting for household use. People said that using rainwater for bathing, washing or drinking caused coughing and stomach aches and made them sick. Potential for contamination of water collected from roofs and due to corrosion of distribution pipes and storage containers in other locations is well documented (e.g. (Alam & Sadiq1989; Simmons *et al*. 2001).

Photo 4.2 Water collecting container, *kusin*, in the Lequidoe area

Photo 4.3 Rainwater collecting tank and bamboo pipe, Triloka area

5. Expected climate future for Timor-Leste

5.1 Climate models and projections – a cautionary note

Most climatic projections are based on Atmosphere-Ocean General Circulation Models (GCMs). Projections based on general circulation models are made with greatest confidence at continental and larger scales with reduced confidence at regional or meso-scales (IPCC 2007). Predictions for islands are associated with even more uncertainty. Timor island, with approximate dimensions of 60 x 500 km, is small compared with the typical general circulation models grid-cell resolution of 100-500 km and the topography is variable, reaching elevations of almost 3000 m. In Timor-Leste the absence of long term climatic data is also a major limitation for testing the validity of climate change models and projections. Climatic data for Dili is only available from 1950's and there are many gaps in the mid 1970s and around 2000. Figure 5.1 provides annual rainfall and mean air temperature for Dili showing these gaps. Automatic weather stations were installed at the airport in Dili by the Australian Bureau of Meteorology data but only provide a data stream from 2003 onwards.

Climatic records for Kupang (West Timor) and northern Australia are more complete than those for Timor-Leste these locations are useful as surrogate locations as they share a strongly mono-modal, seasonal rainfall distribution similar to that of Dili and the northern parts of Timor-Leste. Katzkey et al. (2010) (cited in Lasco and Boer 2006) presented rainfall data for Kupang from 1892 to the 1940s with some data up until 1979. There does not appear to be trend of change in annual rainfall but there does appear to be a slight increase in dry season rainfall and a weak trend of decrease in wet season rainfall. There are some decadal trends in rainfall in two comparative monsoonal locations in Indonesia selected by Lasco and Boer (2006), *i.e*. Kupang and Jakarta. A slight decline from 1900s to1920s is evident, with no change from 1920s to 1940s, and a slight increase 1940s to 1980. Given these trends, it is likely the rainfall over the last 100 years has not experienced significant changes, which is in contrast to north Australia, which is experiencing an increase in rainfall of approximately 10 mm per decade, especially since the 1980's (www.bom.gov.au/climate/change/aus_cvac.shtml).

At the time of publishing this report, the most recent national projections for Timor-Leste are those published by the Pacific Climate Change Science Program (Australian Bureau of Meteorology and CSIRO 2011; available at www.cawcr.gov.au/projects/PCCSP/publications.html).

5.2 Summary of most recent climate change projections for Timor-Leste

Climate projections for Timor-Leste are given by:

- Barnett et al. (2007), based on nine different general circulation models that are used in the IPPCC Third Assessment Report (IPCC 2001);
- Regional projections for Indonesia and Timor-Leste based on CSIRO-CCAM with 60km resolution by Katsfey et al (2010) cited in Lasco & Boer (2006);
- Projections based on coarse-resolution general circulation models and medium-resolution downscaling (Acil 2010);
- Climate change in Timor-Leste – a brief overview on future climate projections (Kirono, 2010);
- A plain language account of climatic projections for Timor-Leste is also provided by the Pacific Climate Change Science Programme (PCCSP 2011).

Average annual temperature is projected to increase by about 0.8^{o}C by 2020 (Table 5.1, Acil 2010). There are minor differences in the predicted changes in average temperature with season (Table 5.1).

Projections of changes in rainfall are made with greater uncertainty than those for temperature. Changes rainfall between years is affected by the southern oscillation index (SOI); there is a strong association between the SOI and dry season rainfall and onset of wet season rainfall (Kirono 2010). In Kupang, with a similar mono-modal seasonal rainfall distribution to Dili, there is a positive but weak correlation of SOI with dry season rainfall (Lasco & Boer 2006). The prediction of a small (2% by 2020) increase in annual rainfall comprises an increase in the wet season and little change or a slight decrease in rainfall in the dry season (Table 5.1).

Table 5.1. Climate change projections for temperature and precipitation for Timor-Leste. Projections are relative to the 1961-1990 reference period, presented in (Kirono 2010), derived from data presented in (Acil 2010).

		Projected changes					
		2020		2050		2080	
		mean	range	mean	range	mean	range
Air temp (°C)	Annual	+0.8	+0.6 to +1.0	+1.5	+1.2 to +1.7	+2.2	+1.6 to +2.7
	Dec-Feb	+0.7	+0.6 to +1.0	+1.5	+1.2 to +1.7	+2.2	+1.6 to +2.6
	Mar-May	+0.8	+0.6 to +1.0	+1.5	+1.2 to +1.7	+2.2	+1.7 to +2.6
	Jun-Aug	+0.7	+0.6 to +1.0	+1.5	+1.2 to +1.7	+2.1	+1.7 to +2.6
	Sep-Nov	+0.9	+0.7 to +1.0	+1.5	+1.3 to +1.8	+2.1	+1.8 to +2.6
Rainfall (%)	Annual	+2	-1 to +6	+4	-2 to +7	+6	-3 to +8
	Dec-Feb	+3	-2 to +6	+5	0 to +9	+5	0 to +12
	Mar-May	+4	-2 to +7	+5	-2 to +10	+7	-2 to +12
	Jun-Aug	0	-8 to +17	0	-18 to +15	- 5	-20 to +18
	Sep-Nov	0	-10 to +19	0	-11 to +18	--1	-20 to +17

Knutson *et al*. (2010) described the latest analysis of trend detection and attribution and future projections for shifts in frequency and intensity of tropical cyclones. This review suggested that extreme tropical cyclones will become slightly more intense by 2-11% by 2100) and potentially more frequent. Rate of rainfall within 100 km of the storm centre of the most intense storms is likely to increase by 20%. Their modelling also suggests there will be a decrease in the globally averaged frequency of less intense cyclones by 6-34% by 2100 (Knutson *et al*. 2010). There are predictions of increased variability in the climate, including increased variability in total annual rainfall and seasonality of rainfall, increased frequency of hot days and heat waves, and increased frequency and severity of droughts and floods. This prediction is consistent with the observation for northern Western Australia that in the 15 year period 1974-1988 there was an increase of 42% in storms of category 3 or 4 (Harper & Callaghan 2006) in (Kirono 2010).

Sea level is predicted to rise by 3.2 to 10 cm by 2020, 8.9 to 27.8 cm by 2050, and 18 to 79 cm by 2095, relative to conditions in 1990 (Kirono 2010).

5.3 Expected impacts of climate change on water availability and quality

The changes in total rainfall are uncertain and likely to vary with location. Rainfall events associated with extreme storms are expected to have a higher rainfall rate (Knutson *et al*. 2010). More intense rainfall events are likely to result in increased runoff, greater erosion and sedimentation, and decreased water quality. Indicative recharge zones have been mapped by GA however further investigation is required to predict the impacts of changing rainfall patterns on rates of recharge in different locations and with different land use.

During the dry season, the combined effects of increased temperature and little or no significant difference in rainfall could result in significant reductions in run off volume, as well as the seasonal drying out of some springs. Springs at higher elevations on fractured rock are the least reliable springs, and there is far less certainty for availability of water from these springs and their use for sourcing piped water than from springs on other aquifer types.

There is a greater risk to infrastructure, such as damage to roads, due to increased flooding events and increased intensity of rainfall (Acil 2010).

6. Sensitivity and exposure to future climate change with respect to groundwater resources in Timor-Leste

Geosciences Australia (GA) has classified the major aquifer types in Timor-Leste according to rock type and potential relative yield within each aquifer type (Fig. 6.1). Storage and flow characteristics are comparable within an aquifer type however they are not necessarily comparable between aquifer types. For example, the yield of a high yielding localised aquifer is lower than that of a high yielding sedimentary aquifer.

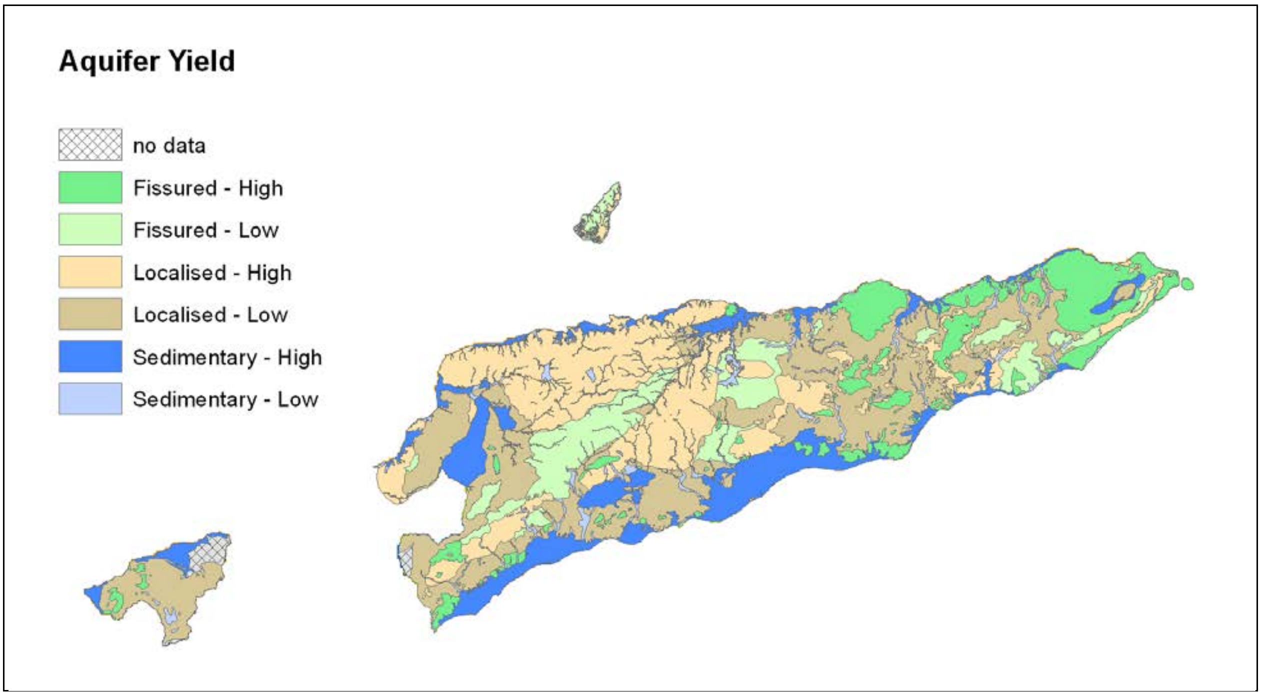

Figure 6.1 Aquifer types according to Wallace *et al.* (2011a,b).
Note that localised aquifers are lower yielding than the other aquifer types, with the “Localised – Low” category having negligible yield.

From this classification GA has derived a map of relative aquifer yield (Fig. 6.2). Sensitivity of aquifer yield to climate change is greatest on localised aquifers. For localised aquifers, changes in rainfall are quickly observed in the outflow from springs. These aquifers provide little buffer to seasonal and inter-annual variations in rainfall. The localised aquifers with low relative yield are largely impermeable so may be considered as confining units rather than functioning as aquifers (Luke Wallace GA pers comm.).

The map of classification of aquifer yield (Fig. 6.2) was overlain with the model of current rainfall distribution (Fig. 2.3) to produce another map of sensitivity of aquifer yield to changing rainfall (Fig. 6.3).

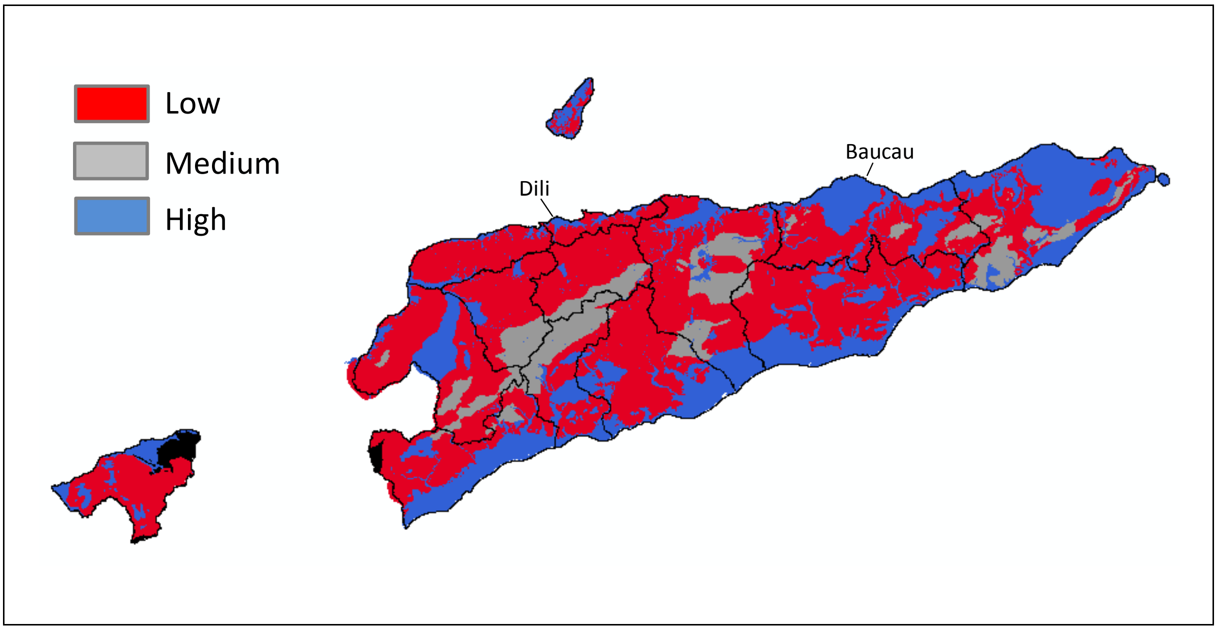

Figure 6.2 Ranking of relative aquifer yield according to Wallace *et al.* (2011a).
Ranking derived from Fig. 6.1 with a yield ranking of low attributed to all localised aquifers, a ranking of medium to fissured aquifers that are relatively low yielding, and a ranking of high to fissured aquifers that are relatively high yielding and all sedimentary aquifers (Wallace 2011a).

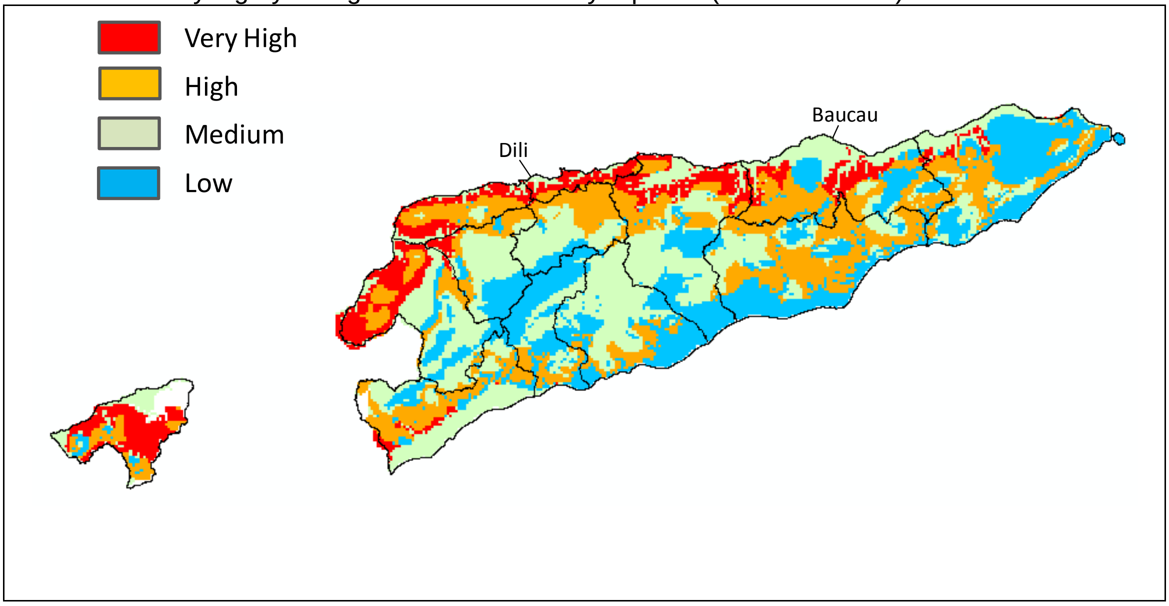

Figure 6.3. Predicted sensitivity to reduced water availability.
Sensitivity derived from a combination of modelled current rainfall distribution (Fig. 2.3) and ranking of aquifer yield (Fig. 6.2). For example, locations with low current rainfall and aquifers of low potential yield were ranked as high or very high sensitivity in Fig. 6.3.

This analysis indicates that water resources in areas along the central northern coast and in Oecussi are expected to be particularly sensitive to climate change (Fig 6.3).

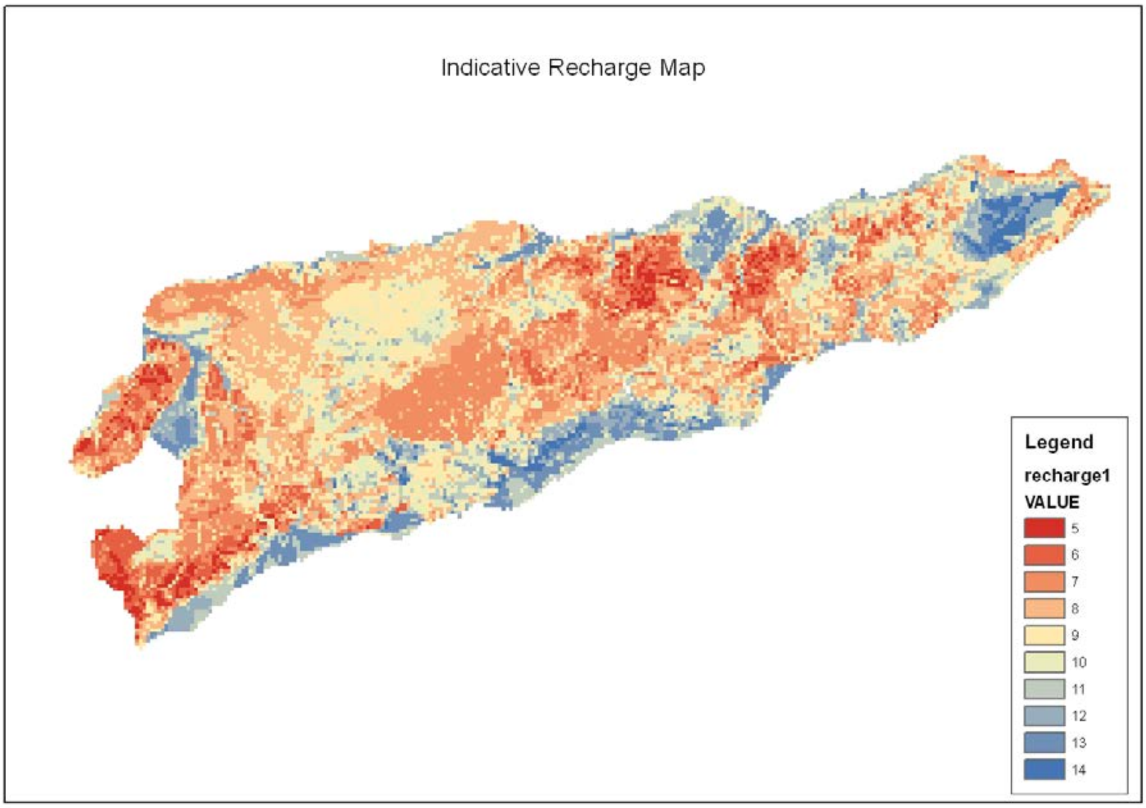

Figure 6.4 Indicative recharge from low (red) to high (blue).
Recharge derived by GA (Wallace *et al*. 2001a,b) by overlaying hydrogeology (Fig. 6.1), land use/cover (Fig. 3.2), soil types, slope, and rainfall (Fig. 2.3).

In general and where possible, management plans should aim to maintain or increase recharge rates to ensure adequate water yields from aquifers, including maintaining the buffering capacity of aquifers in times of less or more variable rainfall. For fissured and sedimentary aquifers, groundwater can be a significant resource, such as for the major towns of Baucau and Dili respectively. It is important that aquifers are sufficiently and consistently recharged to provide adequate groundwater in the long term. In the central highland regions of Timor-Leste, recharge rates are relatively low and recharge is closely linked in time and space to the flow of water from springs.

Rates of recharge, i.e. rates of water entering the aquifer systems, are affected by multiple factors used to indicate the relative recharge rates shown in Fig. 6.4. In some situations changes to land use and land cover can have a large effect on rates of recharge. Further investigations are needed to fully understand the effects of land use on recharge rates in a range of geologies and topography. The characterisation of aquifers by GA (Wallace 2011b) has significantly increased our understanding of the hydrogeology of Timor-Leste, however, further investigations are needed to understand the processes related to connectivity between aquifers and the implications of changes to land and water use on aquifer yields in neighbouring sites.

7. Assessment of potential impact on groundwater resources in Timor-Leste

Sensitivity to climate change has been described above by a ranking of sensitivity of potential aquifer yield to changes in rainfall (Fig. 6.3). Sensitivity was also related to population pressure. Population density indicates the locations where population is concentrated, e.g. indicated by household population data recorded in the 2004 census (Fig. 2.1). Household level population data are not available for the 2010 census because of concern for confidentiality. Population pressure (at the scale of Sub-Districts) was derived from a combination of the population density in 2010 and population growth between the 2004 and 2010 census. Sub-Districts with both high population density and rapid population growth were deemed to be highly sensitive in terms of population pressure.

Potential impact of population pressure was represented in two ways, in Figs. 7.1 and 7.2. In both figures potential impact is a function of exposure (current rainfall, Fig. 2.3) and sensitivity of aquifer yield to changing rainfall (Fig. 6.1). In Fig. 7.1, population pressure was population density (using household population data from 2004), and in Fig. 7.2, population pressure was a combination of population density in 2010 and population growth from 2004 to 2010.

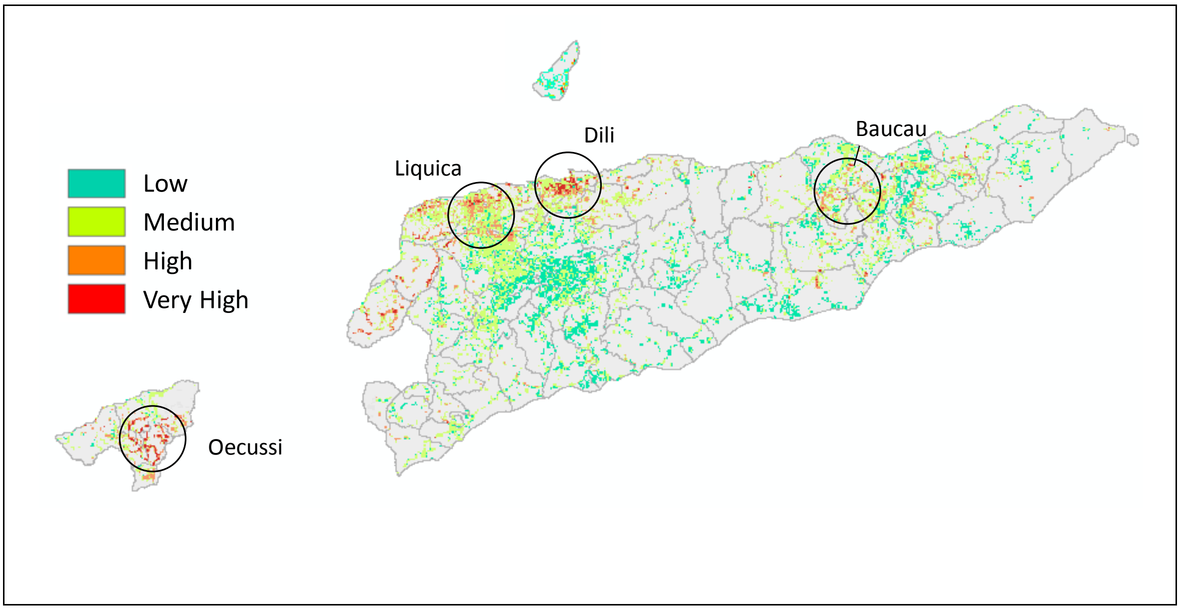

Figure 7.1 Potential impact of climate change, as a function of sensitivity of potential aquifer yield and population density for 2004.
Circled areas encompass areas of high potential impact.

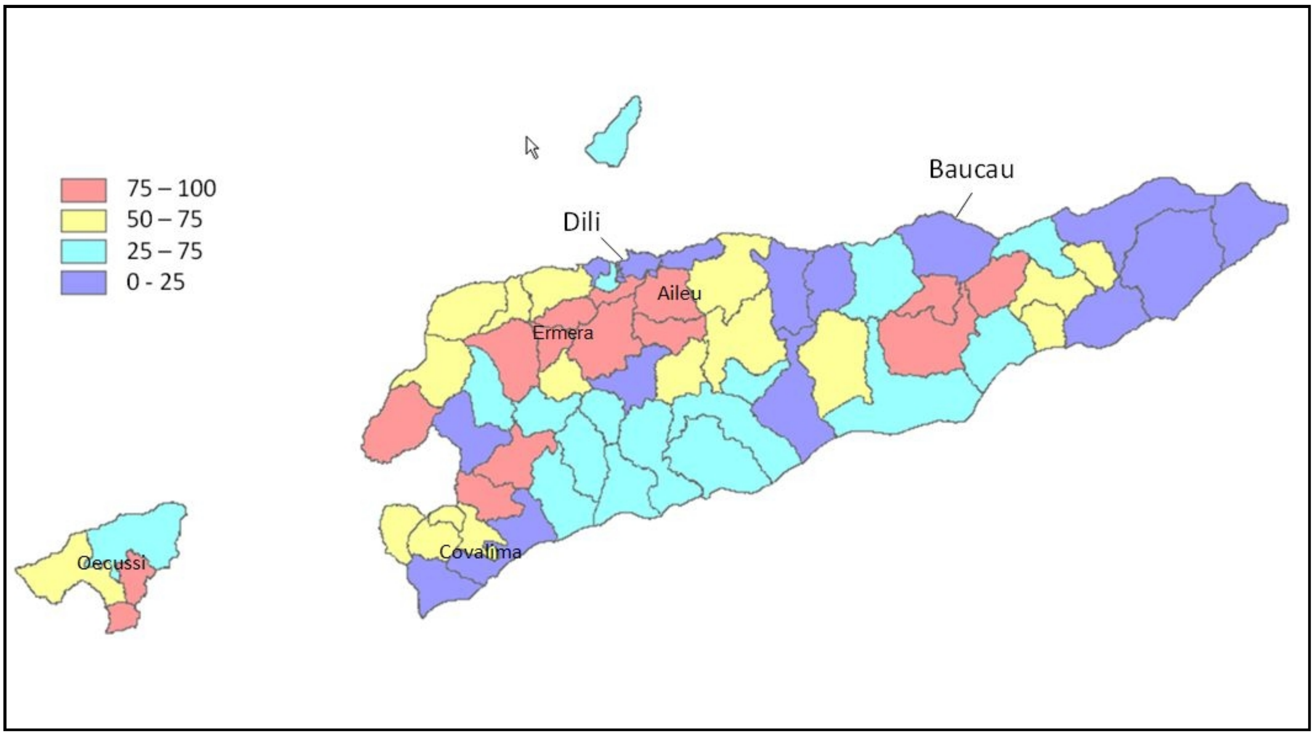

Figure 7.2 Percentage of population by Sub-District living on localised aquifers.
Based on 2004 census population distribution data.

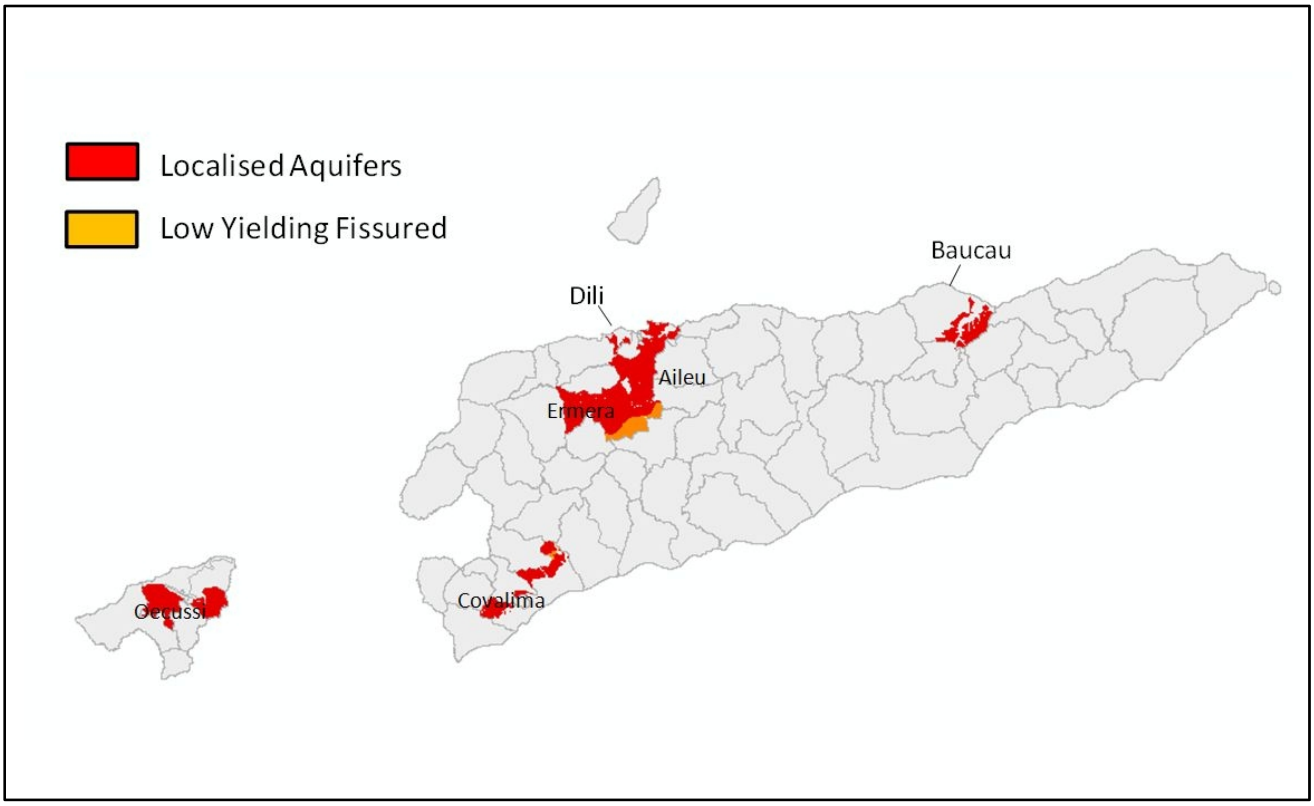

Figure 7.3 Areas of high potential impact, measured as a function of high population pressure.
Defined as Sub-Districts with population increase between 2004 and 2010 greater than 20% and population density greater than 80/km^2 (Fig. 7.2) and in regions of high exposure with respect to potential aquifer yield (Fig. 7.1).

In this analysis, Dili was identified as an area of high potential impact to climate change as highlighted in Figures 7.1 and 7.3 despite being underlain by a high yielding sedimentary aquifer. Dili and the surrounding peri-urban areas are considered to be an area of high potential impact because of the high population density, high population growth and dependence on groundwater (Table 7.1). Dili is underlain by a shallow sedimentary aquifer, and a deeper sedimentary aquifer of a larger capacity that is partially confined by clay lenses. Changes in rainfall patterns and intensification of land use on the slopes surrounding Dili could reduce recharge rates and thus water availability. Sea level rise and the associated risk of salt water intrusion also pose a substantial threat to groundwater quality. Dili is also in a relatively low rainfall area (Fig. 2.3; described as a potentially highly drought prone zone in the NAPA of Timor-Leste, limiting alternative water storage and capture options. Despite the presence of a high yielding aquifer, population pressure results in the Dili area having a high potential for adverse impacts on water quality and yield in the future. There is potential for water availability concerns due to over extraction of groundwater in the long term, such as are experienced in Perth in Western Australia where a large population is reliant on groundwater. Monitoring of water table levels and aquifer yields, and regulation of ground water extraction are necessary to ensure sustainable utilisation in the long term.

Liquica has been identified as an area of high potential impact because the aquifers here are mostly localised and relatively low yielding, and rainfall is relatively low (Table 7.1). The sedimentary aquifer underlying Dili becomes narrower with distance west of Dili and is a very narrow coastal strip at Liquica.

The Liquica District borders the western part of the highlands, comprising the Districts of Ainaro, Aileu, Bobonaro, Emera, which have large and increasing populations, also living on localised aquifers that are highly sensitive to climate change. Over 70% of people in Ainaro, for example, live on areas underlain by fractured rock with virtually no groundwater resources. This region has relatively high rainfall and so there is potential here to collect rainwater for domestic use for greater water security. Changing land use due to increasing population in this region could potentially reduce ground water recharge and groundwater resources lower in the catchment. Increasing the capacity to use rain water in this region could be a useful adaptive measure for those communities living on low yielding aquifers.

The analysis also identified Oecussi and Baucau as potentially experiencing high impact due to climate change (Fig 7.1 and 7.3; Table 7.1).

Most of Oecussi is underlain by fractured rock of extremely low potential yield, so that about 56% of the population have access to virtually no groundwater resources. Many parts of the enclave are experiencing high population pressures (Fig. 2.3). Most indicators show that this region has high levels of poverty and poor health which potentially reduces their adaptive capacity.

Baucau has a fast growing population (increased 24% from 2004 to 2010) with large demands on water for horticulture, crop production and some inland aquaculture. Although aquifer yields are generally high in the Baucau area, there are areas on low yielding aquifers, such as the urban area of Kota Baru and the hinterland near Venilale. Continued high population growth in this region will place significant stress on the limited groundwater resources of this region.

It is noted that Lequidoe is not listed in Table 7.1 but has been identified by RWSSP and World Vision (Lindsay Furness pers comm) as highly at risk. Although water supply is good in the western part of Aileu, Lequidoe, on the eastern side, has comparatively low rainfall and aquifer yield.

Table 7.1 Sub-Districts of potentially high impact.
Based on high population density and/or low aquifer yield potential.

District	Sub-District	Population density (persons/km^2)	Dominant aquifer type	% of population in Sub-District living on aquifers of high-medium sensitivity
Dili	Christo Rei	845	Sedimentary, high yielding	1
	Vera Cruz	1030		
	Dom Aleixo	3186		
Liquica	Liquica	41	Localised, low yielding	30
Baucau	Venilale	103	Fissured	32
	Baucau	125		
Oecussi	Oesilo	101	Localised, low yielding	56
	Pante Macasar	94		

8. Adaptive capacity and vulnerability to climate change in relation to groundwater in Timor-Leste

8.1 Adaptive capacity to climate change impacts

“Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences” (IPCC 2007). At a national scale, rankings of adaptive capacity are usually integrative measures such as the UNDP Human Development Index (HDI). Haddad (2005) noted that indices, such as HDI, are insufficient because they do not incorporate “the normative or motivational context of adaptation”. Many possible indicators of adaptive capacity have been proposed, including wealth, technology, education, information, skills, infrastructure, access to resources, and management capabilities (IPCC 2001). In the current study, some potential indicators were investigated using data that was readily available from the National Census (NSF & UNFPA 2010) and the Demography and Health Survey (NSD 2009). Many papers describe the role of social capital, or the “ability to act collectively”, as a determinant of adaptive capacity (e.g. Adger (2003)). In the current study, social data collected at selected field sites has provided some information about social aspects of adaptive capacity.

Poverty measured by income

In the present study, poverty was used as an indicator for adaptive capacity at the District level, with poverty being defined as percentage of the population in the two lowest wealth quintiles.

Many possible indicators of adaptive capacity may be correlated with poverty or inversely correlated with wealth. Wealth at the household level can be an indicator of adaptive capacity as it combines a range of factors related to the resources available to deal with changing conditions.

> “Wealth quintiles provide a consistent measure of combined indicators of household income and expenditures. The wealth quintile, as constructed, uses information on household ownership of various consumer items, ranging from household assets like a television, means of transport like a bicycle, and ownership of land and farm animals, to dwelling characteristics, such as source of drinking water, sanitation facilities, and type of building materials used in the construction of houses.” (NSD 2010; Timor-Leste Demographic and Health Survey (2009-10)).

Wealth is concentrated in Dili District, where 71% of the population is in the highest wealth quintile (NSD 2010). Using the percentage of the population in the two lowest income quintiles as a measure of poverty, Dili District has markedly less poverty (2%) compared with all other Districts (33% to 63%; Fig. 8.1; NSD 2010).

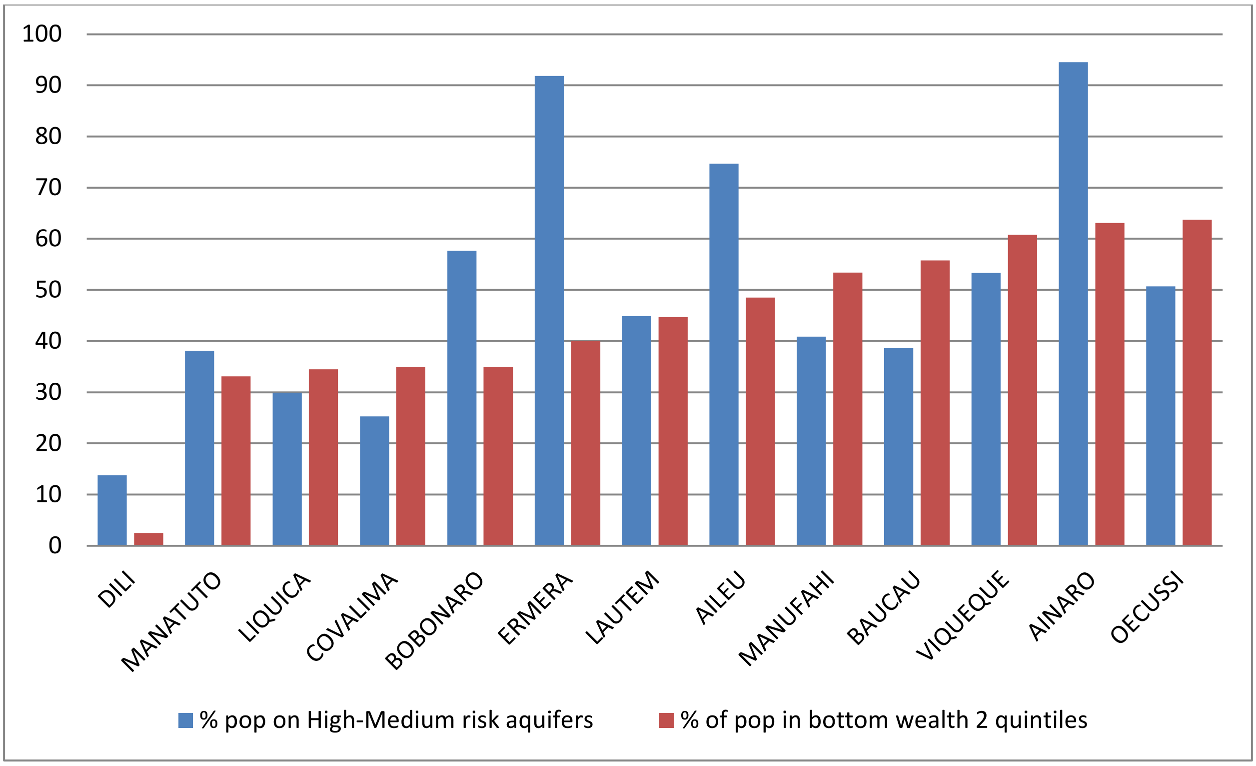

Figure 8.1. Sensitivity of potential aquifer yield and measure of poverty.
Sensitivity of aquifer yield in blue; % population living on aquifers of medium to high sensitivity; Poverty in red; % population in two lowest wealth quintiles.

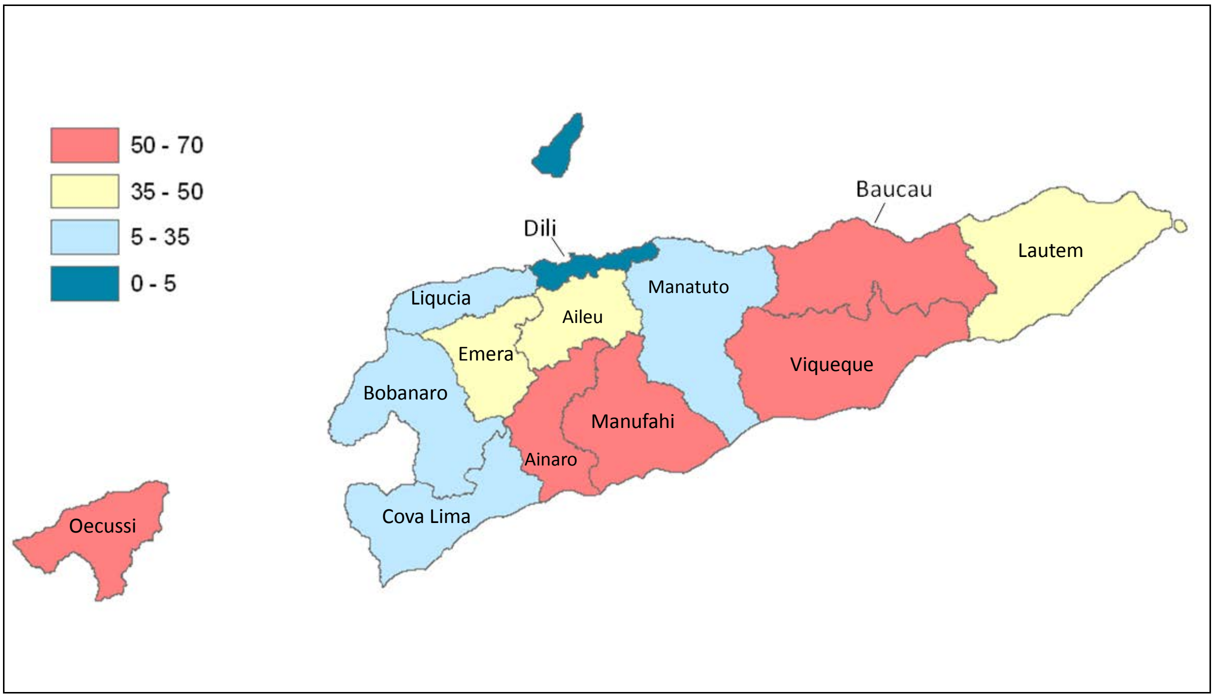

Figure 8.2 Map of indicator of poverty based on 2010 census data.
Poverty measured as % of population in two lowest wealth quintiles in each District.

Comparison of potential indicators of poverty, education and health

Adaptive capacity is made up of

- willingness to change - influenced by awareness, education and political will
- ability to change - wealth, health, social capital
- know-how to change – having viable options that are adoptable (relative advantage and trialability factors) and also having the technical skills and knowledge needed for implementation

In order to broaden the consideration of adaptive capacity for people in Timor Leste, 18 potential indicators of adaptive capacity were determined for each of the Districts.
To broaden the consideration of adaptive capacity, 18 potential indicators of adaptive capacity were determined for each of the Districts. These potential indicators can be loosely grouped as characteristics of wealth, education, and health of households:

- Wealth: % in two lowest income quintiles, owning radio, owning a motorbike, concrete or tiled floor in house, iron roof on house, electric light in the house
- Education: never attended school, use of mosquito nets
- Health: indicators of child malnutrition (height for age, weight for height, weight for age, anaemia), child vaccination

Details of these potential indicators and the sources of data from which they were derived are listed in Appendix III. Scatter plot matrices (SPLOM) were constructed to investigate correlations between these parameters and principal components analysis (PCA) was undertaken to quantify the contribution of each in the ranking of Districts (Appendix III).

The investigation of other potential indicators of adaptive capacity (listed in Table 8.1) using SPLOM and PCA (Appendix III) is summarised here. The indicator of poverty (% of population in two lowest wealth quintiles) was negatively correlated with ownership of a motorbike, a concrete or tiled floor in the house, a corrugated iron roof, electric light in the house, and positively correlated with use of wood for cooking. The values of these parameters for Dili were outliers. When the data for Dili were excluded from these analyses, these correlations between parameters were weaker although generally showed the same trends (Fig. III.2). This group of potential indicators of adaptive capacity reflect relative poverty and illustrate that Dili is both relatively wealthy compared with the rest of Timor-Leste and has relatively high capacity to pay for adaptive measures.

There were no correlations between these measures of poverty and the parameters related to education, children's health and use of mosquito nets by pregnant women and children (Fig. III.1 and III.2). There was a positive correlation between the proportion of the population who had not attended school and indicators of poor child health (malnutrition and anaemia, Fig. III.1 and III.2). There was a negative correlation between the proportion of children with no vaccinations and the use of mosquito nets by children and pregnant women, possibly indicating the relative effectiveness of public health programs. Not surprisingly, use of mosquito nets by children and pregnant women were highly correlated, suggesting that either one of these parameters could be a proxy for both. Similarly, there were correlations between two of the measures of child malnutrition, i.e. proportions of children with height for age and weight for age more than three standard deviations below the mean. The potential indicators related to health may reflect public health programs that have targeted poorer communities.

Ranking of Districts according to these potential indicators of adaptive capacity are listed in Table 8.1.

Social capital is an important component of adaptive capacity (Adger 2003). Our field studies revealed examples of communities and households cooperating to adapt to current climatic variability (Table 8.2). Examples of adaptations vary with site and the more highly developed adaptations were not associated with greatest water insecurity within the sites in our study. Examples of adaptations to seasonal water shortages included households carrying water great distances and harvesting rainwater from their roofs, and communities moving temporarily to lower elevations to access water when springs ceased flowing in the late dry season. In some sites, management of water resources was maintained at the community level for the protection of springs from degradation and over-utilisation. Further investigations are required to fully describe the aspects of social capital that contribute to adaptive capacity at both the community and District levels in Timor-Leste.

As expected, our field studies showed that within the urban areas of Dili there is high adaptive capacity associated with costly measures including pumping water from deep and shallow aquifers and buying water.

In general, empirical evidence suggests an association between high levels of poverty and low levels of social capital, due to increased competitiveness for scarce resources, and low levels of trust (Feldman & Assaf 1999). Social capital relies on trust within communities, institutions and agencies of governance. In a post-conflict nation such as Timor-Leste low levels of trust could be expected. However, our field studies (Table 8.2) indicated that some relatively poor communities demonstrated adaptive capacity indicative of high social capital including effective community management of water resources and accessing water sources from distant locations when necessary. The substantial resilience and adaptive capacity of the rural communities of Timor-Leste should be acknowledged and further developed to address the challenges of changes to water resources created by climate change.

In summary, this investigation of some potential indicators of adaptive capacity highlights the contrast between the wealth and living conditions in Dili compared with other Districts. However, other characteristics that may indicate adaptive capacity, (e.g. proportion of children immunised and women's participation in key decisions) gave a different ranking of Districts. Further study is required to evaluate potential indicators of adaptive capacity by comparison with observed adaptations. Readily available data, such as those used in Table 8.1, do not measure social aspects of adaptive capacity.

Table 8.1. Ranking of the Districts in East Timor based on a set of potential indicators of adaptive capacity.
Potential indicators of adaptive capacity are described and investigated in Appendix III.

Potential ranking of adaptive capacity	Poverty	Radio	Mbike	Concrete or tile floor	Iron roof	Electric light	Wood for cooking REVERSE RANKING	Drinking water - piped indoors or outdoors	Never attended school REVERSE RANKING	Child vaccination	Child malnutrition			Child anaemia REVERSE RANKING	Use of mosquito net		Women participate in decisions
											Ht4age REVERSE RANKING	Wt4Ht REVERSE RANKING	Wt4age REVERSE RANKING		children	pregnant women	
Least	Oecussi	Viqueque	Ermera	Viqueque	Oecussi	Ermera	Ermera	Baucau	Ermera	Manufahi	Ermera	Aileu	Oecussi	Manatuto	Ainaro	Ainaro	Lautem
	Ainaro	Oecussi	Ainaro	Ainaro	Viqueque	Ainaro	Covalima	Covalima	Oecussi	Dili	Bobonaro	Manatuto	Ermera	Baucau	Manufahi	Ermera	Covalima
	Viqueque	Lautem	Viqueque	Baucau	Baucau	Oecussi	Liquica	Viqueque	Ainaro	Liquica	Ainaro	Viqueque	Bobonaro	Lautem	Ermera	Manufahi	Baucau
	Baucau	Covalima	Baucau	Ermera	Manatuto	Bobonaro	Oecussi	Ainaro	Bobonaro	Ermera	Oecussi	Oecussi	Baucau	Oecussi	Baucau	Baucau	Manufahi
	Manufahi	Manatuto	Manatuto	Oecussi	Manufahi	Manufahi	Viqueque	Lautem	Liquica	Ainaro	Baucau	Ermera	Ainaro	Bobonaro	Liquica	Liquica	Dili
	Aileu	Baucau	Liquica	Aileu	Ainaro	Aileu	Aileu	Aileu	Manatuto	Baucau	Manufahi	Bobonaro	Liquica	Viqueque	Viqueque	Oecussi	Aileu
	Lautem	Bobonaro	Lautem	Manatuto	Covalima	Viqueque	Ainaro	Manufahi	Viqueque	Manatuto	Covalima	Ainaro	Manufahi	Liquica	Bobonaro	Lautem	Viqueque
	Ermera	Liquica	Aileu	Manufahi	Bobonaro	Covalima	Baucau	Ermera	Manufahi	Bobonaro	Liquica	Manufahi	Covalima	Aileu	Lautem	Viqueque	Ainaro
	Covalima	Manufahi	Oecussi	Lautem	Ermera	Liquica	Lautem	Oecussi	Covalima	Viqueque	Viqueque	Baucau	Viqueque	Manufahi	Oecussi	Aileu	Ermera
	Bobonaro	Aileu	Manufahi	Liquica	Aileu	Baucau	Bobonaro	Manatuto	Baucau	Oecussi	Manatuto	Liquica	Aileu	Covalima	Aileu	Bobonaro	Liquica
	Liquica	Ainaro	Bobonaro	Bobonaro	Lautem	Lautem	Manufahi	Bobonaro	Aileu	Covalima	Lautem	Covalima	Manatuto	Ainaro	Manatuto	Covalima	Oecussi
	Manatuto	Ermera	Covalima	Covalima	Liquica	Manatuto	Manatuto	Dili	Lautem	Lautem	Aileu	Dili	Dili	Dili	Dili	Dili	Manatuto
Most	Dili	Dili	Dili	Dili	Dili	Dili	Dili	Liquica	Dili	Aileu	Dili	Lautem	Lautem	Ermera	Covalima	Manatuto	Bobonaro

Poverty	% population in two lowest wealth quintiles	Census 2010
Radio	% households that own a radio	Census 2010
Mbike	% households that own a motorbike	Census 2010
Floor	% houses with concrete or tiled floor	Census 2010
Roof	% houses with corrugated iron roof	Census 2010
Light	% houses with electric light	Census 2010
Wood	% households that use wood as a fuel for cooking. Note, wood not necessarily only fuel for cooking	Census 2010
Water	% households with drinking water delivered by pipe, either indoors or outdoors	Census 2010
NoEd	% individuals 5 years or older who have never attended school	Census 2010
Vacc	% children who have received the four main vaccinations, i.e. DPT, polio, hepatitis B, measles	Demography and Health Report 2010
NoVacc	% children who have received no vaccinations	Demography and Health Report 2010
Mal	Measure of malnutrition. % children with height for age more than 3 standard deviations below average	Demography and Health Report 2010
Wt4Ht	% children with weight for height more than 3 standard deviations below average	Demography and Health Report 2010
Wt4age	% children with weight for age more than 3 standard deviations below average	Demography and Health Report 2010
Anaem	% children with anaemia	Demography and Health Report 2010
NetK	% children who slept under any kind of mosquito net the night before the survey	Demography and Health Report 2010
NetW	% pregnant women who slept under any kind of mosquito net the night before the survey	Demography and Health Report 2010
W4Dec	% women who participate in decisions relating to four areas, i.e. own healthcare, major household purchases, daily needs, visit to friends & family	Demography and Health Report 2010

8.2 Existing adaptations or coping strategies

Communities in rural Timor-Leste demonstrate a range of strategies for coping with current climatic variability, as described from our field studies. These aspects of adaptive capacity are not necessarily related to wealth and are indicative of social capital. Where water supply from springs ceased during the dry season, some communities coped by accessing water from springs at lower elevations, in some cases living temporarily at lower elevations.

The situation in the Sub-District of Lequidoe exemplifies these problems and some community responses. Lequidoe is water insecure. Although located in the mountains with an altitude of over 1200m, Lequidoe tends not to receive the orographic rainfall generated in the dry season which falls in the wetter neighbouring area of Remexio to the north. In Lequidoe, the vegetation is stunted, (Photos 8.1), indicative of relatively low rainfall, soils which are shallow, nutrient-poor and of low water holding capacity, and low yielding fractured rock aquifers. The communities in Lequidoe are mainly concentrated along the main ridge lines, however families tend gardens and harvest coffee at lower elevations. Water supply to ridge tops is problematic. There were mixed responses regarding reasons for living on ridge tops and willingness to move to lower elevations closer to water sources: some respondents said that they were encouraged to live on the ridges by the Indonesian administration to enable better access to services and infrastructure, and many people said that their ancestors had always lived on ridge tops and they would not consider moving elsewhere.

Photo 8.1 Houses on ridgeline in Lequidoe area, with sparse vegetation cover

Some communities in Lequidoe have access to water piped from springs, although the volume delivered by the pipes decreased significantly with distance along the ridgelines due to off-takes and holes in pipes. In general infrastructure is poorly developed and maintained. People reported that the piped water becomes dirty and discoloured during the wet season and that the springs at higher elevations become dry during the dry season, in about August each year. When piped and spring water cease or become unsuitable, people collect water from springs at lower elevations until they also become dry, eventually hand carrying water from the river many hundreds of metres below their households. It appears that people in this area are relying on a very shallow, low-yielding aquifer for which yield is directly linked to rainfall and is recharged locally (Wallace 2011a). If the wet season is relatively short, these springs will become dry earlier in the dry season. If rainfall events become more intense, even if total rainfall does not change, there may be increased run off and less recharge to these aquifers. If there is increased runoff in the wet season, there is likely to be increased sedimentation and greater particulates present in water supplied in pipes.

In some areas piped water is not available at all, such as in at least two *aldeia* in the Fahe Ria suco (Aileu District). People here carried water at least twice a day from two sources; a spring that provided low quality water only useful for vegetable gardens, and from a more distant source (40-60 minutes walk) for drinking. About 42 families relied on these two water sources and sometimes people waited hours for sufficient water flow for collection. There variability in the yields of springs reported within this area was consistent with the localised nature of the aquifers in this fractured rock. Similar to communities in Lequidoe, many of the households interviewed in Fahe Rio moved temporarily to the water sources at lower elevations in the late dry season in order to prepare gardens closer to available water, in some cases returning to their houses on the ridge tops at night.

Collection of rainwater could ameliorate water shortages due to unreliable domestic water supply. As described in section 4.5, in some communities rainwater is collected and used, in some communities there is interest in doing so, and in some communities there is a strong aversion to the use of rainwater.

Table 8.2. Access to water sources and adaptation to water shortages at field study sites.

* Data from 2010 Timor-Leste National Census. # Data from Demographic and Health Survey. Other data from field studies 2011. √ indicates field results recorded this factor in this area.

District		Sources of drinking water * (% households)					Wealth # (% households)		Water sources			Access to water		Water storage		Adaptation to seasonal unavailability of water		
		piped water	bore water	spring	collected rainwater	water vendor	lowest 2 income quintiles	highest income quintile	pump from deep aquifer	access shallow aquifer	collect from springs	piped water from springs	buy water	rain water collection	holding tank	relocate tempor-arily to lower elevations	hand carry water from lower elevatio ns	comm.-unity manage-ment
DILI		**40**	**21**	**6**	**1**	**<1**	**3**	**71**										
	Dili - urban area								√	√		√	√					
	Dili city - commercial								√	√		√	√		√			
	Dili - peri-urban & rural								√ some	√	√	√ unreliable					√	
BAUCAU		**9**	**1**	**54**	**1**	**6**	**56**	**12**										
	Baucau new town								√		√	√some						
	Baucau old town										√	√						
	Buruma Sub-District	17									√ unreliable	√		√	√			√
MANTATUTO		**20**	**7**	**20**	**<1**	**<1**	**33**	**17**										
	Laleia Sub-District	45										√unreliabl e		some aversion				
AILEU		**17**	**<1**	**24**	**<1**	**<1**	**49**	**8**										
	Lequidoe Sub-District	10									√ some	√ unreliable		√ some		√	√	
ERMERA		**19**	**1**	**22**	**<1**	**<1**	**40**	**7**										
	Railaco Sub-District	10									√ unreliable						√	

9. Vulnerability to climate change with respect to groundwater resources

Vulnerability to climate change is the product of (i) potential impacts of climate change and (ii) capacity of a system or community to adapt to these impacts.

(i) A ranking of potential impacts of climate change (Fig. 7.3) was derived from the following factors:

- groundwater resources susceptible to climate change, with greatest potential impacts predicted for areas with low aquifer yield (especially localised, fractured rock aquifers, Fig. 7.2);
- modelled annual rainfall (Fig. 2.3), with greatest potential impacts predicted for areas of low rainfall;
- population pressure (defined as between 2004 and 2010; Fig. 2.7b), with greatest potential impact predicted for areas with both high population density and high population growth).

(ii) Adaptive capacity was indicated by a measure of poverty (Fig. 8.2), in the absence of a more comprehensive indicator of adaptive capacity. The limitations of this measure of adaptive capacity have been discussed in section 8.

A ranking of relative vulnerability to climate change with respect to groundwater resources (Fig. 9.1) was derived by overlaying rankings of potential impacts (Fig. 7.2) and adaptive capacity (Fig. 8.2).

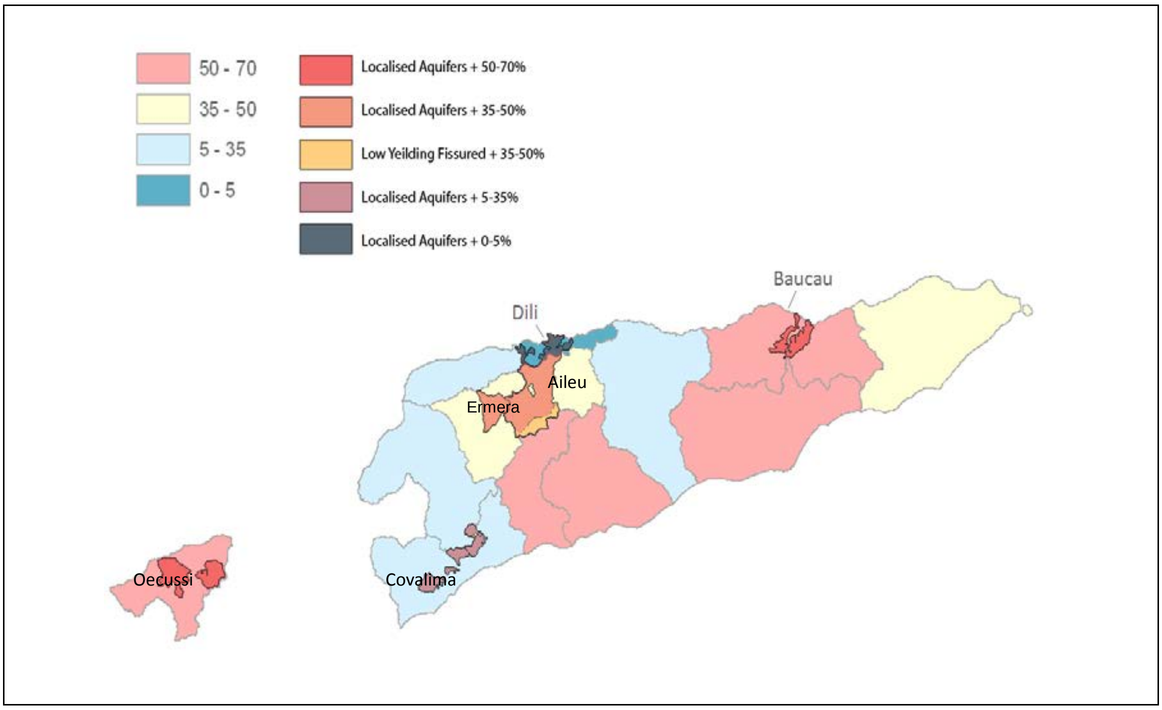

Figure 9.1 Base map of poverty overlain by high potential impact of climate change on groundwater resources.
Poverty as percentage population in two lowest income quintiles in Districts of Timor-Leste (legend on left, Fig. 8.2); potential impact of climate change on groundwater resources (legend on right, Fig. 7.3).

The Districts highlighted in the potential impact mapping (Fig. 7.1 and 7.3) occur at the extremes of the poverty scale (Table 8.1). From this ranking, Dili appears not to be highly vulnerable, with relatively high wealth and low potential impacts. However, the exceptionally high population pressures in Dili and surrounds, and the high potential impacts of climate change on aquifer yield on the surrounding hills, mean that Dili may be considered highly vulnerable. Greater wealth and associated adaptive capacity in Dili reduces vulnerability, however the importance of implementing adaptation options successfully is extreme because it is the capital city and because of the magnitude of the population potentially affected.

In contrast, Ainaro and Oecussi are highly vulnerable Districts because a large proportion of their population is dependent on aquifers of medium to high sensitivity, and these are the two poorest Districts in the country, suggesting low adaptive capacity (Table 8.1). People in these Districts are highly vulnerable to changes in water availability or quality.

The areas identified as highly vulnerable to projected impacts of climate change on groundwater resources are also vulnerable to variability in climatic conditions between seasons and years. With the establishment of a baseline, and regular monitoring of, climate and hydrology data in Timor-Leste, it will be possible to assess variability in climate and availability and quality of water resources. This monitoring can inform targeting of adaptation options and developing adaptive capacity in the areas most vulnerable to the impacts of climate change and climatic variability.

Table 9.2 provides a summary of the assessment of vulnerability for each District. It is noted that District level considerations mask the variability within each District. Some Districts encompass a wide range of conditions. A finer geographic resolution is necessary for the design of adaptation strategies.

Table 9.2 Summary of vulnerability assessment of groundwater resources to climate change.

District	(1)	(2)	(3) Potential impact (1+2)	(4) Adaptive capacity		Relative vulnerability (3+4)
	Population pressure	Groundwater insecurity		Inverse of Poverty *	Comments	
Aileu	M-H #	H	H	M	water insecure	H
Ainaro	L-M	L	M	H	poverty	M
Baucau	L-H	L	L-H	H	functional water management	M
Bobonaro	L-M	L-H	L	L	areas of water insecurity	L
Covalima	L-H	L	H	L	areas of water insecurity	L-H
Dili	H	L	H	L	high population pressure	H
Ermera	L-H	H	M-H	M		M-H
Lautem	L	L	L	M		L
Liquica	L-M	M	M	H	areas of water insecurity	M-H
Manatuto	L	L-M	L-M	L	areas of water insecurity	L-H
Manufahi	L	L-M	L	H		M
Oecussi	H	L-H	H	H	poverty	H
Viqueque	L	L-H	L	H	areas of water insecurity	M-H

Rankings are indicated by letters and colours; L=low, M=medium, H=high
* Poverty is likely to be inversely related to adaptive capacity. Ranking is according poverty and inverse to adaptive capacity, e.g. H (red) = high ranking for poverty and low ranking for adaptive capacity.

10. Adaptation options

Adaptation to climate change does not happen in isolation from the multiple factors affecting resource management processes, whether in Timor-Leste or elsewhere.

In the Australian context, for example, land clearing, cultivation practices, irrigation practices, flow regimes, groundwater extraction, invasive animals, weeds, fire regimes and inappropriate subdivision and coastal development all have much greater impact on natural resources and ecosystems than climate change *per se* (Campbell 2008). Climate change amplifies the impact of some of these factors, may alter the dynamics of interactions between them, and makes achieving best practice standards even more important. However, climate change adaptation does not mean radically different approaches to natural resource management (NRM) or sustainable agriculture. Climate change raises the stakes and increases the risks, but it does not require a fundamentally different approach: best practice NRM is still best practice.

Indigenous people in northern Australia are aware of and concerned about climate change and have observed 'strange changes' in the natural environment in recent decades and consequent impacts on bush foods (Petheram *et al.* 2010). However, these concerns were secondary compared with the pervasive issues of extreme poverty and economic marginalisation, such as health, education, housing, substance abuse, employment and personal security. Addressing these overarching social issues is likely to better equip these communities to handle climate change impacts than measures more narrowly focused on climate change adaptation.

Similarly, climate change adaptation in Timor-Leste is most usefully considered in the context of the broader issues of food security, sustainable agriculture and natural resource management (Smit & Wandel 2006). This report highlights some particular areas of vulnerability with respect to groundwater resources, where targeted measures would be potentially useful. The most effective climate change adaptation strategy in Timor-Leste will need to be placed in the context of widespread implementation of sustainable agriculture and NRM practices at community, landscape and national scales.

The biggest threat to groundwater resources in Timor-Leste is not climate change *per se*, but over-extraction, contamination, inappropriate landscape burning, land clearing, erosion and unsustainable land use such as over-grazing, feral animals and fuel-wood harvesting on steep slopes. Climate change may exacerbate the risks and the consequences associated with these practices, which underlines the importance of getting these basics right. The challenges for Timor-Leste should not be under-estimated. These challenges, and the necessity to set them within a broader framework of food security, sustainable agriculture and natural resource management, are recognised and reflected in the National Adaptation Programmes of Action for Timor-Leste (NAPA).

10.1 National Adaptation Programmes of Action for Timor-Leste

The National Adaptation Programmes of Action (NAPA) for Timor-Leste was released in 2010. It is closely linked to National Development goals. Its creation was in part a response to the United Nations Framework Convention on Climate Change, and in part a component of the 2010 National Priority on food security, in recognition that the livelihoods of the people of Timor-Leste are closely linked with natural resources and environment and that these resources are vulnerable to climate change.

NAPA for Timor-Leste describes the vulnerability of key sectors, informed by a community consultation process. These concerns centre around changes to water resources – increased intensity of rain events (flooding and landslides), sea level rise, reduced availability of water in the dry seasons — and consequent impacts on agricultural production, reduced biodiversity especially in the coastal zone, damage to infrastructure, health concerns related to less available water in the dry season, and reduced water quality.

NAPA notes awareness of climate change is high and the resilience of the people to change is high, evidenced in coping strategies already in place. Capacity of organisational structures is variable. Capacity with respect to technical and financial resources is generally low but improving.

Table 10.1 Short-list of adaptation options from the draft Timor-Leste NAPA.

Sector		Proposed key adaptation activities
Agriculture-Agro Forestry	1	Develop integrated sustainable land management promoting fixed/permanent agriculture, reduce burning, reduce erosion, increase soil fertility
	2	Integrated agro-forestry and watershed management including climate change dimension
	3	Improve planning and legal framework for sustainable and balanced food for livestock production under climate change conditions
Water Availability, Accessibility and Quality	4	Build climate consideration and environmental friendly infrastructure to protect water sources (springs, streams, wells, etc) to provide safe water supply during climate change extreme event periods
	5	Creating/enhancing water harvesting model and water distribution system as well as management at all levels to avoid water shortage due to climate change
	6	Control of quantity of water use by industry, and water pollution control standardization (medium) including coffee processing waste management in a climate change context
Terrestrial, Freshwater & Marine Ecosystems & Biodiversity	7	Education and awareness and pilot demonstration on sustainable agriculture and forest management: to increase resilience and reduce climate-related impacts of shifting cultivation and unsustainable upland farming practices
	8	National legislation: forestry to reduce illegal logging and burning and to strengthen customary law - ownership by local communities
	9	Reforestation of degraded lands with fuel-wood plantations to rehabilitate degraded land and soils and reduce deforestation
Human Health	10	Strengthening SISCA especially on health issues related to climate change related diseases.
	11	Strengthening integrated early warning system in community on airborne, vector borne diseases and epidemics.
	12	Reviewing existing guidance and standard issues by Minister of Health on respiratory, airborne and vector diseases to take climate change into consideration.
Human Settlement & Infrastructure	13	Viability study and pilot project to lay underground cables and other exposed equipment to climate change.
	14	Review existing laws, regulations and standards and enhance CC-resilient infrastructure and pass new legislation to strengthen and guarantee national development for regulation quality of materials and building codes and practices and law enforcement.
	15	Protection against strong wave damage offshore infrastructure thereby impacting on the distribution of gas and oil - to reduce accidents and destruction of off-shore oil and gas infrastructure: i) early warning system equipment; ii) data information to show occurrences; iii) equipment protection.
Disaster Management	16	Physical infrastructure - civil engineering and natural vegetation method - to prevent landslides in hillsides, roads and river banks
	17	Establishment of early warning systems in areas identified as vulnerable to risks of disasters such as floods and storms
	18	Enhance Government Strategies on responding to drought

10.2 Local adaptation options - current and potential

The people of Timor-Leste already have adaptation strategies in place to cope with the variability in their climate. Table 10.2 summarises the major exposures, sensitivities and potential impacts of climate change on groundwater resources, and some existing and potential adaptations. Insights into potential barriers to uptake and implementation were obtained from information collected in the field about current adaptation strategies and the reasons for these not being adopted in some areas.

Table 10.2 Components of vulnerability of groundwater resources to climate change, and some adaptations.

* NAPA ref refers to the relevant section within the NAPA (Table 10.1) for each potential adaptation.

Exposure	Sensitivity	Potential impacts	Current coping strategies (adaptations)	Potential coping strategies (adaptations)	NAPA ref*
Extreme dry year	Greatest sensitivity in localised, fractured rock aquifers	- Springs cease flowing for longer period - Wells and bores become dry	- People move temporarily down catchment due to crop failures - Some reliance on food aid - Collect rainwater (in few villages)	- Pumping water to higher locations	4
				- Wider range of crops adapted to drought and harvest at staggered times	1
				- Collect rainwater (more widely) for drinking and irrigating gardens	5
				- Construct water storages & distribution systems	5
Late and/or erratic start to wet season	Greatest sensitivity in localised, fractured rock aquifers	- Springs cease flowing during dry season, affecting supply of drinking water and water for gardens	- Hand carry spring water large distances to water crops	- Supplement rain with irrigation water during crop establishment	5
				- Wider range of crops that are harvested at different times	1
Extreme wet year with less frequent but more intense rainfall events	Least buffering capacity in localised, fractured rock aquifers	- Flooding of fields on valley floor and coastal plains, and widespread crop losses Compounding food shortages due to crop losses and seed supplies for later plantings - Destruction of roads & homes -Increased pest and disease incidence, particularly locust plagues -Contamination of water by sediments and seepage	- Some reliance on food aid	- Treatment of water, especially for drinking	4
				- Improve drainage systems	1
				- Terracing & soil conservation practices	1
				- Investigate crop selection & management to resist pests	1
Reduced recharge of aquifers		- Springs stop flowing - River flow reduced - Wells dry or saline	- Alternative water sources as above	- Land use to maintain/increase recharge rates	4, 8
				- Alternative water sources as above	4, 8
Sea level rise	Greatest sensitivity in coastal plains with low relief	- Wells/bores become saline - Irrigation fields become saline from rising groundwater	- Repair damage - Supplement coastal agricultural production with activities in hinterland	- Construct infrastructure on higher land	14, 15
				- Develop alternative agriculture on higher land	1, 3

10.3 Adaptation options in broad context

Adaptation options are listed in Table 10.2 against specific anticipated exposures and impacts of climate change. The specific adaptation options listed above can be integrated into five areas for action, as discussed below.

1. Documentation and monitoring of ground water resources – to improve understanding of water availability

Improved management of water resources in Timor-Leste requires effective monitoring of water availability, regulation of water use and a greater understanding of the processes determining ground water availability.

The establishment of a network of monitoring bores/wells across the most vulnerable locations, and pump testing of those bores/wells is needed to determine transmissivity of the aquifer and sustainable yields. Such a network would also be useful for monitoring water quality and collecting isotope samples for age dating of water. A focus of groundwater monitoring should be to improve understanding of the relationships between land use and recharge in different Districts. Understanding connectivity of aquifers and water supplies will also inform wise location of potential pollutants, i.e. industrial sites, fuel distributors and sewerage, to minimise adverse impacts on water quality. Such considerations need to be integrated into urban and rural planning frameworks.

Further work is needed to improve understanding, characterising and quantifying groundwater resources and hydro-geological systems and processes in Timor-Leste. High priority areas include the location and transmissivity of the recharge zones, as well as recharge times, of aquifers supporting densely populated areas, for example the Dili, and Suai Districts. This information is critical to understanding and managing groundwater resources into the future.

2. Integrated water harvesting and irrigation maintenance – to build local resilience and adaptive capacity

At present rainwater harvesting is ad hoc and small scale. There is potential for rainwater collection from house roofs to be useful, especially in areas with low-yielding aquifers (e.g. fractured rock aquifers) but relatively high rainfall (e.g. parts of Ermera). Storage of water can entail health risks if not installed and maintained appropriately. While some areas, such as at Lequidoe, expressed strong interest in taking up rainwater harvesting, it is clear that in some Districts there are significant cultural and social barriers to widespread adoption of this strategy, in addition to technical and economic constraints. Comprehensive education, training and extension programs, preferably assisted by practical demonstration projects and some incentives to encourage uptake, are needed to ensure uptake, and to establish appropriate standards of design, installation and maintenance.

There is scope within those areas with existing irrigation infrastructure to expand and improve maintenance of existing irrigation assets and improve productivity from irrigated agriculture. Ideally, this would be done in such a way that it builds local incomes, for example through payments into local communities for system maintenance and consideration of strategies to build local equity and responsibility. One suggestion from interviews and discussions was the establishment of a *chefe de bee/irigasi* (chief of water / irrigation) to be the steward for water in each suco and paid a small remuneration. . These developments should be focussed on Districts identified in this report as being the least adaptively capable (Fig 8.1).

Geoscience Australia is investigating the potential to store water underground within aquifers in Timor Leste.

3. Agricultural diversification - to build resilience and adaptive capacity

Water insecurity, food insecurity, and compounding health and economic impacts, all feed the continuing cycle of poverty in Timor-Leste. Groundwater and surface water are critical considerations in dealing with food security because agricultural productivity in Timor-Leste is severely limited by availability of water and may be increased if there was increased irrigation with groundwater. Many adaptations related to diversification of agricultural systems and introduction of agricultural practices that will sustain improved yields can be regarded as ‘no regrets’ options, i.e. beneficial regardless of climate change.

The devastating impacts of an unusually wet season on food security were illustrated in 2011. The 2010-2011 wet season brought record rainfall to Timor and Northern Australia, which resulted in delayed and heightened food shortages in communities at risk on the island of Timor during 2011, and impacting problems into 2012 due to the loss of seed for planting for the 2011-2012 season. This is expected to further impact on food reserves towards the end of 2012. The increased rainfall destroyed the maize and vegetable harvest and prevented planting, resulting in a loss of stored food and cash incomes. Many communities rely heavily on groundwater to produce vegetables and perennial crops which provide basic sustenance for households and generation of cash income. Availability of cash is key for households in withstanding climate shocks and building resilience.

In the longer term, pressure on surface water and groundwater resources in a warming and more variable climate will be more manageable if there is a greater range of crops, including species or varieties that can tolerate periods of low or no rainfall. In diversifying crops and varieties, consideration should be given to increasing the acceptability of crops that are adapted to the environmental conditions in Timor-Leste. Examples include sorghum which was traditionally eaten by humans and is now regarded as chicken/animal feed, high nutrient varieties such sweet potato varieties with high vitamin A, and crops that have good storage properties such as root crops that are stored in the ground and some maize varieties being trialled by Seeds of Life. Many of these are already present and grown in Timor-Leste, but more work is needed to successfully introduce these crops to other locations.

4. Improving governance (policy and regulation) – to reduce waste and over use, to secure availability and access, to increase adaptive capacity

The Government of Timor-Leste has commenced policy development on monitoring extraction from groundwater resources. Assistance to the government on the implementation of water extraction monitoring across the most vulnerable locations, as recommended under item 1 above, will underpin and inform the development of this policy framework. Ideally such a framework would recognise the connectivity of groundwater and surface water resources, constrain groundwater use within sustainable yield limits, and discourage activities that risk groundwater contamination.

Adapting to current climatic variability and future climate change in the face of competing sustainable development factors is the primary challenge for adaptation at both the local and national levels (Adger *et al*. 2003). Governance of water resources should include the development and preparation of procedures and safety nets before climate shocks are experienced: e.g. cash transfers conditional on local preparations for impacts, implementation of public works programs to supplement rural incomes, and provision of targeted food aid. Payment for maintenance and management services into local communities would increase local equity in water management. Local engagement would reduce the dependence of local communities on the government for provision of all services and solutions to maintenance and management issues.

For effective implementation of such a policy framework, there would need to be an awareness raising program integrated into broader education and training programs on sustainable agriculture and natural resource management. The Farmer Field Schools are an example of such an approach, with proven success in the Asian region, particularly in Indonesia, Cambodia, Philippines and Vietnam (Winarto 2004). Public awareness campaign on water conservation strategies for households, businesses, government agencies, hotels and tourism ventures, and schools could also be effective.

10.4 Potential implementation approaches for options

The actual costs of any adaptation will depend on design and mode of implementation. Cost can be simply cost of construction or initial implementation, or can take the broader view of costs which includes long-term costs of maintenance. The costs included in Table 10.3 merely indicate relative costs of the adaptation options listed.

The implementation of adaptation options will be most effective, locally appropriate and sustained if the implementation is undertaken through local partnerships. Specific adaptation options should be part of local adaptation plans with genuine local engagement at the suco, District and Sub-District levels. The development of local adaptation plans and the design and implementation of new adaptation options should build on existing adaptation strategies, work with existing local knowledge and perceptions. The process of planning and management should be an iterative process of monitoring, planning, implementation, on-going monitoring, assessment and evaluation, and adjusting plans, i.e. an effective adaptive management system. Where possible, the development and implementation of adaptation options should also increase local capacity.

Suggested improvements to agricultural productivity and land and water management require on-going monitoring and investigation of processes.

The acquisition of these data should be used to build local capacity to collect relevant high quality data and to analyse and interpret these data for local context. Networks and systems for sharing data and knowledge should be built into future activities, to encourage cooperation between agencies, NGOs and university staff in Timor-Leste.

Table 10.3 Potential adaptations and potential barriers to implementation and relative cost

Potential adaptations (from Table 10.2)	Potential barriers to implementation	Relative cost
- Pumping water to higher locations	- Expense - Insufficient water yield from sources lower in catchment - Resistance from downstream users - Lack of maintenance	High
- Wider range of crops adapted to drought and harvest at staggered times	- Reluctance to adopt new agricultural crops and practices	Medium
- Collect rainwater (more widely)	- Some local perceptions that collected rainwater is dangerous to health	Low
- Construct water storages & distribution systems	- Lack of maintenance - Poor understanding of ownership	High
- Supplement rain with irrigation water during crop establishment	- Unwillingness to use different system - Lack of maintenance	Medium
- Wider range of crops that are harvested at different times	- Expense - Reluctance to move and adopt new agricultural practices	Medium
- Treatment of water, especially for drinking	- Expense - Reluctance to move and adopt new agricultural practices	Medium
- Improve land drainage systems	- Expense - Reluctance to move and adopt new agricultural practices	Medium
- Terracing & soil conservation practices	- Reluctance to adopt new agricultural practices	Low
- Land use to maintain/increase recharge rates	- Lack of knowledge about impacts of land use on recharge rates for different locations	Medium
- Construct infrastructure on higher land	- Expense & lack of suitable (flat) land at higher elevation	High
- Develop alternative agriculture on higher land	- Reluctance to adopt new agricultural practices	Medium

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Appendix I. Spatial Analysis Methods

Population Density

The map of population density that was derived from household data (i.e. Fig. 2.5) was created using dwelling location data from the 2004 census obtained as a point shape file attributed with number of inhabitants. These data were converted to a raster grid with a 500m x 500m cell size of population density using a point to raster function. The resulting map therefore showed population density with a grid area of 0.25 km^2.

Population distribution and change maps

These maps where produced by attributing a Sub-District shape file with the 2010 census data. This was subsequently intersected with the aquifer mapping and an attribute query was conducted to produce the potential impact map shown in figure 7.2.

Predicted sensitivity to reduced water availability

This map was produced by multiplying rainfall and hydrogeology grids reclassified into sensitivity classes as shown in Table I.1. The classification of the hydrogeology grid was based on work conducted by GA.

Table I.1. Sensitivity classes for hydrogeology and rainfall

Hydrogeology	**Sensitivity Class**
Localised Low Yielding	3
Localised High Yielding	3
Fissured Low Yielding	2
Fissured High Yielding	1
Sedimentary Low Yielding	1
Sedimentary High Yielding	1
Rainfall (annual)	**Sensitivity Class**
0-1500mm	3
1500-2000mm	2
>2000mm	1

The resulting multiplied grid was reclassified as follows:

Sensitivity Value	**Sensitivity Class**
1-2	Low
3-4	Medium
5-7	High

Potential impact map

This map was produced by multiplying the water availability map (Fig. 6.3) with the population density grid (Fig. 2.5) and reclassified as follows:

Population Density*	**Class**
0-10	1
10-50	2
50-100	3
100-500	4
500+	5

**Population density is number of people per 500 meter grid cell.*

The resulting multiplied grid was reclassified as follows:

Impact Value	**Impact Class**
0-5	Low
5-15	Medium
15-25	High
25-45	Very high

Appendix II Social Data Collection - Water resources in selected sites in Timor-Leste: water availability and quality – Methods and Analysis

Aims

This field study aimed to document the range of water resources used by rural villagers in selected sites in Timor-Leste: the seasonal availability of these resources, the uses of water from various sources, and the importance of these resources for rural livelihoods.

Sites

The study sites corresponded to field sites that represent the three major aquifer types described by GA: a sedimentary aquifer (with intergranular porosity) in the Dili area, fractured rock aquifers (with localised porosity) in the Aileu area, and a limestone karstic aquifer (with fissured porosity) in the Baucau area.

The Dili and Aileu sites are sites for field activities by GA in June, and the Baucau is a site of existing studies by the BESIK group in Timor-Leste.

1. Dili area

Capital city and largest city in Timor-Leste, located on the north coast. It is known that 60% of the water supply to Dili is from groundwater.

2. Aileu area

Aileu District is a mountainous area, about 35 km south of Dili. It produces maize, sweet potato and cassava, with cash crops include, citrus, vegetables and some coffee.

3. Baucau area

Baucau District is on the north coast. It is a major food growing area, with high production of fruit, vegetables, rice, some maize, beans, groundnuts, cassava and sweet potatoes. Relatively evenly distributed rainfall and developed agricultural practices result in relatively high agricultural productivity.

Methods

Focus Group Discussions (FGDs) were conducted to coincide with field activities investigating groundwater resources and processes (conducted by Geoscience Australia). FGD were held with women and men and mixed groups. Household interviews were used to follow up on FGDs: to fill in and cross check information gathered in the FGDs. Key informants from NGO's and church groups were also interviewed using similar questions to the household interviews. Many of the large hotels in Dili were asked about the sources of their water and their water use to gauge the extent of water use in a growth industry and to gauge the extraction from the aquifer by water vendors.

Seasonal calendars were created during the FGDs and household interviews. These calendars were a series of concentric circles with Church festivals marked in one circle and a circle for indicating the likely timing of events such as onset of rain, planting and harvesting, and another circle for indicating the seasonal availability of water from various sources and the timing of any anticipated concerns regarding water quality or availability.

Topics for Focus Group Discussions:

- What water resources are used by the community?
- What seasons of the year is water available from these various sources?
- How does water availability from these sources vary from year to year?
- What concerns, if any, are there about the quality of water from these various sources?
- What concerns, if any, are there about access and availability of water from these various sources?
- How does water availability affect livelihoods in this community?
- What do you do to cope with water shortages?
- How far do you go to collect water – how long does it take?
- What do you do to cope with water quality problems?

- What do you imagine will be the problems with water supply in the future, and how do you think the community will cope?

For FGD of elderly community members:

- From your memories, has water availability changed over the years? If so, from what sources and in what ways?
- Do you associate years or seasons of water shortage with any particular seasonal or environmental conditions?
- What environmental cues do you use for farming activities? E.g. preparing fields, planting crops? Has the reliability of these cues changed over the years?
- Are there any traditional custodians or practices around the water sources

Household interview questions:

- What water resources are used by the household?
- What seasons of the year is water available from these various sources?
- How does water availability from these sources vary from year to year?
- Are there concerns about the quality of water from these various sources?
- Are there concerns about access and availability of water from these various sources?
- How does water availability affect livelihoods in this household?
- What do you do to cope with water shortages?
- How far do you have to go to collect the water, how long does it take?
- What do you do to cope with water quality problems?
- Who usually collects the water?

Data collected

1. Audit of current water resources
    a. Location and accessibility
    b. Uses
    c. Seasonal and yearly variability in supply and perceived quality
2. Past supply and reliability of water resources – long-term perspective from elderly villagers
3. Current strategies for coping with any problems with water shortages or poor water quality
4. Concerns for the future regarding water availability and quality
5. Any traditional management or practices around water

Data analysis, outputs and outcomes

The data was used for consideration of the impacts of climate variability at the community and household levels, to understand the perceptions and processes underlying these impacts, and to identify potential adaptive strategies. Information about current uses of water resources (including any problems associated with access, seasonal supply, and quality) gave information about impacts on livelihoods and health. Discussions with elderly villagers provided information about long term changes in water resources and the impacts of these on livelihoods.

This research informed assessments of adaptive capacity. Comparisons between sites provided information about different attitudes to adaptation options. Adaptations that already occur were described using the information collected about coping strategies for dealing with any problems with water resources that occur seasonally or from year-to -year. Discussions with villagers about concerns for future changes (e.g. in population or livelihoods or water resources) provided information about future impacts and adaptations as perceived by the villagers. This information gave some insight for the discussion of potential adaptation options that are culturally appropriate.

The field study was conducted in collaboration with researchers from the national Timor Loro Sae (UNTL), and so the study has built capacity in-country to conduct this type of in-depth study of processes and responses.

Summary

The study provided detailed information about availability and uses of water resources at three sites which represent the major aquifer types in Timor-Leste. This information included a description of changes to resources within living memory, and adaptations that have already been made in response to annual and seasonal variability in water resources. This information supplemented physical studies of water resources and supply conducted by GA. This study enabled CDU to make a more informative assessment of adaptive capacity and adaptation options with respect to climate change impacts on groundwater in Timor-Leste.

Appendix III – Comparisons of Potential Indicators of Adaptive Capacity

Potential indicators of adaptive capacity

There are many potential indicators of adaptive capacity which have been discussed in the literature (e.g.(Haddad 2005)).

In this study a range of potential indicators of adaptive capacity at the District level were derived from available data. These potential indicators included parameters related to poverty, education, health and access to services, and are listed in Table III.1. This is not a comprehensive list of potential indicators of adaptive capacity. It does not address the ability to "act collectively" (Adger 2003), i.e. the awareness, will and effectiveness of governance structures, either government or traditional, to adapt to changing resource availability. The field studies provide some information about these aspects of adaptive capacity.

Table III.1. The potential indicators of adaptive capacity at the District level: the label used in the analyses, a description of each indicator and the source of the data.

Label of potential indicator used in diagrams	Description of the indicator of adaptive capacity	Source of data
Poverty	% population in two lowest wealth quintiles	Census 2010
Radio	% households that own a radio	Census 2010
M'bike	% households that own a motorbike	Census 2010
Floor	% houses with concrete or tiled floor	Census 2010
Roof	% houses with corrugated iron roof	Census 2010
Electricity	% houses with electric light	Census 2010
Wood	% households that use wood as a fuel for cooking. Note, wood not necessarily only fuel for cooking	Census 2010
Water	% households with drinking water delivered by pipe, either indoors or outdoors	Census 2010
No school	% individuals 5 years or older who have never attended school	Census 2010
Full vac	% children who have received the four main vaccinations, i.e. DPT, polio, hepatitis B, measles	Demography and Health Report 2010
No vac	% children who have received no vaccinations	Demography and Health Report 2010
Mal	Measure of malnutrition. % children with height for age more than 3 standard deviations below average	Demography and Health Report 2010
Wt4Ht	% children with weight for height more than 3 standard deviations below average	Demography and Health Report 2010
Wt4age	% children with weight for age more than 3 standard deviations below average	Demography and Health Report 2010
Anaemia	% children with anaemia	Demography and Health Report 2010
NetK	% children who slept under any kind of mosquito net the night before the survey	Demography and Health Report 2010
NetW	% pregnant women who slept under any kind of mosquito net the night before the survey	Demography and Health Report 2010
DecW	% women who participate in decisions relating to four areas, i.e.	Demography and Health Report 2010

Validity of the potential indicators considered

Further investigations are needed to determine to what extent the potential indicators reflect adaptive capacity. The present study offered limited opportunity to test potential indicators of adaptive capacity. Further study is required to make a more comprehensive assessment of adaptive capacity at community, District and national levels.

Correlations between potential indicators

The potential indicators (Table III.1) were chosen to reflect a range of aspects of capacity to adapt, however, it is likely that some of the potential indicators will be highly correlated. For example, we might expect that, without aid intervention, poverty will be highly correlated with many other potential indicators: e.g. negatively correlated with % ownership of goods, % costly housing materials, and education levels, and possibly positively correlated with access to health services. However, poverty will not be the sole determinant of these parameters. All possible indicators will be affected by many factors including geographic access to services and to resources, the presence and effectiveness of public health and other rural development interventions, and social and cultural factors in each community.

The extent to which the indicators listed in Table III.1 were correlated was investigated by constructing scatter plot matrices (SPLOM), and the contribution of these indicators to the ranking of Districts was investigated using principal components analyses (PCA). For virtually all potential indicators the value for Dili was an outlier, and so SPLOM and PCA were carried out first for all Districts and then with Dili excluded.

In Figures III.1 and III.2, the upper right panels are scatter plots with a LOESS smoother to aid with interpretation, the plots along the diagonal shows histograms of the parameter for each District, and the lower left panels are estimated pair-wise correlations, with font size proportional to estimated correlation coefficients.

Scatter Plot Matrices (SPLOM)

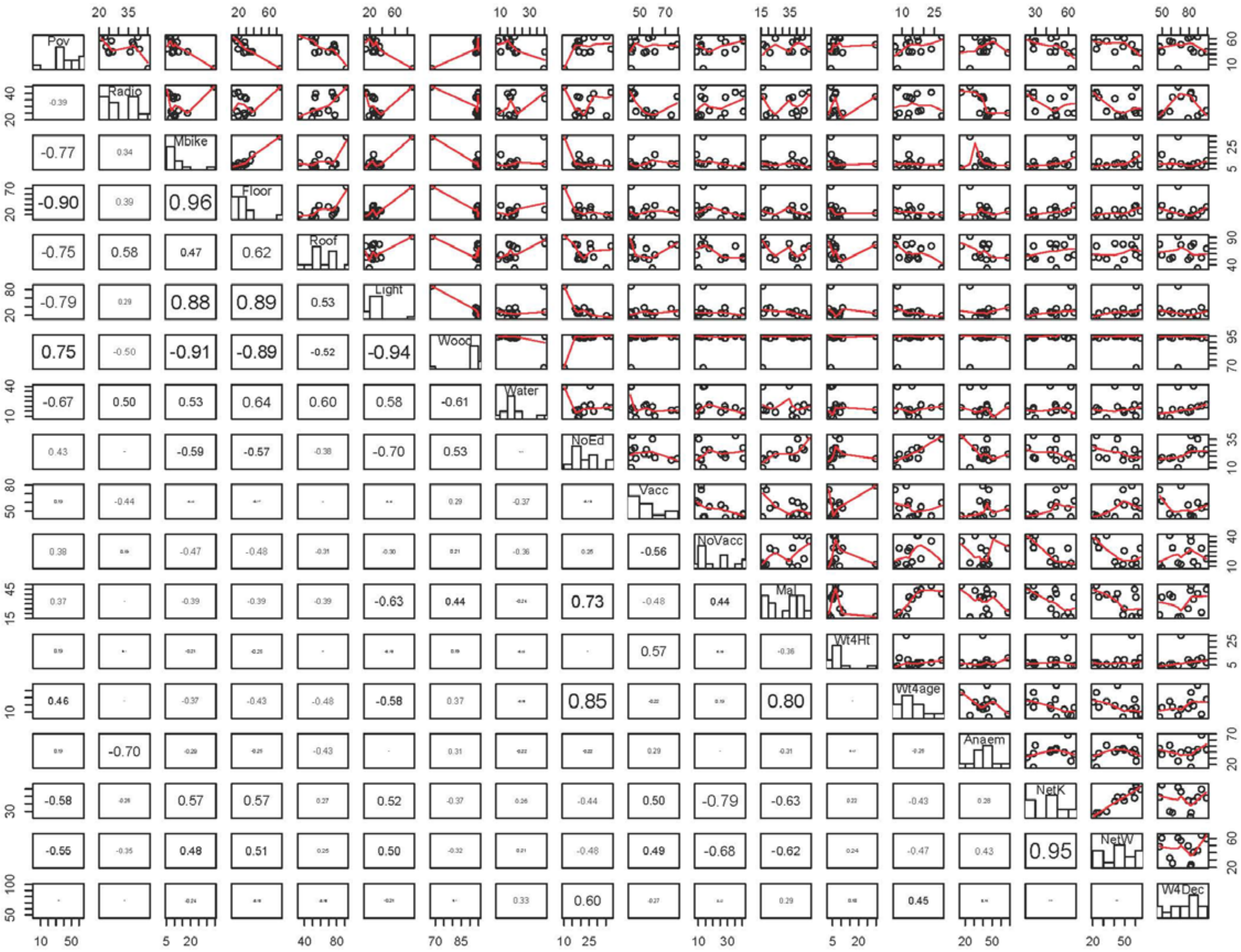

Figure III.1 Scatter Plot Matrix of potential indicators of adaptive capacity for all Districts in Timor-Leste.

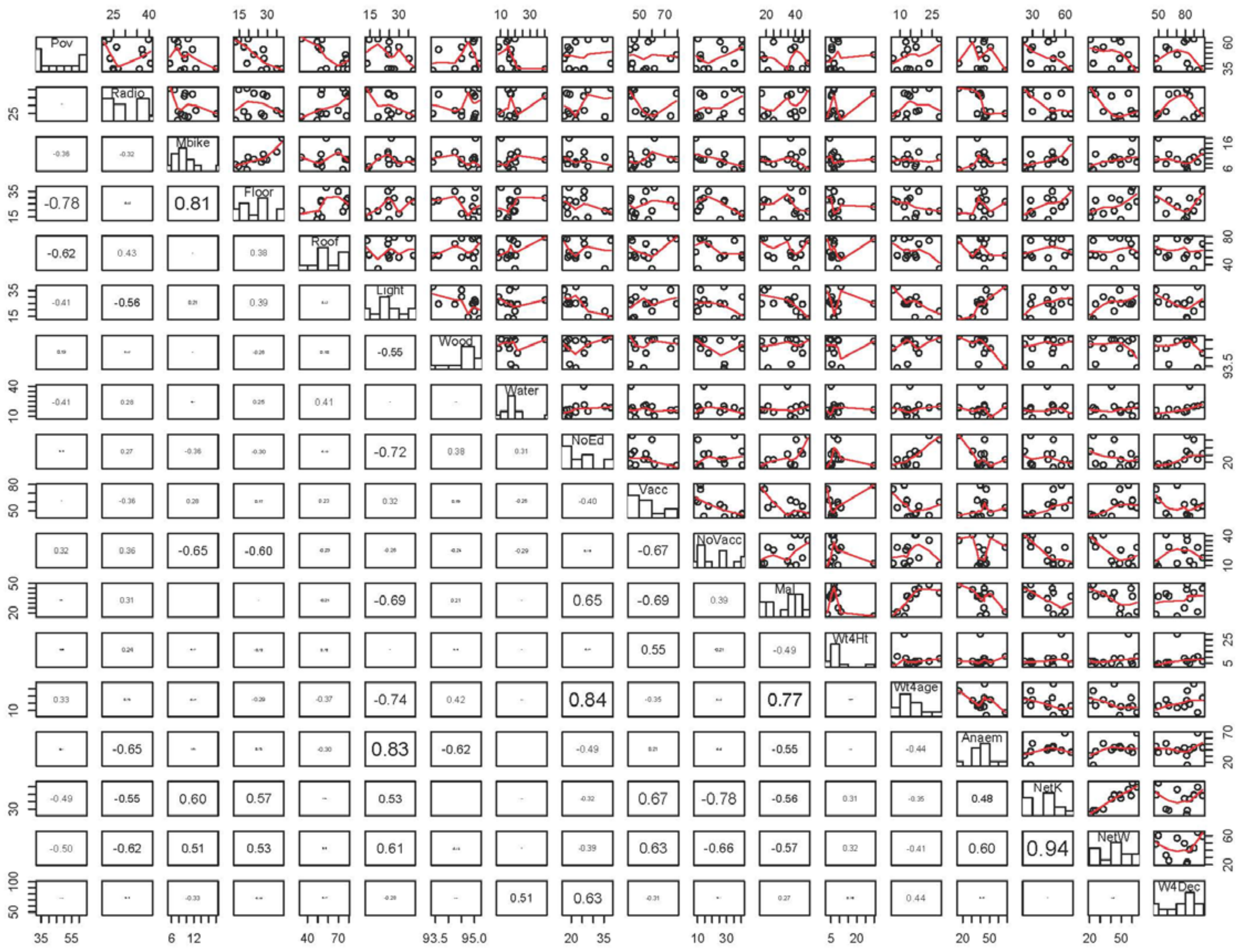

Figure III.2 Scatter Plot Matrix of potential indicators of adaptive capacity for Districts except Dili.

Principal Component Analyses (PCA)

In the PCA for potential indicators of adaptive capacity all Districts (including Dili), the first two axes explained 64% of the variation, and for Districts excluding Dili, the first two axes explained 52% of the variation.

Districts are represented by the first 3-4 letters of their name and the potential indicators of adaptive capacity are represented by arrows labelled with abbreviations given in Table III.1.

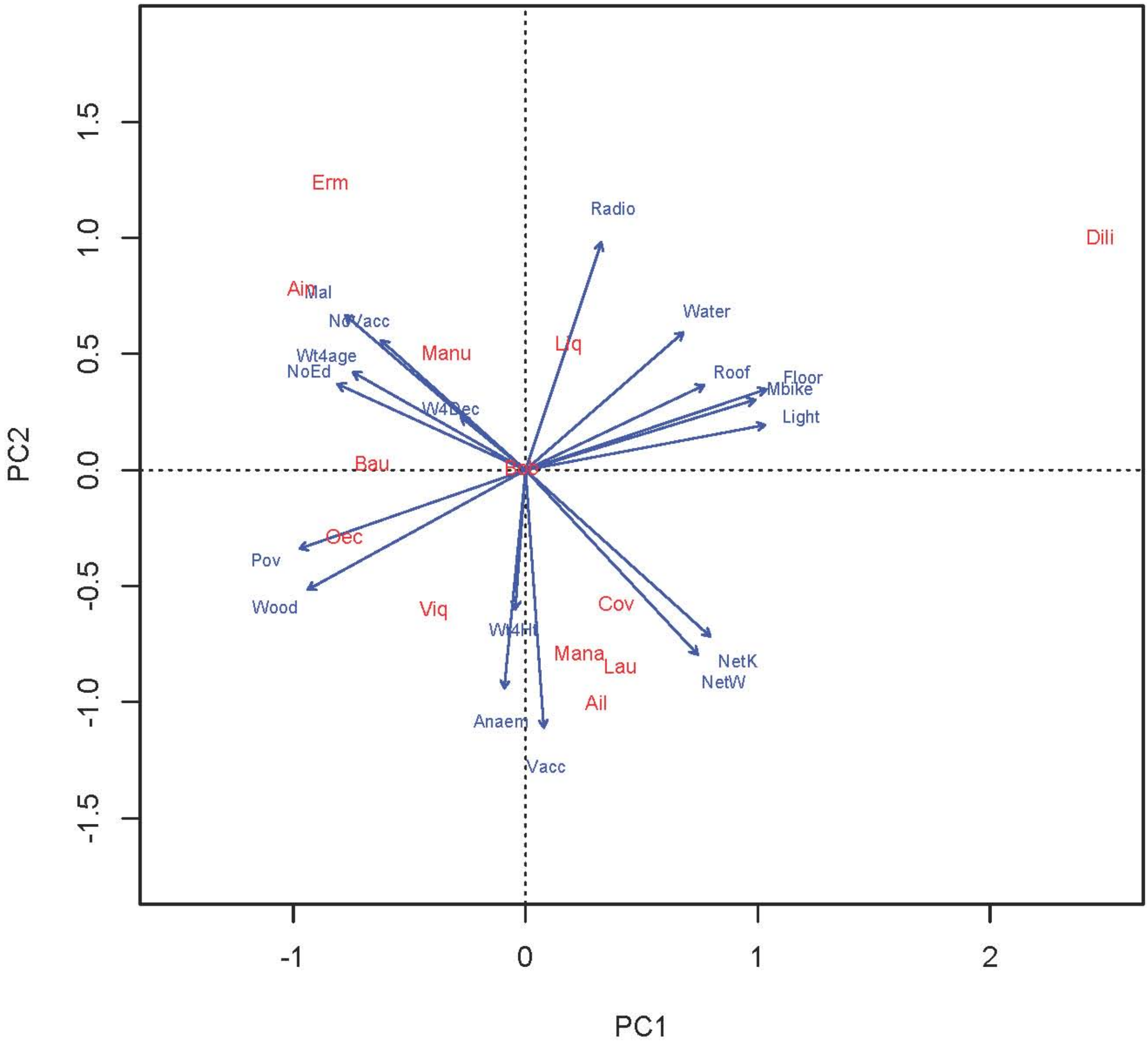

Figure III.3. Principal Components Analysis of potential indicators of adaptive capacity for all Districts in Timor-Leste.

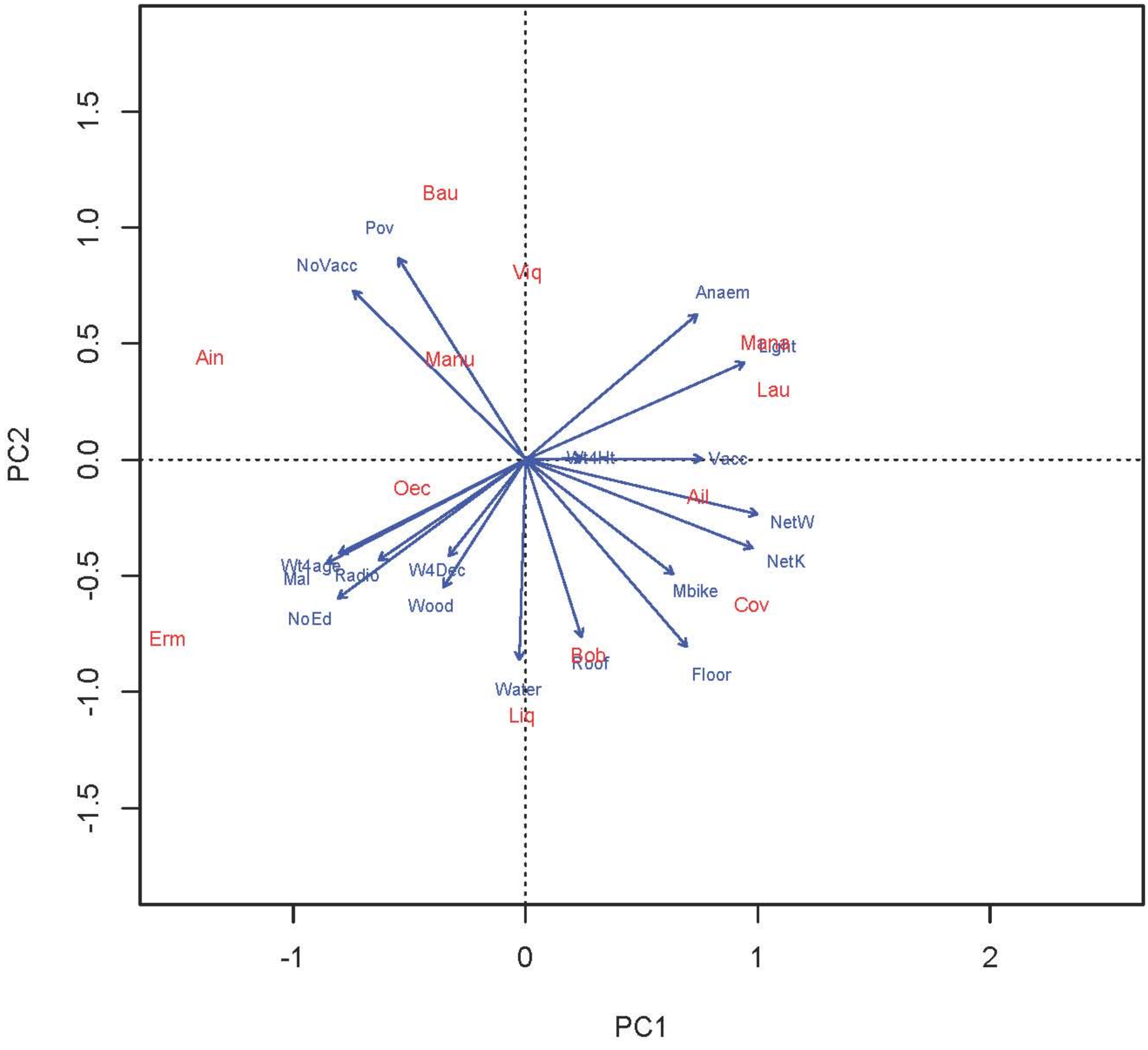

Figure III.4. Principal Components Analysis of potential indicators of adaptive capacity for Districts except Dili.
Labelling as for Fig. III.3.