Report

Jon Barnett, Suraje Dessai and Roger N. Jones

Vulnerability to Climate Variability and Change in East Timor

This paper presents the results of a preliminary study of climate vulnerability in East Timor. It shows the results of projections of climate change in East Timor. The country's climate may become hotter, drier, and increasingly variable. Sea levels are likely to rise. The paper then considers the implications of these changes on three natural resources—water, soils, and the coastal zone—and finds all to be sensitive to changes in climate and sea level. Changes in the abundance and distribution of these resources is likely to cause a reduction in agricultural production and food security, and sea-level rise is likely to damage coastal areas, including Dili, the capital city.

INTRODUCTION

On 23 November 2003, East Timor held its first national workshop on climate change (1). This was the result of a series of meetings and studies about environment and development issues in East Timor in which climate change was raised as a problem of concern by some districts (2) and authors (3–5). At the workshop, national leaders, including Prime Minister Dr. Mari Alkatiri, expressed concern about the risks of climate change. This paper presents the results of a preliminary study of climate vulnerability in East Timor. It examines projections of climate change in East Timor and the implications of these changes for the climate sensitive and socially important resources of water, soils, and the coastal zone. It then considers the way these physical changes may affect agricultural production and food security.

MATERIALS AND METHODS

Vulnerability refers to the potential for loss (6). There are many different methods for assessing vulnerability to climate change and many different scales and sectors for analysis (7). While there is no consensus on the best approach to vulnerability assessment, in general they entail considering one or more of: exposure to climate risks, susceptibility to damage, and capacity to recover. It is difficult to determine the superiority of any given approach to vulnerability (8). Regardless of the definitions used and the approach taken, for the sake of clarity, comparability, and theoretical and methodological development, each vulnerability study should make clear the definitions it uses and the method of assessment it deploys (3, 8)

In this paper we follow the Intergovernmental Panel on Climate Change's definition of vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes" (9). We adopt a hybrid approach to assessing vulnerability in East Timor. Ours is a national-level assessment focusing on existing sensitivities to climate variability rather than a comprehensive assessment by sector or region. We do this for three reasons: because there is relatively more data on these obvious and current problems than on other aspects of East Timor's social and environmental systems (see below), because these are more concrete than speculations about future vulnerabilities, and because such an analysis leads to no-regrets recommendations for policy (8).

A challenge in conducting this assessment was the limited amount of data describing environmental conditions in East Timor. This lack of data is one of the many detrimental effects of the history of colonization, occupation, violence, and neglect of sustainable development in East Timor. In particular, historical climate records are sparse, making it difficult to examine present climate risk. Several stations measured meteorological data for varying periods during 1914 to 1975, but many of these records are incomplete. It is unclear how much data were recorded during the period of Indonesian control (1975 to 1999), and some records appear to have been destroyed during the withdrawal of Indonesian forces in 1999. Since then there has been no consistent collection of meteorological or hydrological data. In November 2000, 50 rain gauges were distributed around the country by the Department of Agriculture and funded by AusAID, but few data have been collected. The Australian Bureau of Meteorology in Darwin has installed automatic weather stations at the main airports (Dili, Baucau, and Suai), but the data are not routinely publicly available. Data on a range of climate-related processes like river flows, tides, flooding, and groundwater levels are also lacking. Thus, there are currently insufficient baseline data upon which to base scenarios of future climate changes and assess their impact on environmental and social systems.

The human drivers of environmental change in East Timor are also poorly understood (at least by outsiders). Since 1999 there have been quantitative studies of living conditions in East Timor, but as yet there have been few qualitative studies of social systems, let alone social–environmental interactions. This paper draws on available data and studies, including a limited number of peer-reviewed academic publications. It also draws heavily on information gathered through our own observations from field trips, interviews, and informal discussions during October 2003, and participation in the First National Workshop in November of that year. On this basis we can draw some general conclusions about vulnerability to climate change in East Timor.

EAST TIMOR AND ITS CLIMATE

East Timor became a sovereign nation in May 2002. Prior to this it endured 400 years as a Portuguese colony, followed by 24 years of violent occupation by Indonesia. The Indonesian occupation ended after a UN-sponsored referendum resulted in the people of East Timor favoring independence from Indonesia (10). This was followed by a violent withdrawal of Indonesian army, militia units, and public servants in September 1999 in which up to 2000 East Timorese were murdered, many buildings were burned, a quarter of the population was forcibly deported to the Indonesian territory of West Timor, and gross domestic product (GDP) declined by 25%–30% (11–13).

East Timor's GDP is USD 341 million, of which agriculture accounts for approximately 30% (14). GDP per capita is USD 413, and 41% of its population people live below the poverty line of USD 0.55 per day (13, 14). Estimates of population vary, with the latest estimate being 924 642 people (15). Infant

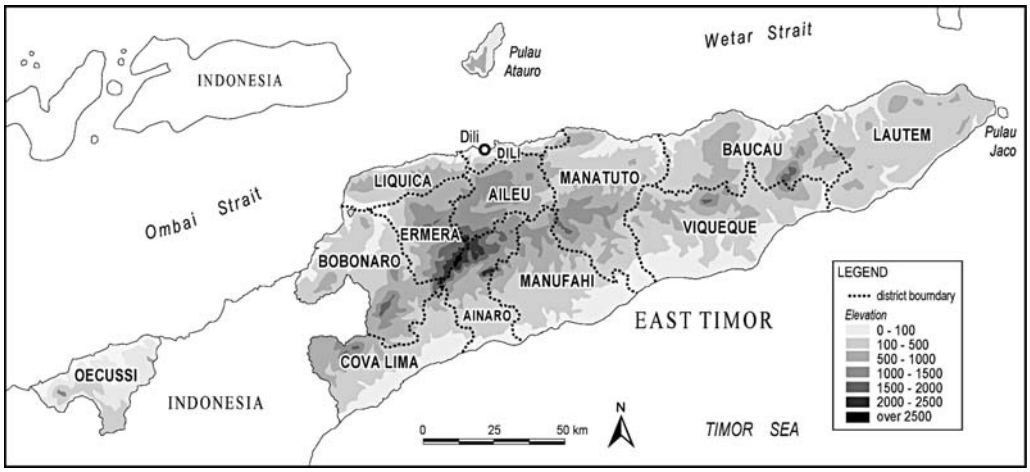

Figure 1. East Timor, districts, and topography.

mortality and maternal mortality are high, and 45% of children under 5 years old are underweight (13). The majority of the population (75%) lives in rural areas, and 46% of rural people live below the poverty line (13). Most of the rural poor are engaged in subsistence production.

East Timor is a relatively small country with an area of 14 874 km^2 (4). It is a very mountainous country (Fig. 1). Most of the country has a slope of between 8% and 25% (16), and it has been suggested that as much as 44% of the country may have a slope of more than 40% (4). Much of East Timor is covered in shallow rocky soils that are alkaline, are not particularly fertile, do not store water well, and are easily eroded (17). Better soils are found in river valleys, flat lands, and along the southern coast. The nature of the soils are a function of the geological substrate in East Timor, which is largely limestone and coral; temperature, which is sufficiently high to ensure that soil nutrients decompose faster than they accumulate; and topography, which renders many soils prone to erosion (17, 18).

East Timor's climate is influenced by the Asian monsoon system. There are two distinct rainfall patterns: the northern monomodal rainfall pattern, which produces a 4–6 month wet season beginning in December that affects most of the northern side of the country and tapers to the east; and the southern bimodal rainfall pattern, which produces a longer (7–9 month) wet season with two rainfall peaks starting in December and again in May, which affects the southern side of the country (19). Figures 2 and 3 show that annual rainfall is very low along the northern coast of East Timor (<1000 mm y^{-1}), low to moderate throughout the central and elevated areas (1500–2000 mm y^{-1}), and moderate (>2500 mm y^{-1}) in high altitude areas. In common with most tropical locations, intense downpours of rainfall are common.

As is characteristic of the tropics, there is little seasonal variation in temperature. Keefer reports that at any given place, monthly mean temperatures vary by no more than 3°C between the coolest months of July and August to the warmest months of October and November (19). Diurnal (daily) temperature variations range from 7°C to 13°C (19). Figure 4 shows that temperature decreases with altitude: for example, in Maubisse, which is 1400 m above sea level, the mean monthly temperature is approximately 17°C in July and 24°C in November, compared with Liquica, which is 25 m above sea level and where the mean monthly temperature is approximately 25°C in August and 31°C in February (19).

Variability in East Timor's climate is significantly influenced by the El Niño Southern Oscillation, which in El Niño years changes the timing and volume of rainfall (20). In some places, such as Ainaro and Lautem, annual rainfall is up to 50% less than average in El Niño years. In others, such as Bacau and Oecussi, annual rainfall in El Niño years is greater than average. In all places El Niño suppresses rainfall in the January–March wet season, with some places experiencing only 25% of the rainfall usually received in these months. In general, the wet season is delayed by 2 to 3 months in El Niño years, with implications for crop planting and food security. In the year following an El Niño, rainfall can be higher than the annual average, with implications for flooding.

RESULTS

Human activity is very likely to continue to change the composition of the atmosphere during the twenty-first century. This will increase global mean temperature and lead to sea level rise (21). Global mean surface temperature is projected to increase by between 1.4°C and 5.8°C and global mean sea level to rise by between 9 and 88 cm by 2100 (21). These ranges are subject to both scientific uncertainties and to the range of future greenhouse gas emission scenarios. The global hydrological cycle is likely to be more vigorous with the prospect of more intense rainfall events, and extreme warm temperatures are likely to become more frequent (21).

Projections of future climate change are generally made with the use of coupled atmosphere–ocean global climate models (AOGCMs), which provide a comprehensive, but still uncertain, representation of the climate system. Uncertainties are particularly large for small and mountainous islands like East Timor where higher spatial resolution models are required. This is because the topography and land–sea interface of a small island cannot be represented in a global climate model. Furthermore,

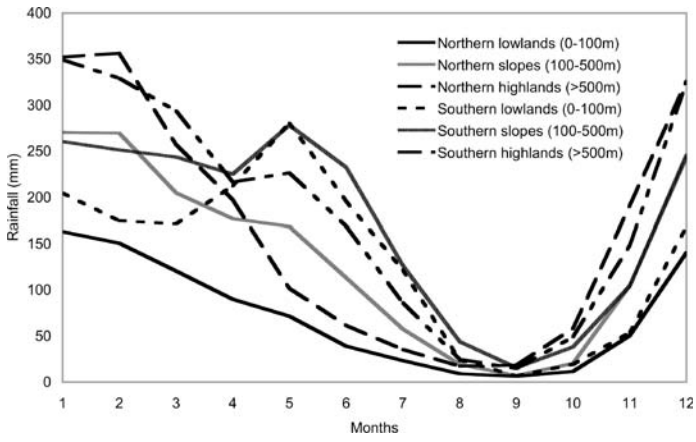

Figure 2. Monthly distribution of rainfall for key regions in East Timor.

Figure 3. Average annual rainfall (reprinted from *Atlas de East Timor* [16] with permission from LIDEL).

opposing trends that could potentially occur on either side of the island cannot be resolved in a single grid square.

Figure 6 shows ranges of change in rainfall projected by nine different climate models from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Intergovernmental Panel on Climate Change (IPCC) Data Distribution Centre surrounding the island of Timor. Table 1 shows the climate models that inform Figure 6. The upper panel shows the wet season from November to April, where small increases or decreases in 2030, expanding to $\pm 20\%$ by 2070, are projected (as described in the sparsely stippled area). The models are not indicating great increases or decreases in the wet season, nor do they indicate whether increases or decreases are more likely. The middle panel shows the period May to July, which is the second wet season in the south and the early part of the dry season in the north. This shows that most models project decreases in rainfall that appear to be quite large, reaching -80% by 2070. However, the models may not simulate the bimodal pattern of the wet season adequately, so they should not be interpreted as representing a significant loss of rainfall in that season (this would need to be investigated more closely). In the lower panel, showing the dry season between August and October, the models indicate a small increase ranging to substantial decreases. The substantial decreases in the middle and lower panels are due to the very small amounts of rainfall simulated during these periods—even a small decrease will have a large impact in percentage terms. Temperature changes from the same nine models were investigated and showed that warming was likely to be slightly less than the global average, ranging between about 0.3°C to 1.2°C in 2030 and 0.8°C to 3.6°C in 2070.

The AOGCMs that are used to provide these estimates of future climate change are less reliable in predicting extreme climate events such as drought and flood. In general, increases in the intensity of extreme short-term precipitation events are expected, but changes in the frequency of droughts and floods (resulting from sustained high rainfall) are uncertain, although the hydrological cycle is expected to become more vigorous. Of great concern is a possible link between climate change and El Niño events, which may be more severe in the future as the Pacific shifts to a more El Niño-like pattern.

We now turn to discuss the possible impacts of these changes on three resources that are clearly climate sensitive, of which we have some modest understanding, and which are important to people's livelihoods in East Timor: namely water resources, soils, and the coastal zone. We then consider the way these physical changes may affect agricultural production and food security.

Water Resources

Water is a critical resource in East Timor. As explained previously, climate change could result in a drier dry season, rain may fall as fewer but more intense events, and El Niño events, which result in delayed rain and less rain, may become more severe. These changes may exacerbate East Timor's existing problems with drought, floods, and water quality.

If climate change results in less rainfall in the dry season, then this will be a significant problem because East Timor is already vulnerable to drought because of high year-to-year rainfall variability combined with minimal water resource infrastructure. Lack of water in the dry season is common, particularly on the northern side of the island, affecting agricultural production

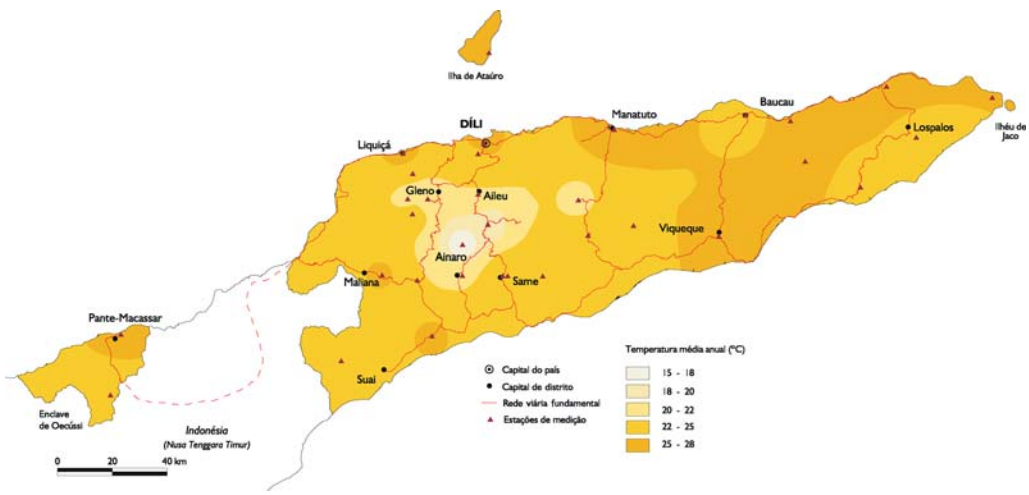

Figure 4. Average annual temperature (reprinted from *Atlas de East Timor* [16] with permission from LIDEL).

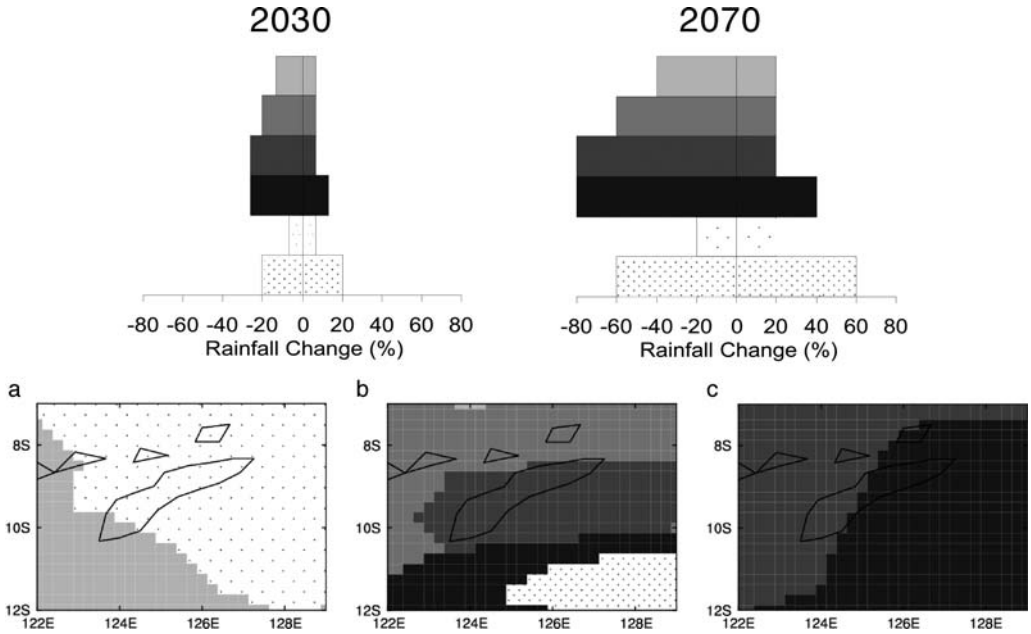

Figure 5. Ranges of possible change in rainfall for 2030 and 2070 gathered from nine climate models for the Timor region. The upper map shows the wet season (November–April), the central panel shows the second wet season (south)/early dry season (north) from May–July, and the lower panel shows the dry season (August–October).

and water quality. Farmers identify rainfall and water availability as the principal environmental constraints on agricultural production (3). Drought in 2001 to 2002, and the late arrival of the wet season in 2002 to 2003 resulted in an estimated 34% decline in maize production between 2002 and 2003 (22). As a result, 110 000 people were identified as being in need of food aid, particularly in the drier maize producing districts of Aileu, Ainaro, Ermera, and Liquica (23).

East Timor is also prone to flooding, especially on the southern side of the country. Cova Lima, Manufahi, and Viqueque each receive more rainfall than northern districts, and experience two wet seasons each year. Intense rainfall events often cause flooding in these places. For example, unseasonal rains in June 2003 resulted in intense flooding and associated landslides in Manufahi and Cova Lima, which affected 778 families and caused damage to 74 houses and 610 ha of rice paddy (24). The severity of these flooding events is most probably exacerbated by upland farming practices that causes soil erosion (discussed further in the Soils section), and the damage caused by landslides downstream is also a function of deforestation (4). Climate change may result in more frequent and more intense rainfall events such as these which, when coupled with existing processes that cause deforestation and soil erosion, could increase flood damage and landslides.

Water quality is also a problem in East Timor. Abrantes presents data that indicate that only 25% of water samples in Manatuto met district standards for water quality (25). Water quality in East Timor is less a function of inadequate waste disposal systems (although in most places water treatment systems are lacking), and more of suspended sediments in water courses due to erosion of slopes (see Soils section). In places where water is supplied via subterranean infiltration—such as in much of Lautem district—this is less of a problem. If climate change results in more intense rainfall episodes and land clearing continues unabated (which increases rates of erosion), then these problems of turbidity may worsen.

Soils

Soil erosion caused by clearing of vegetation on steep slopes is a major environmental problem in East Timor (26). Given current trends in land use, coupled with possible changes in rainfall patterns due to climate change, rates of soil erosion may increase in the future. Clearing land of established vegetation increases runoff rate and volume (less water permeates into the soil), which in turn means increased rates of soil erosion, increased risk of flooding downstream, and increased sediment loads and decreased water quality downstream (25). It also increases the risk of landslides, which are a problem in East Timor and which have resulted in deaths (3, 4). Further, the absence of established vegetation means less retention of soil moisture, meaning that soils are drier and agricultural productivity is less than could be achieved in more settled mixed farming systems.

Clearing of vegetation occurs as part of maize production in highland areas. However, the denudation of hills is not solely due to shifting cultivation. It is also a legacy of the use of defoliants during Indonesia's war against the Timorese in the

Table 1. Climate model simulations analyzed in Figure 5. Further information about the non-CSIRO simulations may be found at the IPCC Data Distribution Centre (http://ipcc-ddc.cru.uea.ac.uk/). Note that DAR125 is a regional climate model.

Center	Model	Emission scenarios post-1990 (historical forcing prior to 1990)	Years	Horizontal resolution (km)
CSIRO, Australia	Mark2	IS92a	1881–2100*	400
CSIRO, Australia	DAR125 (RCM)	Nested in Mk2 with IS92a	1961–2100	125
CSIRO, Australia	Mark3	SRES A2	1961–2100	200
Canadian CCCM	CCCM1	1% increase in CO_2 p.a.	1900–2100	400
Canadian CCCM	CCCM2	IS92a	1961–2100	400
Hadley Centre, UK	HadCM2	1% increase in CO_2 p.a.	1861–2100	400
Hadley Centre, UK	HadCM3	IS92a	1861–2099	400
DKRZ, Germany	ECHAM4/OPYC3	IS92a	1860–2099	300
NCAR, USA	NCAR	IS92a	1960–2099	500

* Pre-1990 period common to the SRES simulations.

late 1970s (27), harvesting of forest resources during the period of Indonesian occupation (26), and changes in energy availability since the Indonesian withdrawal in 1999. In response to the removal of the subsidy on kerosene that existed under Indonesian rule, wood has become a cheaper source of fuel for cooking (4). Subsequently, clearing of trees to produce fuel wood that is sold to district centers is also evident throughout most of the country. Our observations suggest that this is a well-organized market that is taking very large quantities of wood from rural areas. The demand for fuel wood is rational in the absence of cheaper sources of fuel, and the supply of this wood by people in rural areas is equally rational as means to earn cash income.

So, the principal driver of soil erosion is human activities. However, if climate change results in more intense rainfall events interspersed with intense dry spells, this may exacerbate soil erosion.

The Coastal Zone

As mentioned earlier, global mean sea level may rise by between 9 and 88 cm by the year 2100. Because Timor is in a tectonically active region, local land movements are likely to be an important part of relative sea level rise. Given East Timor's relatively pristine coastal environment, a rise of 9 cm over 100 years may pose no significant problems, except possibly for Dili. However, a change of 88 cm may pose some problems. Increased shoreline erosion is possible. Rising sea level can also cause saltwater intrusion into freshwater aquifers, affecting salinization of water used for drinking and agriculture. Coupled with a potential increase in severe rainfall events, it can also cause more extreme flooding at the mouths of rivers. Infrastructure such as buildings and roads, and activities such as agriculture that are close to the shore may be affected by shoreline retreat. Parts of the main road from Dili to Com via Bacau run close to the water's edge. In some places, such as Oecussi, neap tides can cause inundation of settled and farmed areas with seawater, which suggests that such places are vulnerable to rising sea levels.

The capital, Dili, seems at first glance to be moderately vulnerable to sea level rise because it is situated on a coastal plain extending inland to the base of a steep mountain range. It is also intersected by the Comoro, Bemorl, and Benmauc rivers, and although these rarely flood, if climate change increases intense rainfall events, then increased peak flows coupled with sea level rise could cause flooding in Dili. Sea level rise is an important concern because the city contains 19% of the country's population, it is the seat of government, and it is the location of the vast majority of public services and major international agencies. It is also the site of the country's major port and airport. Available evidence suggests that Dili's population grew by 39% between 2001 and 2004, putting further pressure on infrastructure damaged during the violence of 1999, and placing added demands on social services such as health care and education (15).

Counterbalancing this vulnerability to sea level rise is the remarkably pristine condition of much of East Timor's coastline outside of Dili. Because of the relative lack of development along Timor's coasts, the coping ability of the coastal zone seems high. Coral reefs everywhere seem relatively free from damage due to human activities. This increases their resilience to sudden rises in sea surface temperature, which in degraded reefs can impede recovery following thermal bleaching (28). There are significant stands of mangroves along much of East Timor's coast. These assist in restricting the movement of sediment from the land onto reefs, which can degrade the health of reefs. They also protect shorelines from high-energy waves that cause erosion, and they are breeding areas for many species of fish that are consumed. This suggests that investments in infrastructure for tourism (which is seen as a means to increase national income) will have to be developed carefully.

Agricultural Production

Agriculture is the most important socioeconomic sector in East Timor, accounting for approximately 85% of employment (29). Some 94% of sucos (an administrative district composed of a number of villages) report that farming is their main source of income (30). Nevertheless, East Timor is a net food importer. Given that this sector is critical to people's welfare, and is highly sensitive to climate change and variability, assessments of the vulnerability of agricultural systems is therefore a priority.

Maize is the most abundant and accessible crop, making it the most important source of food supply in East Timor. In 2002, 106 100 t of maize was produced relative to 35 200 t of rice, and 13 500 t of cassava (22). In most places maize is grown in shallow soils on steep slopes using shifting cultivation practices involving burning existing vegetation and planting seeds in the ashes. Westerberg estimates that up to 20% of the country is burned each year for maize production (31). In mountainous areas, population densities are sufficiently high, and the amount of land available restricted because of coffee plantations, that there is not enough land to allow for sufficient periods of fallow for this to be an ecologically sustainable form of production. As a consequence, declining yields are likely (if not already being experienced) due to soil erosion and nutrient depletion.

Maize is vulnerable to drought and irregular rainfall because it is not irrigated, and therefore relies on reliable and regular rainfall in the wet season; because most soils are not particularly fertile; and because maize production occurs on steep slopes. The unpredictability of rainfall affects the timing of planting; planting too early can waste seeds, depleting scarce seed stocks (22). In the longer term, soil erosion may also be exacerbated by changed rainfall regimes.

Rice is the second most important food crop in East Timor in terms of volume produced. Areas that are able to produce at least one rice crop per year tend to experience more food security than those that cannot, except in situations where crops are damaged because of flooding (13). Rice is mostly grown in relatively flat areas on the southern side of the island. In these places, the main harvest period is from August to October following the wet season. In northern areas, less rice is produced, and the main harvesting period is from July to August (22). Over 50 sucos are able to produce two crops per year because of the dual wet season, and three produce three crops per year (30). The second crop accounts for only 10% of total production, with the bulk of production coming from single crops irrigated by rain-fed flooding (22).

Irrigation is a critical input for rice production. Of 498 sucos, 286 have irrigation of some kind, and these roughly correspond to the areas that produce at least one rice crop per year (30). However, most of these systems operate in the wet season only, there being insufficient water in the dry season and no significant water storage systems for year-round irrigation of crops. Approximately 10 000 ha of irrigation rice systems are still damaged and require rehabilitation. The areas that produce a single crop each year, and which account for the bulk of rice production, may be sensitive to climate change, particularly if rainfall in the wet season decreases. All rice crops in flood prone areas may experience reduced production in the future because of increased flood events. Increased temperature may result in increased evaporation of water from paddies.

Coffee is the most important cash crop in East Timor, accounting for approximately 90% of foreign exchange (29). Some 25 000 families derive a significant proportion of their income from coffee production, and a further 15 000 families derive a small portion of income from it (29). However, the real price of coffee is now some 25% of the price in 1960 because of overproduction, commodity dependence, and increasing concentration of power in the hands of a few agribusinesses in the supply chain (32). This latter factor has shifted the share of production income from producers toward those involved in trading, marketing, and retail (33). Indeed, prices to producers in Timor are now so low that farmers are reluctant to harvest coffee beans and maintain the coffee crop (13).

Coffee requires an average annual rainfall of some 2000–3000 mm y^{-1} and relative humidity of 70%–90% (3). It also requires a distinct dry season for flowering and ripening of berries (3). For these reasons, coffee is grown in the northern and southern highlands, and is a major crop for most sucos in Aileu, Ainaro, Ermera, Liquica, and Manufahi (30). Rising temperatures and increased rainfall may alter humidity at lower altitudes where coffee is grown and shift the altitude band favorable for coffee production upward. Increased rainfall in the dry season may also have an adverse effect on flowering and ripening of berries.

Food Security

Food security is defined as a situation "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary and food preferences for an active and healthy life" (34). This has three components: food availability (supply), ability to access food (effective demand), and the ability to utilize food (nutrition). So, a food-secure household is one that has a sufficient quantity of nutritious food acquired through their own production (availability) and/or by purchasing food (access), and being healthy enough to absorb the nutrients and energy from the food consumed.

Many households in East Timor are already food insecure. In the "hungry season" from November to February, when stores of maize and rice from the previous harvest become depleted, many families do not have enough food (30). Indeed, in all districts at least 50% of sucos report having families with insufficient food in January, with as many as 96% of sucos reporting this in the predominantly maize growing districts of Ermera, Liquica, and Oecussi (30). The United Nations Development Program reports that 45% of children are underweight, indicating a high degree of food insecurity for many households (13).

In terms of food availability, aggregate national production is in most years insufficient to meet the food needs of the whole population of East Timor. Most rural households are reliant on their own production of food, usually maize, rice, and cassava, and it is this household production that is most vulnerable to climate change and the principal reason why climate change may be a food security problem for many people in East Timor (given existing levels of agricultural intensification). But limited household food production is not a problem if households have enough income to purchase food. Poverty, then, is a major impediment to food security. Given that approximately 41% of the population lives below the national poverty line, when household production falls because of climatic events, there is insufficient income to purchase additional food (13).

Households in Dili and the second major city of Bacau, many of which have one or more wage earners, are less likely to experience food insecurity because people there are better able to purchase food (providing there is no major inflation in food prices in urban centers) (35). Many rural households rely primarily on subsistence production, supplemented with some cash income from picking coffee or selling surplus rice. In recent years, food insecurity has been most pronounced in coffee growing areas in part due to the very low prices paid for coffee, in part due to the destruction in agricultural capital in 1999 (notably livestock, tools, seeds, and the displacement of labor), and in part due to reduced household food production due to drought.

The third element of food security is the ability of people to fully utilize the food they eat to extract the necessary energy and nutrients. An inability to do this is called secondary malnutrition, and it is essentially a problem of ill-health (for example diarrhea is a common cause of secondary malnutrition). East Timor has significant rates of communicable diseases that may affect nutrition, including malaria and tuberculosis (29). Low life expectancies (57.4 y), a high infant mortality rate (80 per 1000 live births), and a maternal mortality rate of 860 per 100 000 births reflect a general problem in population health in East Timor (13, 29). Malaria is endemic throughout the country, which accounts for 66% of absenteeism from school (29). Poor water quality in some parts of the country is already a cause of persistent diarrhea.

Climate change is thought to have some significant impacts on human health in the tropics (36). Increased temperature coupled with changes in rainfall can change the distribution and concentration of mosquitoes, which are vectors for diseases such as malaria and dengue fever. Declining water quality due to more intense rainfall events leading to increased erosion leading to an increased volume of suspended sediments can cause an increase in waterborne diseases such as cholera and diarrhea.

So, climatic events can and may continue to have an impact on food security because of excess dependence on climate-sensitive household food production and a lack of employment and other income earning opportunities. A secondary effect of climate change on food security may arise through an increase in diseases, resulting in secondary malnutrition.

CONCLUSIONS

East Timor is vulnerable to climate change. The country's climate is hot, dry, and variable, and climate change may cause it to become hotter, drier in the dry season, and increasing variable. Sea levels are likely to rise. East Timor's economy and the livelihoods of the vast majority of its people are heavily dependent on natural resources that are sensitive to changes in climate. In this paper we have considered three natural resources—water, soils, and the coastal zone—and found all to be susceptible to changes in climate and sea level. If climate change affects changes in the abundance and distribution of these resources, then agricultural production will decline, food insecurity will increase, and coastal areas, including the capital, may be damaged. Offsetting these risks, however, is the adaptability, ingenuity, and tenacity of the East Timorese: There can be no discounting their capacity to adapt to climate change given that it is nowhere near as dangerous as their long struggle for independence.

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Jon Barnett is an ARC Fellow at the University of Melbourne. His address: School of Social and Environmental Enquiry, University of Melbourne 3010, Victoria, Australia.
E-mail: jbarn@unimelb.edu.au

Suraje Dessai is a Senior Research Associate at the Tyndall Centre. His address: Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, United Kingdom.
E-mail: s.dessai@uea.ac.uk

Roger N. Jones is a Principal Research Scientist at CSIRO Atmospheric Research. His address: Climate Impacts Group, CSIRO Atmospheric Research, Private Bag No.1, Aspendale, Victoria 3195, Australia.
E-mail: roger.jones@csiro.au