Climate Risk and Vulnerability Assessment

May 2021

Timor-Leste: Water Supply and Sanitation Investment Project

ABBREVIATIONS

ADB	-	Asian Development Bank
CMIP	-	Coupled Model Intercomparison Project (number that follows is the phase)
CRVA	-	Climate Risk and Vulnerability Assessment
DMA	-	District Metered Areas
ENSO	-	El Niño–Southern Oscillation
STP	-	Septage Treatment Plant
GEF	-	Global Environment Facility
INDC	-	Initial Nationally Determined Contribution
MDB	-	Multilateral Development Bank
NAPA	-	National Adaptation Program of Action
NASA	-	National Aeronautics and Space Administration
RCP	-	Representative Concentration Pathway
USAID	-	United States Agency for International Development
WSSIP	-	Water Supply and Sanitation Investment Project
WTP	-	Water Treatment Plant

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EXECUTIVE SUMMARY

1. The proposed project aims to enhance water supply and sanitation infrastructure in secondary cities in Timor-Leste, in order to facilitate sustainable economic growth. The cities of Lospalos, Same and Viqueque have been selected for the project, based on their potential for economic growth, and communication and transport linkages. The total project cost is $62.5 million, of which Asian Development Bank (ADB) will finance $47 million, the government of Timor-Leste will provide $12.5 million, and co-financing of $3 million from the Global Environment Facility (GEF) is anticipated. The outputs of the project are:

(i) Output 1: Regulatory environment improved
(ii) Output 2: Water supply and sanitation infrastructure improved
(iii) Output 3: Institutional effectiveness improved

2. This Climate Risk and Vulnerability Assessment (CRVA) will focus on the infrastructure improvements under Output 2.

3. Timor-Leste has a hot and humid tropical climate influenced by the Western Pacific monsoon and the mountainous relief of the island. Rainfall varies significantly from north to south, with parts of the north of the island receiving as little as 500mm/year, whereas the western mountainous areas can receive up to 2800mm/year. The wet season lasts from December to March in the north of the island, with a prolonged 8-month dry season, but extends from November to June or July in the south of the island.

4. Historical trends in climate are difficult to estimate because of the disrupted nature of the meteorological record. It is clear that average annual temperatures have increased, however estimates of the rate vary, from 0.16°C/decade since 1950, to a more modest 0.11°C/decade from 1979–2005. Estimates of trends in precipitation vary; the Timor-Leste National Adaptation Programme of Action (NAPA) estimates a decrease in rainfall from 1961–1990, whereas United States Agency for International Development (USAID) suggest an overall increase from 1901 to 2009, but decreasing rainfall for many areas since 1990.

5. The vulnerability assessment identified high vulnerabilities related to (i) water scarcity during low rainfall and periods of drought (ii) flooding during extreme rainfall events iii) landslides, and (iv) extreme heat. The future climate changes for southern and eastern Timor-Leste by the mid-century (2050s) are for hotter conditions, with general model agreement on greater annual precipitation but strong inter-annual variability driven by El Niño-Southern Oscillation (ENSO), and potential changes to seasonality.

(i) Under the RCP4.5 climate scenarios temperatures rise by around 1C compared to the historical baseline, with increases in annual precipitation likely to be in the range of +2%-+12%, and increases in the number of days with extreme rainfall of up to 25%.
(ii) Under the RCP8.5 climate scenarios temperatures rise by 1.2C-1.6C compared to the historical baseline, with increases in annual precipitation likely to be in the range of +1%-+17%, and increases in the number of days with extreme rainfall of up to 17%.
(iii) Rainfall variability in Timor-Leste is driven by the ENSO cycle, and the evolution of ENSO under climate change will play an important role in determining drought and inter-annual variability in rainfall in the country. Changes in the ENSO cycle are still not well captured by climate models, however, the latest research indicates

that El Niño events may become both more frequent and more severe over the course of the century.

6. The projected changes in future climate should be considered in planning and design to ensure that infrastructure is climate resilient and the project delivers benefits under a range of future scenarios. Key climate change risks are:

(i) Drought and water availability: Timor-Leste water sources are sensitive to water scarcity from intermittent and unreliable rainfall associated with seasonality, as well as regular droughts, associated with El Niño events in particular. This causes dry/low river flows and reduced groundwater recharge during the dry season.

(ii) Flooding: The project cities are all at high risk of flooding, largely from flash floods caused by high rainfall intensities and increased surface runoff. All water supply and sanitation infrastructure is at risk of flooding and contamination. High intensity rainfall that causes flash floods may also reduce groundwater recharge for aquifers and available water. Floods also impact treatment processes through power outages and reduced treatment processes.

(iii) Landslides: Heavy rainfall causes regular landslides in areas of steep topography and are a risk for Same and Viqueque in particular. Landslides can damage water supply and sanitation infrastructure, and block watercourses or decrease water quality.

(iv) High temperatures: With increased temperatures, water demand will increase for drinking water and agricultural/industry use despite low supply, putting pressure on water sources. Timor-Leste watercourses are fast-flowing and intermittent and so are sensitive to increased temperatures and evaporation reducing water availability and water quality.

7. The overall project responds to the existing climate vulnerability context by improving water supplies for communities with limited access to water and poor sanitation facilities. It is well aligned with climate change priorities in Timor-Leste, including the NAPA, and the Initial Nationally Determined Contribution.

8. The assessment of residual risk to the project is not possible to robustly undertake in the absence of the results of the ongoing assessments of groundwater conditions and availability. Without data on likely sustainable yields from the different aquifer systems, and how they would perform in drought conditions, it is difficult to judge whether the water supply solutions proposed are suitably resilient.

9. The project includes $3 million of co-financing from the GEF, which includes a contribution of $2.4 million towards the resilience of the water and sanitation infrastructure components of the Water Supply and Sanitation Investment Project (WSSIP), $0.5 million to strengthen hydrological observation and monitoring, and $0.1 million for awareness-raising activities relating to climate resilience. Assessment of climate finance for the project, combining incremental and proportional approaches, based on available costs, estimates the Climate Finance (Adaptation) contribution of the project to be $6.45 million (10.3%) including the GEF contribution, and $3.45 million (5.5%) if the GEF portion is excluded.

I. INTRODUCTION

A. Project Description

1. Timor-Leste has experienced rapid urbanisation since independence; however, this has resulted in gaps in the provision of basic water supply and sanitation services, and unsustainable solutions to the provision of these services. The government recognises the need for long-term infrastructure investment in the sector, and has adopted a target of achieving 100% coverage for urban water supply and sanitation by 2030.

2. The proposed project aims to enhance water supply and sanitation infrastructure in secondary cities in Timor-Leste, in order to facilitate sustainable economic growth. The cities of Lospalos, Same and Viqueque have been selected for the project, based on their potential for economic growth, and communication and transport linkages. The total project cost is $62.5 million, of which ADB will finance $47 million, the government of Timor-Leste will provide $12.5 million, and cofinancing of $3 million from the GEF is anticipated. The outputs of the project are:

(i) **Output 1: Regulatory environment improved.** The project will support the project cities in developing, approving, and implementing a gender and socially inclusive institutional development roadmap that will guide the transfer of urban water supply and sanitation functions of the SMASAs to BTL, the newly established state-owned utility,[1] with consideration for appropriate information and communication technology, and digital solutions to improve efficiency in public service management. At the sector level, the project will support MPW in establishing service delivery guidelines on water supply and preparing a sanitation action plan for citywide inclusive sanitation.[2]

(ii) **Output 2: Water supply and sanitation infrastructure improved.** The project will improve access to inclusive water supply and sanitation infrastructure in the three project cities through: (i) construction of 14 water supply storage and 7 treatment facilities; (ii) rehabilitation and expansion of 130 km of water supply distribution network and formation of district metered areas; (iii) installation of meters for 10,000 household connections; and (iv) construction of 12 public toilets and 3 septage treatment facilities, including septage collection and transport.

(iii) **Output 3: Institutional effectiveness improved.** To ensure that infrastructure created under the project deliver services efficiently, the project will enhance the capacity of BTL and the SMASAs to plan, deliver, operate, and maintain water supply and sanitation infrastructure over the long-term. Women's participation in the sector will be encouraged including through enhanced job skills training for both women and men water services employees. To monitor institutional effectiveness, the project will develop and implement customer service feedback and complaint mechanism that ensures accessibility and responsiveness to the specific needs of both male and female customers. Improved O&M arrangements will also be developed to enhance the sustainability of the project assets and services.

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[1] The roadmap will cover key aspects of planning, service delivery, and financial management, and identify solutions that will be implemented over the project period.

[2] Citywide inclusive sanitation aims to achieve the following: (i) everyone in the city has access to and benefits from sustainable sanitation services, and (ii) human waste is safely managed along the whole sanitation service chain.

3. This CRVA will focus on the infrastructure improvements under Output 2, ensuring that the project adequately considers climate change in its design. Notably, the following project components are most relevant in the context climate change vulnerability and resilience:

(i) rehabilitation and improvement of existing water supply storage and treatment facilities,

(ii) rehabilitation and expansion of the water supply distribution network forming district metered areas,

(iii) installation of meters for all existing and new household connections, and

(iv) construction of public toilet facilities and of septage treatment facilities, including septage collection and transport.

4. Opportunities for adaptation, including additional storage and flood protection measures, as well as catchment restoration activities, exist in the project.

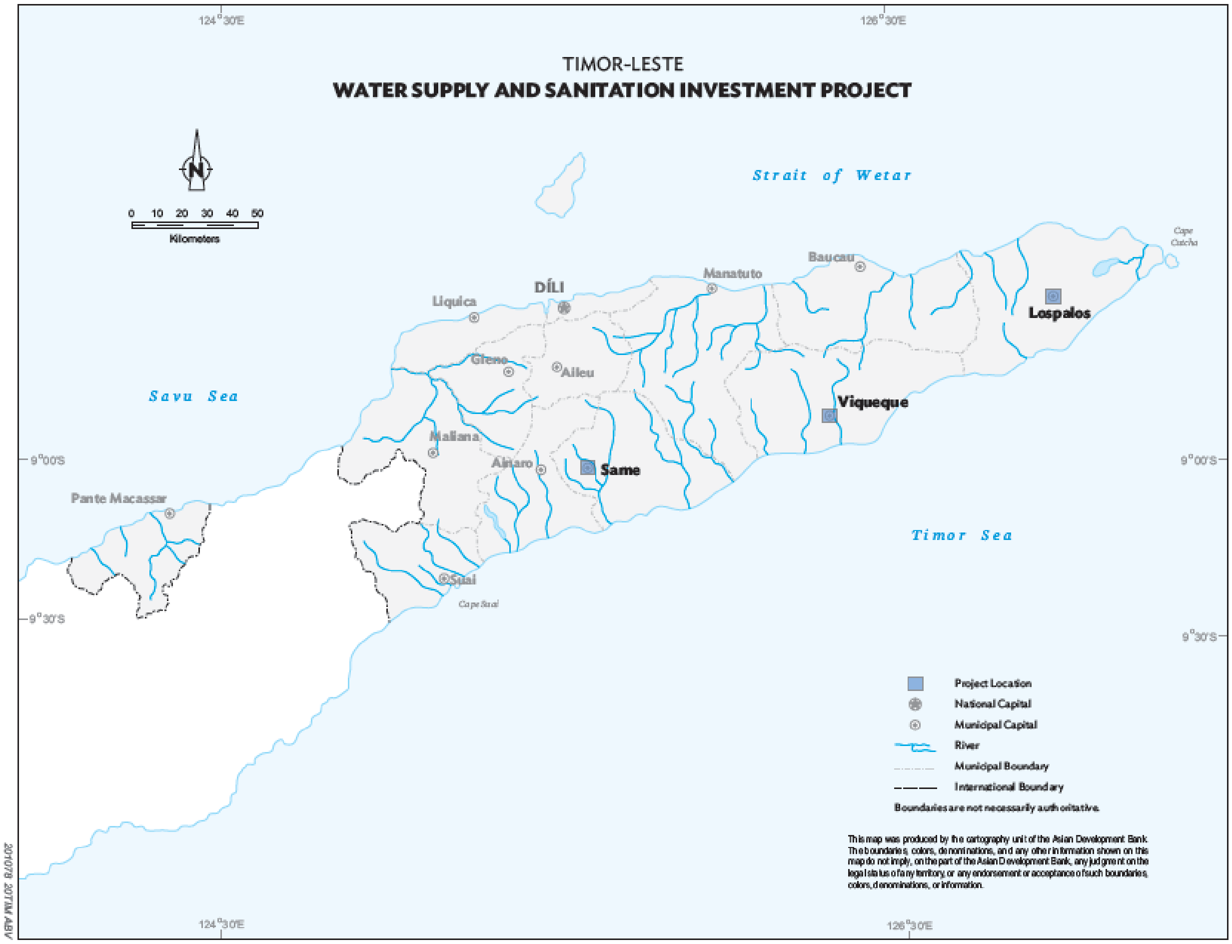
B. Site Locations

5. The sites for the project are in the cities of Lospalos, Same and Viqueque, with their locations within Timor-Leste shown in Figure I-1. Lospalos is the eastern-most municipality of Timor-Leste, and has a population of 21,866. Current water resources are a combination of two springs, and abstraction from a nearby lagoon. Rainfall occurs from Dec-July, with a 4-month dry season from August to November, and peaks of rainfall from May to June, with average annual temperatures around 25°C.

6. Viqueque municipality is located in the Southern lowlands, and has a population of 13,775. The climate is warmer and it receives less rainfall than in the highlands or southern slopes. Temperatures in Viqueque are consistent throughout the year, with maximum temperature that vary between 28°C to 32°C, and rains from November to July. Water supply to the town is via several springs.

7. Same has a population of 25,000 and is located on edge of southern slopes and southern highlands. The annual average temperature for Manufahi municipality is 24ºC, with rains from November to July. Water supply to the town at present is groundwater-based, via several springs.

Figure I-1 - Map of project locations



C. Climate vulnerability

8. The climate of Timor-Leste is described as a hot and humid climate influenced by the West Pacific Monsoon system. The southern region, where the project sites are located, experiences the Southern Bimodal Rainfall Pattern that has a 7-month to 9-month long wet season that peaks in December and May.

9. Timor-Leste experiences frequent floods and droughts due to high rainfall variability; the country usually experiences a drought every 4 years. The climate is greatly influenced by the ENSO which has a large impact on rainfall, sea level and water availability. The country is also subject to tropical cyclones, experiencing 25 cyclones from 1964 to 2002 that originate or pass through the Timor Sea bringing strong winds and storm surges.

10. **Climate vulnerability** is a combination of each site's **exposure** to hazards and the **sensitivity** of the **project components** to climate variables and future climate change. Table I-1 summarises the exposure of each site according to broad scale data sets, such as 'Think Hazard', available concept plans and a review of the site using Google Earth.[3] Exposure ratings have been

[3] Data sources for climate exposure:

1. Think Hazard https://thinkhazard.org/en/

modified based on site specific location as appropriate; for example, where sites are known to have poor drainage and be at risk of flooding the ratings for river and urban flooding have been upgraded (from the regional 'Think Hazard' rating to a new rating based on all evidence). Table I-2 shows the sensitivity of water supply and sanitation to climate variables and climate-related hazards, based on a review of the available literature[4] and supporting project documentation, as well as expert opinion. Table I-4 combines sensitivity score with exposure to describe the relative climate vulnerability of each project component.

11. Overall, the key physical climate risks facing the project cities are droughts, floods and landslides. These pose the greatest risk to water sources and water supply and drainage infrastructure within the project cities. The risk assessment in Section 2 focuses on these climate vulnerabilities.

Table I-1 - Climate exposure of the project sites

City	Extreme Heat	Landslides	River flood	Urban flood (inc flash flooding)	Water scarcity	Cyclone	Comments
Lospalos	Medium	Low	Low	High	Medium	Medium	Flat, dry terrain, no rivers Few trees Prone to flooding due to its flat topography and poor natural drainage
Viqueque	Medium	Medium	Medium	High	Medium	Medium	Steep terrain, dense forests Wooded area Vulnerable to runoff
Same	Medium	High	Medium	High	Medium	Low	Higher altitude 384m of Caraulun

2. Google Earth
3. NASA Shuttle Radar Topography Mission (STRM) digital elevation data.
4. Timor-Leste National Adaptation Programme of Action to Climate Change, 2010
5. Timor-Leste Water Sector Assessment and Roadmap, 2018.
6. Timor-Leste Disaster Management Reference Handbook, 2019.

[4] Data sources for climate sensitivity:

1. Timor-Leste National Adaptation Programme of Action to Climate Change, 2010.
2. Vulnerability assessment of climate change impacts on groundwater resources in Timor-Leste, 2012.
3. Guidance on water supply and sanitation in extreme weather events, 2010.

City	Extreme Heat	Landslides	River flood	Urban flood (inc flash flooding)	Water scarcity	Cyclone	Comments
							River runs through northern Same.

Table I-2 - Climate sensitivity of water supply sector

Climate Hazard	Drought	Heavy rainfall/ Flooding	Extreme heat	Cyclones/ Storms	Landslides
Water sources	Seasonality impacts the water sources. Rivers can have dry/low flows during dry season and flash flooding and high river flows in the wet season Depletion of groundwater aquifers due to reduce groundwater recharge from intermittent/reduced rainfall Shallow well systems run dry Changes in rainfall patterns undermine the viability of critical water supply infrastructure in communities Localised aquifers located in mountain areas have low potential yields and limited opportunities for development. Aquifers susceptible to rainfall changes, responding rapidly (seasonally).	Increased rainfall intensity causes increased rates of runoff leading to reduced groundwater recharge. Contamination of water sources from floodwater and animal faeces Borehole pumping control and treatment installation failure within flooded area.	Timor-Leste rivers are short, fast-flowing and intermittent so are very sensitive to increased temperatures and evaporation.	Stormwater over-flows contaminate local surface waters.	Contamination of water sources e.g increased turbidity. High sediment loads combined with water pollution can make water unfit for consumption and can lead to regular urban water shortages in some areas.

Climate Hazard	Drought	Heavy rainfall/ Flooding	Extreme heat	Cyclones/ Storms	Landslides
Water supply network	Reduced pressure in water supply systems from reduced water and intermittent supply can reduce quality and increase infiltration by contaminants.	Pumping stations flooded. Contamination of clean water supply.	Increased temperatures substantially increase the demand for water. Increased irrigation demands exerts pressure on water supply.	Storms can damage water capture, storage and distribution structures and contaminate water supply. Physico-chemical and bio-systems both affected by influent quality variation.	Destruction/damage of water supply network pipes, valves, pumping installations, wells. Breaks in pipes. Disruption of water supply to local area.
Water treatment	Reduced intakes impacts water treatment plant (WTP) performance.	Damage from storms and flooding to power supply needed to maintain water supply and sanitation services Flooding of WTP buildings Process performance adversely affected by poor raw water quality	Increased surface water temperatures, poorer water quality and lower dissolved oxygen (DO) adversely impact treatment processes reliant on higher DO and as such can lead to operational equipment failure.	Short-term WTP failure. .	Damage to building housing the treatment plant. Disruption to power supply Total/partial destruction of structure, Disruption to treatment due to severely contaminated source water.

Table I-3 - Climate vulnerabilities for project cities (exposure x sensitivity)

Lospalos

Project Components	Extreme Heat	Drought/Water scarcity	River flood	Urban flood	Cyclones /storms	Landslides
Water sources	Medium x Medium	Medium x High	Low x High	High x High	Low x Low	Low x High
Water supply + network	Medium x Low	Medium x Medium	Low x High	High x High	Low x Medium	Low x High
Water treatment	Medium x Low	Medium x Medium	Low x High	High x High	Low x Medium	Low x High

Viqueque

Project Components	Extreme Heat	Drought/Water scarcity	River flood	Urban flood	Cyclones /storms	Landslides
Water sources	Medium x High	Medium x High	Medium x High	High x High	Medium x Low	Medium x Medium
Water supply + network	Medium x Low	Medium x Medium	Medium x High	High x High	Medium x Medium	Medium x High
Water treatment	Medium x Low	Medium x Medium	Medium x High	High x High	Medium x Medium	Medium x High

Same

Project Components	Extreme Heat	Drought/Water scarcity	River flood	Urban flood	Cyclones /storms	Landslides
Water sources	Medium x High	Medium x High	Medium x High	High x High	Low x Medium	High x Medium
Water supply + network	Medium x Low	Medium x Medium	Medium x High	High x High	Low x Medium	High x High
Water treatment	Medium x Low	Medium x Medium	Medium x High	High x High	Low x High	High x High

D. Vulnerability summaries

Water scarcity

12. Droughts occur regularly in Timor-Leste, and these drought conditions can be made more extreme or extended under El Nino conditions. Timor-Leste water sources are sensitive to water scarcity from intermittent and unreliable rainfall associated with seasonality. This causes dry/low river flows and reduced groundwater recharge during the dry season. Water supply and treatment infrastructure is not as impacted by drought however the reduced inflow of water causes reduced quality of the water supply.

Extreme heat

13. With increased temperatures, water demand will increase for drinking water and agricultural/industry use despite low supply, putting pressure on water sources. Timor-Leste watercourses are fast-flowing and intermittent and so are sensitive to increased temperatures and evaporation reducing water availability and water quality. Increased surface water temperatures also interfere with treatment processes whilst extreme heat can interfere with power supply required for treatment processes.

Floods

14. The project cities are all at high risk of flooding, largely from flash floods caused by high rainfall intensities and increased surface runoff. All water supply and sanitation infrastructure is at risk of flooding and contamination. High intensity rainfall that causes flash floods causes reduced groundwater recharge for aquifers, reducing available water. Floods also impact treatment processes through power outages and reduced treatment processes. Drainage pipes and sewerage infrastructure can be overloaded causing contaminated floods.

Cyclones

15. Timor sea experiences cyclones however these usually have a low impact whilst passing Timor-Leste so do not pose as significant a risk although cyclones are likely to increase in frequency due to climate change. Infrastructure most at risk is the sewerage system which is at risk of overloading from floodwaters caused by cyclones and outages of power required for WTPs.

Landslides

16. Intense rainfall combined with soil erosion is the main cause of landslides in Timor-Leste. Landslides can damage all components of water supply and sanitation such as pipe breakages and blocking drainage systems causing water supply disruptions. Extreme landslides can destroy larger infrastructure such as buildings housing WTP and abstraction infrastructure. Landslides that occur near watercourses contaminate water supply by increasing turbidity and cause further flooding risks by blocking watercourses. Same and Viqueque have steeper topography and as such are at higher risk of water supply disruptions from landslides.

II. CLIMATE CHANGE RISK ASSESSMENT

A. Baseline climate

17. Consistent historical data is scarce in Timor-Leste due to gaps in observations and monitoring during the period of Indonesian rule. Here we characterise the baseline climate for Southern and Eastern Timor, for the area outlined in Figure II-1, using global datasets on historical precipitation, run-off and evapotranspiration from the Catchment Water Explorer (Catch-X).[5] This is followed by descriptions for each of the three sites, drawing on data presented in the project environmental characterisation report.

18. Timor-Leste has a hot and humid tropical climate influenced by the Western Pacific monsoon and the mountainous relief of the island. Rainfall varies significantly from north to south, with parts of the north of the island receiving as little as 500mm/year, whereas the central mountainous areas and southern slopes can receive 1500-2000mm/year.[6] The wet season lasts from December to March in the north of the island, but extends from November to June or July in the south of the island, as shown in Figure II-2. Average annual temperatures vary little throughout the year, but altitude exerts a strong influence, with average annual temperatures ranging from 27ºC on the coast, to 15ºC in the central mountainous areas.[7]

19. There is significant inter-annual variability in rainfall, and associated runoff, based on the modelled data available, as illustrated in Figure II-3. This variability is heavily influenced by the ENSO, which exerts a strong control on rainfall on the island, with ENSO years causing delays to the onset of the rainy season, and a tendency to drought conditions, and La Niña years resulting in increased heavy rainfall.[8]

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[5] Data provided through Catch-X is as follows: Precipitation data is from the global MSWEP dataset, modelled runoff, temperature and evapo-transpiration from the EU-funded eartH2observe dataset. https://ewgis.org/catchx-global/.

[6] Center for Excellence in Disaster Management and Humanitarian Assistance. 2010. *Timor-Leste Disaster Management Reference Handbook, 2019*. Dili.

[7] United States Agency for International Development. 2017. *Timor-Leste Climate Risk Profile*. Dili.

[8] Government of Timor-Leste. Ministry of Economy and Development. 2010. *Timor Leste National Adaptation Programme of Action (NAPA).* Delhi.

Figure II-1 - Area of Catch-X data for Southern Timor

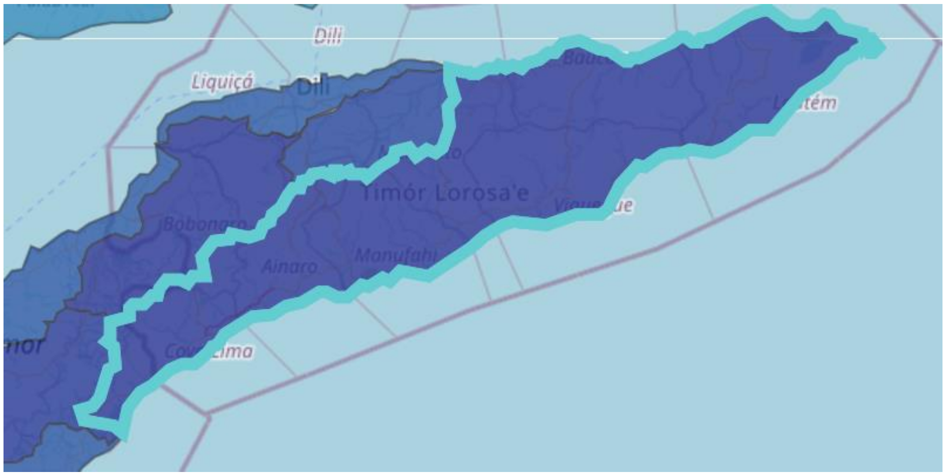


Figure II-2 - Baseline climatology for Southern and Eastern Timor-Leste (1990-2014)

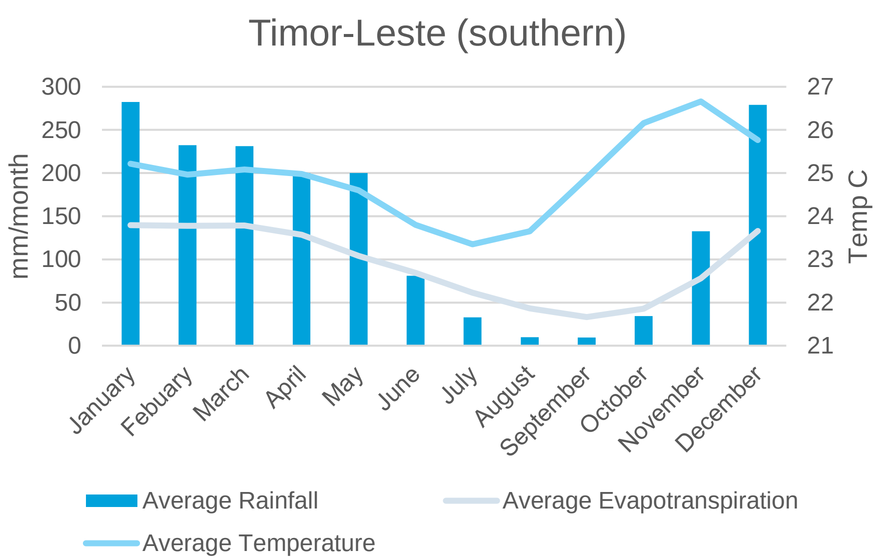
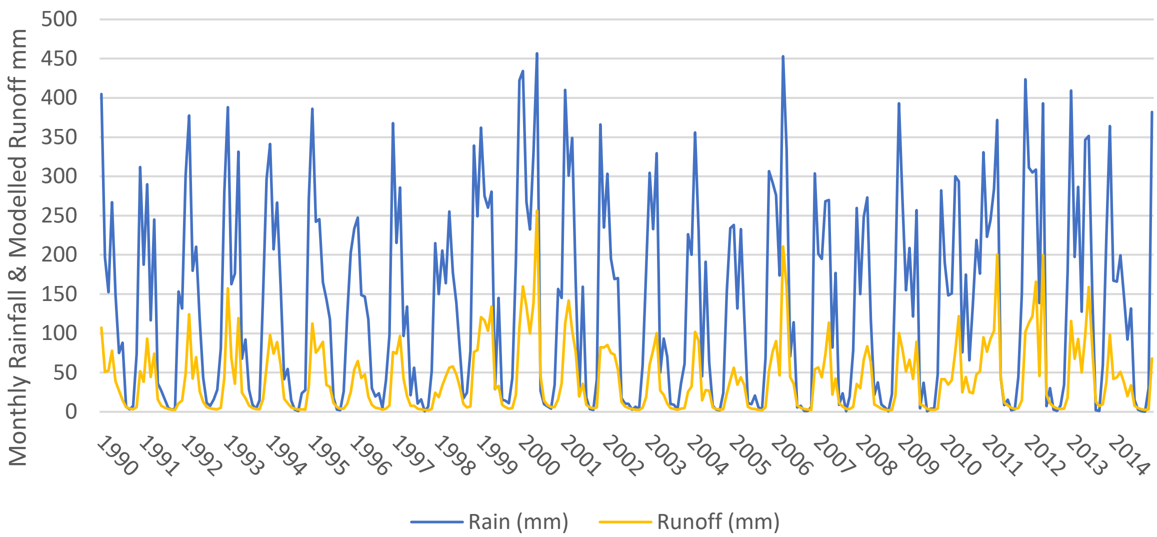


Figure II-3 - Monthly rainfall and runoff (mm) 1990-2014



20. Historical trends in climate are difficult to estimate because of the disrupted nature of the meteorological record. It is clear that average annual temperatures have increased, however estimates of the rate vary, from 0.16°C/decade since 1950,[9] to a more modest 0.11°C/decade from 1979 to 2005.[10] Estimates of trends in precipitation vary; the Timor-Leste NAPA estimates a decrease in rainfall from 1961 to 1990, whereas USAID suggest an overall increase from 1901 to 2009, but decreasing rainfall for many areas since 1990.[11] Analysis of the rainfall data for southern and eastern Timor from Catch X, meanwhile, shows no clear trend in rainfall over the period 1990–2014.

21. The most common climate-related hazard in Timor-Leste is flooding, with landslides, and drought, or prolonged dry-spells also recognised as significant hazards.[12] Significant flood events were recorded in 2001, 2003, 2006, 2013, 2019 and 2020, and a major drought occurred from 2015 to 2017.[13] It is not possible to say with certainty whether the frequency or magnitude of drought and flood events has changed.

B. Project Towns

1. Lospalos

22. Average annual temperature in Lautem municipality is 25°C, with maximum temperatures between 27 °C to 31 °C, and minimum temperatures in the range of 19 °C to 22 °C. Figure II-4 shows average annual precipitation for Lospalos Power Station from 2004–2019. Rainfall occurs from December to July, with a 4-month dry season from August to November, and peaks of rainfall from May to June. Heavy rainfall can cause localised flooding, and drought and water scarcity are also relevant climate-related hazards, as outlined in Section C.

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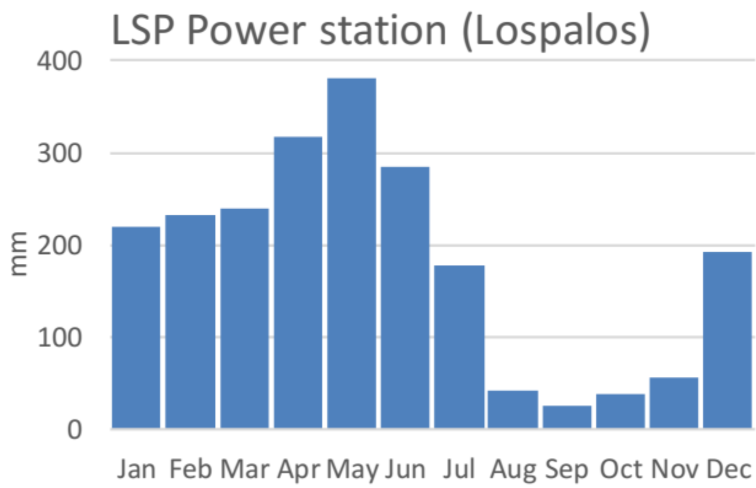
9 USAID (2017) Timor Leste Climate Risk Profile.
10 Timor Leste National Adaptation Programme of Action (NAPA).
11 USAID (2017) Timor Leste Climate Risk Profile.
12 Timor Leste Disaster Management Reference Handbook.
13 *Ibid.*

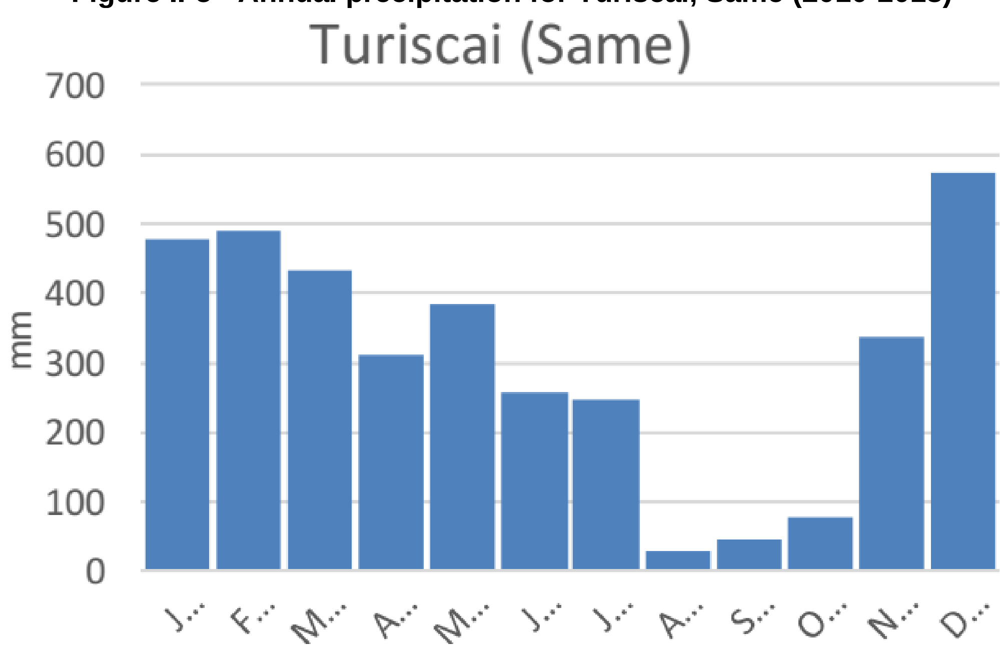
Figure II-4 - Annual precipitation for Lospalos Power Station (2004-2019)



2. Same

23. The annual average temperature for Manufahi municipality is 24ºC, with minimum temperatures from July to September, of around 20 ºC are experienced from July to September and the hottest temperatures from October to December (27ºC to 32ºC). Figure II-5 shows recent data from Turiscai Station, with a 3-month dry season, and rainfall from November to July, with the highest values from December to February. Drought, floods and landslides are the main climate hazards for Same, as elaborated further in Section C.

Figure II-5 - Annual precipitation for Turiscai, Same (2010-2018)

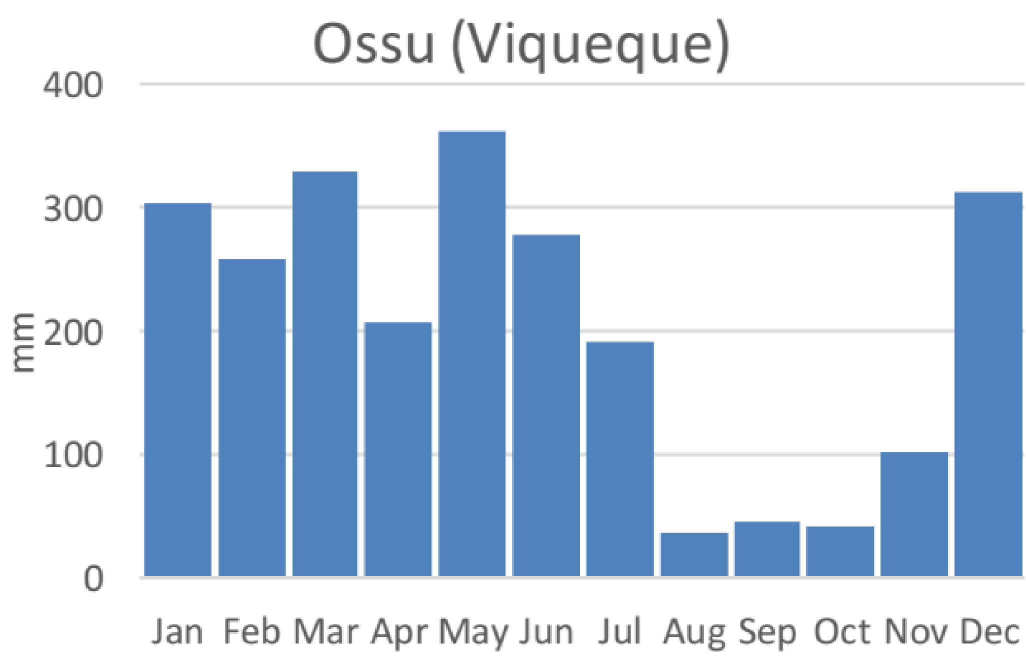


3. Viqueque

24. Temperatures in Viqueque are consistent throughout the year, with maximum temperature that vary between 28°C to 32°C and minimum temperatures from 18°C to 23°C.
Figure II-6 shows the pattern of annual rainfall in Viqueque for the period 2010-2018. Although a short time period, the pattern observed is consistent with historic data for the period 1952-74,[14] and shows a 3-month dry season from August to October, with the rainy season starting in November, and highest in March and May.

25. Flooding, landslides and drought are the major climate hazards in Viqueque, as further elaborated in Section C. Viqueque is also exposed to cyclones, which are a common cause of flooding in the region.

Figure II-6 - Annual precipitation for Ossu, Viqueque (2010-2019)



C. Future climate projections

26. The major climate risks to the project are water availability/drought, flooding, and landslides. This section provides an overview of climate projections for Timor-Leste, and then uses a 'Climate Futures' approach (Section D. 1.) to assess the risks to the project under different representative climate scenarios.

27. This study has reviewed future climate projections based on Coupled Model Inter-comparison Project (CMIP5) including analysis of statistically downscaled climate projections

[14] Government of Timor-Leste historic rainfall records. While not directly comparable, or suitable for use to assess change, the annual pattern provides confidence in the more recent rainfall record, even though it is short.

from the U.S. National Aeronautics and Space Administration (NASA). Climate projections are summarised for both RCP4.5 and RCP8.5, for the time period 2036–2065.[15] RCP4.5 represents a medium-low scenario in which the concentration of greenhouse gasses is stabilised by 2100, whereas RCP8.5 is a high emissions scenario, with no effective mitigation measures.

28. Table II-1 and Table II-2 summarise climate model projections from the CMIP5 ensemble, showing the 25th, 50th and 75th percentile of the ensemble of climate projections. Minimum, Maximum and Average temperatures will all increase under all scenarios, but increases are likely to be lower than the global average. For RCP4.5 average annual temperatures are likely to increase around 1°C for the 2036–2065 period, while for RCP8.5 increases are larger, with 1.2°C-1.6°C expected for 2036–2065.

29. There is broad agreement among the models for an increase in annual precipitation, with larger increases expected in the higher emissions scenario RCP8.5. It is important to note, however, that there are several models which suggest decreases in annual precipitation, as illustrated in Figure II-7.

Table II-1 - Climate Projections for Timor-Leste under RCP4.5

	Changes from the historical baseline (1986-2005)			
	Annual Precipitation %	**Min Temperature C**	**Max Temperature C**	**Average Temperature C**
2036-2065				
25th	2.26	0.72	0.86	0.79
50th	6.13	0.96	0.95	0.92
75th	12.28	1.10	1.14	1.19

Table II-2 - Climate Projections for Timor-Leste under RCP8.5

	Changes from the historical baseline (1986-2005)			
	Annual Precipitation %	**Min Temperature C**	**Max Temperature C**	**Average Temperature C**
2036-2065				
25th	0.99	1.23	1.19	1.24
50th	9.54	1.33	1.33	1.30
75th	17.01	1.55	1.59	1.56

30.

Figure II -8 shows the distribution of rainfall changes throughout the year for RCP4.5 for 2036-2065. The months of June to September are likely to become even drier, largely corresponding to the current dry season, and there is a clear signal for increases in rainfall from February to May.

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[15] Given the planned lifetime of the project it was not considered necessary to consider climate projections for the end of century.

Figure II-7 - Scatterplot of changes in temperature and annual precipitation (RCP4.5). Highlighted scenarios are those used for the simplified Climate Futures scenarios presented below.

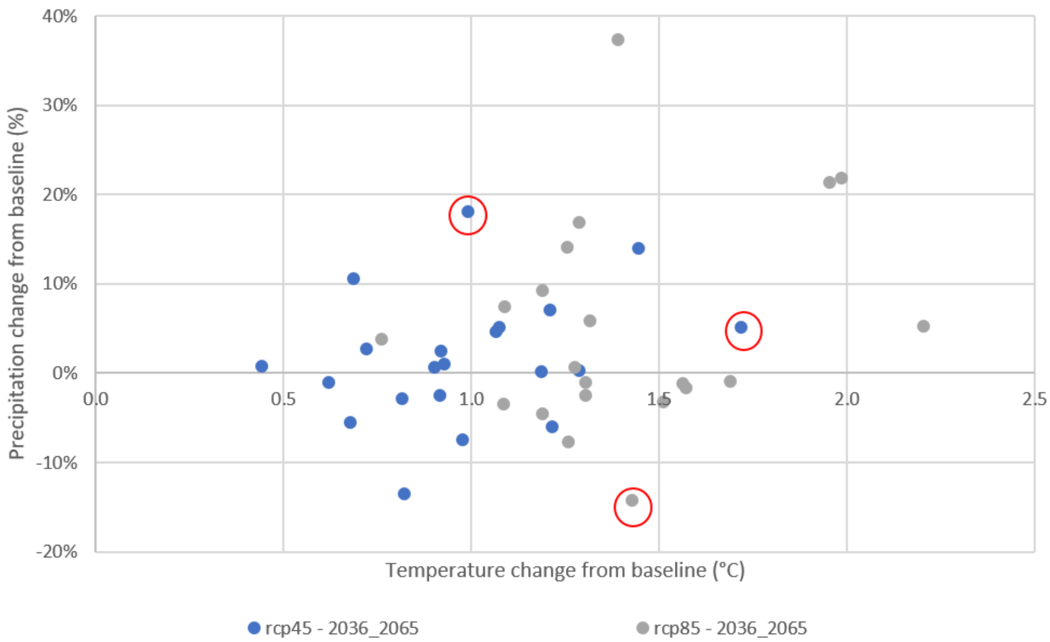
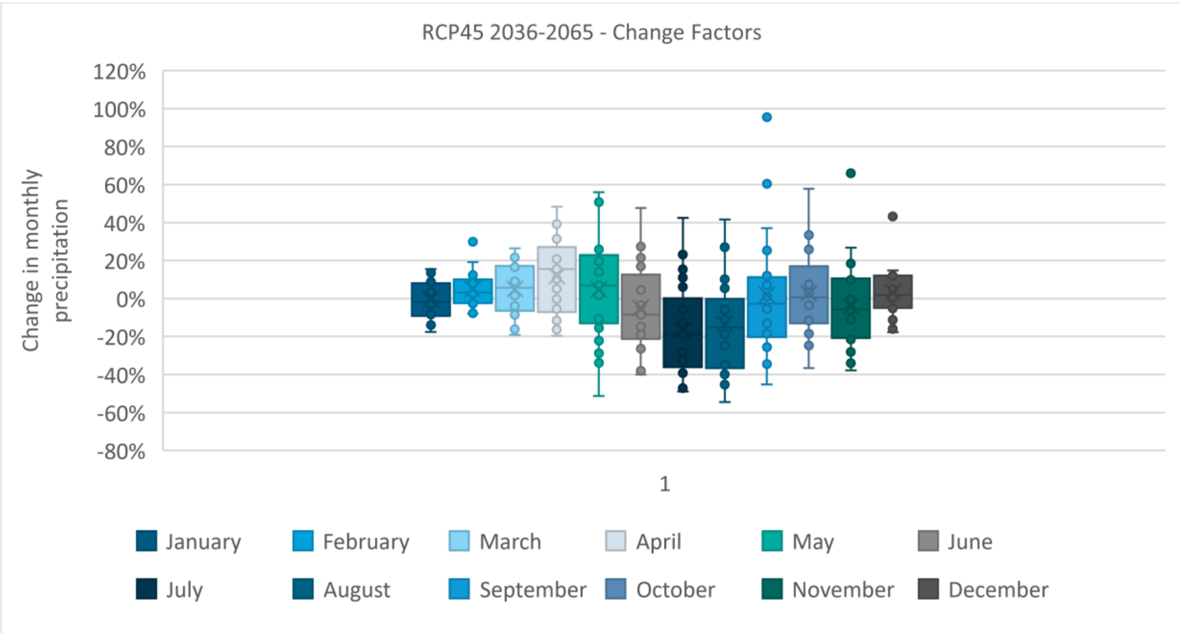


Figure II -8 - Distribution of change in rainfall in different months



31. The intensity of rainfall is expected to increase in Timor-Leste, with larger increases in extreme rainfall towards the end of the century. Analysis of changes in extreme rainfall at the 95th and 99th percentile values is summarised in Table II-3 and Table II-4. Under both RCP4.5 and RCP8.5 there is a clear signal of increased heavy rainfall, with an average +14.5% increase in the number of days exceeding the 99th percentile by mid-century in RCP4.5 and +9.7% increase in RCP8.5.

Table II-3 - Changes in rainfall values (%) for the 95th and 99th percentile (2036-2065, RCP4.5)

2036-2065	95th	99th
25th	-4.38	-2.73
50th	2.01	14.55
75th	17.15	25.45

Table II-4 - Changes in rainfall values (%) for the 95th and 99th percentile (2036-2065, RCP8.5)

2036-2065	95th	99th
25th	0.20	0
50th	4.21	9.73
75th	15.86	16.7

D. Climate Risks

1. Climate Futures Approach

32. Considering the different sources of evidence on climate change, which present a wide range of data for different scenarios and time periods, a simplified “Climate Futures” approach (Whetton et al, 2012) is adopted to consider the risks to the project. The purpose of considering a range of scenarios is to ensure that decision makers understand a range of possible future conditions and adopt “low regret” decisions that have a positive outcome under all scenarios. The proposed investments need to be resilient to future climate change until the mid-century, therefore mid-century climate changes are considered in the format of three simple scenarios:

(i) A “cool and wet” climate change scenario with average warming of 1°C, significant increases in annual precipitation, and a 5% increase in maximum annual rainfall

(ii) a “hot and dry” with warming of 1.4°C, a 14% reduction in annual average rainfall, but also a 45% increase in daily maximum rainfall; this scenario has increased variability and extremes

(iii) a “hot” scenario with 1.7°C of warming, a 5% increase in average annual precipitation and a 10% increase in maximum annual rainfall

Table II -5 - Simplified Climate Futures for risk assessment (2036–2065)

Climate metric	Cool and wet	Hot and Dry	Hot
Average annual rainfall	+18%	-14%	+5%
Dry season length	Decrease	Increase	Decrease
Maximum temperatures	+0.96ºC	+1.6 ºC	+1.76ºC
Average temperatures	+0.99ºC	+1.43ºC	+1.72ºC
Annual Maximum Daily Rainfall	+5%	+45%	+10%
Drought years (10th percentile)	Decrease in dry years	Increase in dry years	No change

33. These scenarios represent a range of plausible future outcomes, and planned infrastructure needs to account for the potential changes presented. The scenarios are summarised below, followed by implications for project design.

34. The Hot and Dry scenario is the most concerning, as the combination of a strong reduction in annual average rainfall, increase in the length of the dry season, and increase in temperatures would significantly reduce water aquifer recharge and water availability at all three sites. In addition, this scenario has an increase in abnormally dry years, and drought years which are drier than in the current climate. While there less rainfall, it is more intense, with an increase in maximum daily rainfall, which means increases in both surface and river flooding are likely, and will also increase the frequency of landslides, both triggered through heavy rainfall alone, and acting in combination with seismic activity.

35. Under the Hot scenario there is a slight increase in average annual precipitation, however, increased temperatures will lead to greater evapotranspiration, and there is unlikely to be much change in available water resources. The frequency and intensity of dry years does not change, meaning that water supply must be able to withstand similar drought years as at present. Maximum annual rainfall increases, although less than in the Hot and Dry scenario, however, increases in floods and landslides are likely.

36. The Cool and Wet scenario would likely increase available water resources, with significantly greater annual precipitation, a decrease in the dry season, and a reduction in the number of very dry years. Even under a scenario which has better outcomes for water resources as a whole, there is a small increase in maximum annual precipitation, and floods and landslides will remain significant hazards.

2. Water resources

37. Water availability is the key climate risk across all three project sites. The project design report notes large uncertainties at all three sites regarding the yield from existing and planned water sources, and the level of sustainable yield from each aquifer. In particular, there are clear discrepancies between the values outlined in the 2016 Masterplan,[16] and the values obtained through recent site observations.

[16] ADB. 2016. *Second District Capitals Water Supply and Sanitation Masterplan*. Manila. Report prepared under TA 8064: Second District Capitals Project.

38. The vulnerability of the different sites to the different Climate Futures is not the same for all project sites. Groundwater resources in Lospalos are not reported to be strongly seasonal, and the hydrogeological context, as well as initial results from test boreholes, suggests that water supply to the city is likely to be more resilient to potential changes in water availability. Additionally, the relatively flat terrain means that landslides are not a risk, and reduces the potential for contamination of water sources.

39. Both Same and Viqueque face significant challenges with seasonality of flow from the springs which comprise the current water supply system. In Same the design report notes that some springs are reported to almost run dry during the dry season, in contrast to strong flows reported in the 2016 Masterplan. The limited dry season, and potentially large inter-annual variability that may be indicated by the discrepancy between the different measurements, suggests that groundwater in the area would be vulnerable to reductions in precipitation or runoff, or an increase in drought conditions. For Viqueque there is limited potential to further exploit groundwater, and as such river intake is proposed. While this may increase reliability of water supply, likely increases in flood frequency and magnitude need to be accounted for in the design of the intake.

40. While uncertainty as to the exact hydrological situation limits the detailed analysis that can take place, it is possible to summarise the vulnerability of the different sites, as laid out in Table II-6 below:

Table II-6 - Climate risk scorecard for Water Resources for the three project sites

	Scenario 1	**Scenario 2**	**Scenario 3**
Scenario Name	**Cool and Wet**	**Hot and dry**	**Hot**
Lospalos			
Same			
Viqueque			

3. Water Supply Network

41. The piping and transmission network for all three sites will be laid underground, and follow roads where possible. This provides a degree of resilience to landslides, however, large events pose a risk if the slope itself where the pipe is buried undergoes movement, with damage to pipes, valves and other infrastructure possible. The increase in extreme rainfall under all three scenarios suggests an increasing risk of landslides, with Same and Viqueque most at risk due to the steep nature of the topography surrounding the project sites.

42. Flooding can affect pumping stations, water storage tanks and water treatment plants required as part of the transmission and distribution system. The increase in extreme rainfall means that an increase in flood frequency and extent is likely, in particular under the Hot and Dry scenario. Design and placement of network infrastructure should take account of these potential changes, either incorporating flood protection measures, or ensuring infrastructure is located in locations with good drainage and where flood risk is limited.

Table II-7 - Climate risk scorecard for Water Supply Network for the three project sites

	Scenario 1	Scenario 2	Scenario 3
Scenario Name	**Cool and Wet**	**Hot and dry**	**Hot**
Lospalos			
Same			
Viqueque			

4. Sanitation

43. The sanitation elements of the projects comprise septage treatment plants (STPs), and the provision of public toilets. Damage from flooding is the key risk to the STPs.

44. The risks to project infrastructure is greatest under Scenario 2, which has a 45% increase in maximum daily precipitation. Smaller increases in precipitation intensity are anticipated across the other two scenarios, however, as well as the wider set of climate models.

45. Given the increase in extreme precipitation, the STPs and public toilets are located in areas with low flood risk.

Table II-8 - Climate risk scorecard for Water Treatment and Sanitation for the three project sites

	Scenario 1	Scenario 2	Scenario 3
Scenario Name	**Cool and Wet**	**Hot and dry**	**Hot**
Lospalos			
Same			
Viqueque			

III. ADAPTATION ASSESSMENT

46. The project benefits from cofinancing of $3 million from the GEF,[17] which is allocated to climate resilience activities, and specifically a contribution of $2.4 million towards the water supply and sanitation infrastructure components of the WSSIP, $0.5 million to strengthen hydrological observation and monitoring, and $0.1 million for awareness-raising activities relating to climate

[17] Global Environment Facility. 2014. *Enhancing Climate Resilience of the Urban Services in Timor-Leste.* Dili.

resilience, as outlined in (Table III-1). In this section we briefly summarise the activities planned in the GEF project and then review any additional measures taken under WSSIP project and highlight areas where there may be an opportunity for additional measures (

Table III-2).

Table III-1 – Summary of GEF co-financing contributions.

Themes	GEF Outcomes	GEF Project Financing
1.Strengthening the climate resilience of infrastructure.	Lospalos, Viqueque and Same water supply infrastructure upgraded and resilient to climate change and climate variability (supplying approximately 92,000 persons)	2,400,000
2. Enabling adaptation through improved decision-making and knowledge development.	Hydrological data providing a basis for improved water supply management and increased adaptive capacity. Includes better monitoring and modelling.	500,000
	Lospalos, Viqueque and Same urban water supply user communities informed about climate change and resilient to climate change and climate variability. Includes improved communications and knowledge management.	100,000
	Total Global Environment Facility cofinancing	*3,000,000*

Table III-2 - Project outputs and climate adaptations

Project output/component	Adaptation included	Further adaptation opportunities
Water Sources and Raw Transmission Mains	Design for each city includes multiple different water sources in order to increase resilience of the system. The eastern boreholes for Same are specifically to supplement dry season flow. Improved intake structures are recommended to capture reliable yield during the dry season and to prevent seepage losses. For all project cities, permanent monitoring will be implemented for existing sources to enhance the limited database and to confirm there is adequate yield. For Same, catchment protection measures implemented to maintain the quantity and quality of current resources.	Monitor aquifer levels and yield from boreholes and springs to be able to quickly identify and decreasing trends. Consider rainwater harvesting in areas where no future water sources were identified. Protect boreholes from surface water ingress Design of river intake for Viqueque should anticipate increases in flood strength. Catchment protection and restoration measures are likely to be beneficial in securing water supply and reducing flood and landslide risk for all cities, as well as having wider social and environmental benefits.

Project output/component	Adaptation included	Further adaptation opportunities
Water Treatment Plant		Consider flood protection of the WTPs, if not possible to remove flood risk through appropriate siting, by raising the building/infrastructure above the maximum flood level.
Water Tanks and Pumping Stations	Increased storage of systems to ensure 24-hour supplies can be maintained. Lospalos - Increased storage and emergency capacities through 3 new reservoirs and 1 bulk water tank – to cope with seasonal demand changes. Emergency storage of 8 hours to provide capacity for gravity distribution systems for short outages of power caused by failure of power supply. Same – augmented reservoirs and 4 new tanks proposed for Same, increasing storage capacity to 4,380m^3 by 2030. Viqueque - Main reservoir and 4 new tanks proposed. Increase available water by 60%.	Most of the tanks are on the ground level – consider flood/runoff protection to avoid contamination. Consider revising storage capacity based on results of hydrogeological assessments.
Transmission Mains	Complete replacement of all service connections to protect against leakage and supply pressure loss.	
Distribution Network	New/replaced pipes with larger diameters to allow for greater capacity. Same – new/augmented pipelines with minimum pipe size increased to 75mm, all old pipes replaced. Viqueque – new/augmented pipelines with partial augmentation of Main Pipe by 3000m to reduce leakage Pipes laid underground – protection from landslides	Have a disaster management plan in place for water supply in case an extreme event disrupts the transmission pipes. e.g. landslides/earthquakes. Provision of spare flood pumps for emergencies
Septage Treatment Plant	On site reuse of treated wastewater to minimise run-off and for irrigation purposes. STPs chosen due to their success in hot tropical climates of Southeast Asia	
Public Toilets	Sites are not located in flood-prone areas.	

47. This section has provided an overview of the climate adaptation measures that currently included in the project design, both under the ADB and GEF-funded elements. Although the exact

volumes contained in the aquifers are not known, the design of the project allows a good level of resilience to potential decreases in water availability. Specifically, for each site, water supply comprises both primary and secondary sources, with boreholes (Same and Lospalos) and river intake (Viqueque) only used if flows from Springs are low. This provides confidence that even if rainfall decreases, there will not be excessive pressure on aquifer resources. Among these, additional catchment restoration and protection measures would be beneficial in securing water supply and reducing flood and landslide risk for all cities, as well as having wider social and environmental benefits.

48. The Multi-lateral Development Banks (MDBs) estimate adaptation finance using the joint MDB methodology for tracking climate change adaptation finance. This methodology is based on a context- and location-specific approach and captures the amounts associated with activities directly linked to vulnerability to climate change. MDBs are required to differentiate between their usual development finance and finance provided with an explicit intent to reduce vulnerability to climate change. Thus, the primary methodology for tracking adaptation finance attempts to capture the incremental cost of adaptation activities, for example the additional amount of drainage capacity or water storage required to account for climate change.[18]

49. The calculation of climate finance for adaption presented below is based on the costs for different project elements provided in the preliminary design report of October 2020, and the associated breakdown of costs provided in Appendix 7 of the report. While this provides an overview of costs for project components for the different cities, information is not provided on, for example, the additional cost of protecting distribution networks against landslides. Therefore, an incremental and proportional approach is adopted that makes some assumptions on project funds that can be allocated to Climate Finance (Adaptation).

Note: the calculation presented does not at present include assessment of institutional capacity-building components of the project.

50.
Table III-3 below summarises the costs for the different project elements as described in the preliminary design report, and the justification for the adaptation finance allocation that was made. Based on the available information, it is not considered that there is currently any climate finance (adaptation) for the water treatment plants, septage treatment plants, or public toilets. To avoid double-counting of climate adaptation finance for the water supply and sanitation infrastructure the final calculation only includes the amount eligible in addition to the GEF contribution of $2.4 million. It also includes an assessment of the activities related to reducing leaks and non-revenue water.

51. The calculations and rationale for the additional water supply needed focuses on increasing supply and coverage to meet increasing population in the project areas. At present, for water sources, only the cost of additional boreholes for Same specifically aimed at buffering dry season water availability has been included as adaptation finance. This assessment has demonstrated that water supply needs to be sustainable under possible hotter and dryer conditions as set out in Scenario 2 in Table II-6. If ongoing hydrological investigations demonstrate that in order to do this there would be a need for additional water sources, and/or additional storage capacity to cover reductions in supply in the dry season and in drought years (beyond what is currently planned in the project), then these additions could be directly considered as adaptation.

[18] European Bank for Reconstruction and Development. 2020. *Joint Report on MDBS Climate Finance*.

52. The activities related to reducing leaks and nonrevenue water, as outlined in Table III-1, could play an important role in adapting to potential decreases in water availability and ensuring adequate supply in the system. There are non-climate reasons to implement these activities, however, a reasonable case can be made that a major outcome is to reduce the water needed in the system, which would provide a buffer against potential reductions in water availability. As such, we suggest that while it is not possible to allocate 100% of the cost to adaptation finance, a proportional allocation of 50% could be applied.

Table III-3 - Climate Finance

Project Component	**Cost (m$)**	**Climate Adaptation**	**Climate Finance estimate (m$)**	**Rationale and assumptions**
Water Sources and Raw Transmission Mains	7.68	Incremental	1.08	Design for each city includes multiple different water sources in order to increase resilience of the system. The eastern boreholes for Same are specifically to supplement dry season flow, so their full cost is counted as climate finance.
Water Tanks and Pumping Stations	10.06	Proportional – 19%	1.91	Water storage has been designed to buffer against periods of low water availability. Climate change is not the sole reason storage is needed, but is a contributing factor.
Transmission Mains	3.91	Proportional – 4%	0.16	The transmission network will be laid underground. The major drivers for this are to reduce human interference with the network, and illegal connections, but also to avoid landslide and flood risk.
Distribution Network	17.63	Proportional – 4%	0.70	The distribution network will be laid underground. The major drivers for this are to reduce human interference with the network, and illegal connections, but also to avoid landslide and flood risk.
Reducing non-revenue water	4	50%	2.0	Activities related to leak detection and repair, and the deployment of a monitoring system to detect and leaks and maintain the pipes will reduce losses and increase the resilience of the system. The introduction of metering for some connections will reduce demand.
Total		9.4%[19]	5.85	Based on GEF project activities, this includes $2.4m of GEF finance.

[19] Calculated as % of total project cost of $62.5 million.

Total including full GEF contribution		10.3%	6.45	With the additional $0.6m for monitoring and capacity-building activities.
Total not including GEF contribution		5.5%	3.45	

IV. CONCLUSION

53. This assessment has outlined the key physical climate risks and vulnerabilities for the Timor-Leste Water Supply and Sanitation Investment Project. Water availability is the overarching risk to all three project sites, with detailed site investigations highlighting that current water supply for Same and Viqueque in particular, is highly seasonal. Floods and landslides also pose significant risks to the planned investments in the project.

54. The future climate changes for southern and eastern Timor-Leste by the mid-century (2050s) are for hotter conditions, with general model agreement on greater annual precipitation but strong inter-annual variability driven by ENSO, and potential changes to seasonality.

- Under the RCP4.5 climate scenarios temperatures rise by around 1°C compared to the historical baseline, with increases in annual precipitation likely to fall in the range of +2%-+12%, and increases in the number of days with extreme rainfall of up to 25%.
- Under the RCP8.5 climate scenarios temperatures rise by 1.2°C -1.6°C compared to the historical baseline, with increases in annual precipitation likely to fall in the range of +1%-+17%, and increases in the number of days with extreme rainfall of up to 17%.
- Rainfall variability in Timor-Leste is driven by the ENSO cycle, and the evolution of ENSO under climate change will play an important role in determining drought and inter-annual variability in rainfall in the country. Changes in the ENSO cycle are still not well captured by climate models, however, the latest research indicates that El Niño events may become both more frequent and more severe over the course of the century.

55. Given limitations with baseline data with regards to flood frequency and magnitude, it is not possible to provide quantitative design recommendations for the project at present. Analysis of climate projections, however, has demonstrated that there is a range of plausible climate futures, and that while a majority of models show wetter conditions, project design should ensure resilience against the hotter, drier conditions outlined in Scenario 2. In particular, we recommend using a 15% decrease in annual precipitation as a stress test to assess the sustainability of water supply against drier conditions. The planned modelling and monitoring activities should help to provide more robust baseline information, and is an important step in building a more climate resilient system.

56. The assessment considers residual risk to the project to be Low. The measures incorporated in the project provide a good level of resilience to climate change over the life of the project.

57. Although the exact volumes contained in the aquifers are not known, the design of the project allows a good level of resilience to potential decreases in water availability. Specifically, for each site, water supply comprises both primary and secondary sources, with boreholes (Same and Lospalos) and river intake (Viqueque) only used if flows from Springs are low. This provides confidence that even if rainfall decreases, there will not be excessive pressure on aquifer resources, and water supply will be adequate over the lifetime of the project. Additionally,

monitoring has been recommended which will build further evidence on the hydrogeological situation, and support future investments.

58. Extreme precipitation increases in all three scenarios analysed, and a large majority of the full ensemble of climate projections summarised in Section C. As such determination of areas of low flood risk, which are suitable for the siting of STPs in particular, should consider the potential for flooding affecting larger areas than at present.

59. The project includes $3 million of co-financing from the GEF, which includes a contribution of $2.4 million towards the resilience of the water supply and sanitation infrastructure components of the WISSP, $0.5 million to strengthen hydrological observation and monitoring, and $0.1 million for awareness-raising activities relating to climate resilience. Assessment of climate finance for the project, combining incremental and proportional approaches, based on available costs, estimates the Climate Finance (Adaptation) contribution of the project to be $6.45 million (10.3%) including the GEF contribution, and $3.45 million (5.5%) if the GEF portion is excluded.

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Appendix A : Climate Projections

A.1 Data Sources

NASA NEX-GDPP

The NASA Earth Exchange (NEX) Global Daily Downscaled Projections (GDDP)[20] dataset has been accessed to provide relevant climate projections for Fiji based on the latest CMIP5 model inter-comparison project. The dataset provides statistically downscaled projections using a quantile downscaling method, Bias-Correction Spatial Disaggregation (BCSD) (Thrasher et al., 2012). The dataset uses 21 GCMs for scenarios RCP 4.5 and RCP 8.5, therefore, there are 42 projections available for analysis in this dataset.

The spatial domain

The entire NEX GDPP dataset is available for access online at a size of 12 Terabytes. To download a manageable portion of the data it was necessary to define a geo-spatial ‘window’ of data using latitudes and longitudes[21] that cover the area of interest. The dataset is having a spatial resolution of 0.25 degrees x 0.25 degrees and has its western boundary at 180˚W; its eastern boundary at 180˚E; its northern boundary at 90˚N; and, its southern boundary at 90˚S. Data for one domain were downloaded for -8.2 to -9.5N, 124.7 to 127.5E.

Variables and time-step

The NEX GDPP dataset provides daily data for precipitation (per), minimum daily surface air temperature (tasmin), and maximum daily surface air temperature (tasmax). Using a daily time-step data allows for estimation of changes in heavy rainfall, high temperatures and other indicators.

Time periods

The baseline period should be reflective of the local observational data period used to characterise the current climate and be of a long enough period such that the effects of weather is averaged out, commonly chosen to be 30 years. It is proposed to use 1976-2005 as the baseline period for the climate change assessment. Future time periods will be centred on the 2050s (2036-2065) and 2080s (2066-2095).

References

Thrasher, B., Maurer, E. P., McKellar, C., & Duffy, P. B., 2012: Technical Note: Bias correcting Climate model simulated daily temperature extremes with quantile mapping. *Hydrology and Earth System Sciences,* 16(9), 3309-3314.

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[20] Acknowledgement: The NEX-GDDP dataset was prepared by the Climate Analytics Group and NASA Ames Research Center using the NASA Earth Exchange, and distributed by the NASA Center for Climate Simulation (NCCS).

[21] The NEX-GDDP dataset uses WSG84 for mapping coordinates.

Catch-X

Catch-X provides free climate data repackaged and processed into river catchment form for across the globe.

The different datasets available include:

- Precipitation (MSWEP);
- Temperature, evapotranspiration and water runoff (eartH2Observe);
- Landcover types (ESA-CCI); and,
- River gauge locations (Global Runoff Data Centre)

Their data is monthly and can be downloaded as a CSV file via the Catchment Water Explorer app: *https://ewgis.org/catchx-global/*

The data we accessed:

In September 2020, Atkins downloaded data for 1 catchment covering the entirety of southern Timor-Leste.

The data accessed were for the time period 1990 to 2014 for the following variables:

- Temperature (degrees Celsius)
- Precipitation (mm)
- Evaporation (mm) and,
- Run-off (mm).

ADB Documents and other sources

Baseline climate information for the project towns was sourced from the Masterplan (2016) and Timor Leste Government sources, accessed in September 2020.

NASA climate projections

	Historical	RCP4.5			RCP8.5			RCP4.5			RCP8.5		
	1976-2005	2006-2035	2036-2065	2066-2095	2006-2035	2036-2065	2066-2095	2006-2035	2036-2065	2066-2095	2006-2035	2036-2065	2066-2095
	Absolute Value							Change Factor					
NorESM1-M	42.28	47.99	45.89	44.71	48.44	47.96	48.19	0.13	0.08	0.06	0.14	0.13	0.14
BNU-ESM	40.24	39.61	39.92	41.47	40.18	37.90	44.14	-0.02	-0.01	0.03	0.00	-0.06	0.10
CCSM4	57.74	64.49	59.06	69.70	61.84	58.41	76.99	0.12	0.03	0.20	0.07	0.01	0.33
MRI-CGCM3	62.17	57.88	65.68	65.46	63.58	62.09	63.56	-0.07	0.06	0.06	0.03	0.00	0.02
MIROC5	56.92	57.08	54.51	51.19	54.08	51.07	57.39	0.01	-0.04	-0.10	-0.05	-0.10	0.01
CESM1-BGC	58.23	57.75	62.18	63.90	65.24	65.64	70.45	-0.01	0.07	0.10	0.12	0.12	0.21
CNRM-CM5	54.06	58.65	56.12	58.49	55.29	62.68	63.15	0.09	0.04	0.09	0.03	0.16	0.18
IPSL-CM5A-LR	43.05	41.28	50.18	50.46	50.67	59.51	67.15	-0.04	0.16	0.17	0.17	0.37	0.55
bcc-csm1-1	42.67	42.21	43.60	43.95	44.96	54.18	49.44	0.00	0.03	0.04	0.06	0.28	0.16
MIROC-ESM-CHEM	39.31	38.90	41.09	40.30	40.99	35.85	33.11	-0.01	0.05	0.03	0.04	-0.09	-0.16
MPI-ESM-LR	45.74	53.09	54.01	60.28	52.07	58.97	61.49	0.16	0.18	0.32	0.14	0.29	0.34
MIROC-ESM	42.23	40.31	42.25	40.34	39.47	41.04	37.33	-0.04	0.00	-0.04	-0.06	-0.02	-0.11
GFDL-ESM2M	49.43	52.16	56.63	61.34	52.49	54.06	63.69	0.06	0.15	0.24	0.06	0.09	0.29
CSIRO-Mk3-6-0	45.34	52.59	49.59	49.00	50.39	49.63	50.61	0.16	0.10	0.08	0.11	0.10	0.12
ACCESS1-0	51.65	47.95	48.90	52.05	236.43	217.75	203.65	-0.07	-0.05	0.01	3.55	3.19	2.92
MPI-ESM-MR	48.65	47.27	48.98	50.30	49.58	49.51	52.78	-0.03	0.01	0.04	0.02	0.02	0.09
GFDL-ESM2G	52.10	62.50	65.03	53.45	61.56	61.91	66.67	0.20	0.25	0.03	0.18	0.19	0.28
inmcm4	48.36	47.76	47.51	48.30	50.04	50.06	57.15	-0.01	-0.02	0.00	0.04	0.04	0.18
IPSL-CM5A-MR	46.70	51.56	51.72	54.87	51.37	60.61	66.12	0.11	0.11	0.18	0.10	0.30	0.42
GFDL-CM3	49.42	56.25	54.70	56.96	58.82	56.89	61.38	0.14	0.12	0.16	0.19	0.16	0.25
CanESM2	39.70	37.47	46.09	38.37	40.10	40.47	45.47	-0.06	0.16	-0.03	0.01	0.02	0.15
Average	48.38	50.23	51.60	52.14	60.36	60.77	63.80	0.04	0.07	0.08	0.24	0.25	0.31

Precipitation

Anomalous data is highlighted in red.

Temperature

	Historical	RCP4.5			RCP8.5			RCP4.5			RCP8.5		
	1976-2005	2006-2035	2036-2065	2066-2095	2006-2035	2036-2065	2066-2095	2006-2035	2036-2065	2066-2095	2006-2035	2036-2065	2066-2095
	Absolute Value							Change Factor					
NorESM1-M	25.62	26.04	26.61	26.83	26.14	26.91	28.03	0.42	0.99	1.20	0.52	1.29	2.41
BNU-ESM	25.65	26.28	26.83	27.09	26.30	27.21	28.27	0.63	1.18	1.44	0.65	1.56	2.62
CCSM4	25.88	26.02	26.49	26.73	26.20	26.96	28.09	0.14	0.62	0.86	0.33	1.08	2.21
MRI-CGCM3	25.58	26.00	26.39	26.87	25.97	26.88	28.00	0.42	0.82	1.29	0.39	1.30	2.42
MIROC5	25.61	26.06	26.54	26.81	26.10	26.79	27.81	0.45	0.93	1.20	0.49	1.19	2.20
CESM1-BGC	25.88	26.13	26.60	26.82	26.15	26.97	28.01	0.25	0.72	0.94	0.28	1.09	2.13
CNRM-CM5	25.65	26.03	26.57	26.93	26.05	26.84	27.97	0.38	0.92	1.28	0.40	1.19	2.32
IPSL-CM5A-LR	25.82	26.47	27.27	27.74	26.52	27.78	29.47	0.64	1.45	1.92	0.70	1.96	3.64
bcc-csm1-1	25.76	26.22	26.67	26.99	26.22	27.04	28.03	0.46	0.91	1.23	0.46	1.27	2.26
MIROC-ESM-CHEM	25.76	26.21	26.83	27.32	26.28	27.33	28.85	0.44	1.06	1.56	0.52	1.57	3.09
MPI-ESM-LR	25.88	26.28	26.79	27.13	26.39	27.20	28.49	0.39	0.90	1.25	0.51	1.31	2.60
MIROC-ESM	25.71	26.24	26.78	27.35	26.11	27.22	28.69	0.53	1.07	1.64	0.40	1.51	2.98
GFDL-ESM2M	25.72	26.01	26.40	26.71	26.16	27.02	27.88	0.29	0.68	0.99	0.44	1.30	2.16
CSIRO-Mk3-6-0	25.65	26.28	26.86	27.37	26.11	27.07	28.37	0.63	1.21	1.72	0.46	1.43	2.72
ACCESS1-0	25.71	26.04	26.69	27.22	26.12	27.10	28.15	0.33	0.98	1.51	0.40	1.39	2.44
MPI-ESM-MR	25.90	26.23	26.72	27.03	26.31	27.16	28.42	0.33	0.82	1.13	0.41	1.26	2.52
GFDL-ESM2G	25.84	26.28	26.53	26.79	26.43	27.10	28.16	0.44	0.69	0.95	0.59	1.25	2.32
inmcm4	25.73	25.81	26.17	26.39	25.90	26.49	27.38	0.08	0.44	0.66	0.17	0.76	1.65
IPSL-CM5A-MR	25.92	26.31	27.12	27.82	26.32	27.90	29.55	0.39	1.21	1.90	0.41	1.98	3.63
GFDL-CM3	25.57	26.40	27.28	27.81	26.54	27.77	29.42	0.83	1.72	2.24	0.97	2.20	3.85
CanESM2	25.90	26.52	27.19	27.43	26.61	27.59	28.81	0.62	1.29	1.53	0.71	1.69	2.91
Average	25.75	26.18	26.73	27.10	26.23	27.16	28.37	0.43	0.98	1.35	0.49	1.41	2.62

Catch-X Data

	Average Total Rainfall (mm)	Average Daily Rainfall (mm)	Average Temperature (DegC)	Average Evapotranspiration (mm)	Average Runoff (mm)
January	282	9.1	25.2	140	79
February	232	8.3	25.0	139	77
March	231	7.5	25.1	139	79
April	200	6.7	25.0	128	75
May	200	6.5	24.6	104	51
June	81	2.7	23.8	84	27
July	33	1.1	23.3	61	13
August	10	0.3	23.7	43	6
September	10	0.3	24.9	33	4
October	34	1.1	26.2	43	6
November	133	4.4	26.7	78	20
December	279	9.0	25.8	133	56

Data from Masterplan (2016)

Monthly rainfall data

	Lospalos		Same		Viqueque	
	Rainfall (mm)	Evaporation (mm)	Rainfall (mm)	Evaporation (mm)	Rainfall (mm)	Evaporation (mm)
January	225	80	350	70	215	105
February	225	65	360	55	195	85
March	260	75	330	70	205	90
April	240	70	260	75	215	70
May	320	70	290	55	245	60
June	320	75	230	50	170	60
July	140	85	140	65	100	65
August	45	105	35	95	25	75
September	15	120	25	115	10	120
October	30	140	50	125	20	150
November	80	130	145	110	70	140
December	230	90	340	105	200	125

Data source: Seeds of Life (http://seedsoflifetimor.org/climatechange/climate-data).