Timor-Leste (TIM): Coffee and Agroforestry Livelihood Improvement Project
Climate Risk and Vulnerability Assessment

A. Introduction

1. ADB (2014) sets out a methodology for identifying climate risks and incorporating corresponding adaptation measures into project design. The overall aim is to reduce the risks to ADB investments. Steps may include climate risk screening (concept phase); climate risk and vulnerability assessment; technical and economic evaluation of adaptation options and incorporation of selected options into project design; and monitoring and reporting.

2. Previous climate screening of the Coffee and Agroforestry Livelihood Improvement Project (CALIP) categorized the overall project climate risk as 'medium'. Hence, in line with ADB procedures, a climate risk and vulnerability assessment (CRVA) should be undertaken. Given the relatively small size of the investment (total investment of approximately $3.2 million), a streamlined CRVA methodology has been used. This report presents the findings from the CRVA.

B. Project Background

3. CALIP is a project to support implementation of Timor-Leste's Coffee Sector Development Plan, 2019-2030 (NCSDP). Coffee is Timor-Leste's largest non-oil export and is grown by 37.5% of all Timorese households with half of these households relying on the crop for cash income. Despite its significance, the coffee sector is currently operating far below its long-term potential. Production is low and volatile, quality is inconsistent, and sector management is weak. As a result, many coffee producing households live in extreme poverty.

4. CALIP will help to address this by strengthening sector management and providing targeted support to smallholder producers. This will help to generate sustained increases in household income, reduce poverty and contribute to the growth of non-oil exports. The project has three outputs: i) more productive coffee and agroforestry production systems established; ii) coffee quality and market linkages improved; iii) sector management and coordination improved.

5. As part of output 1, the project will support an in-depth profiling and suitability analysis of existing coffee varieties, improved management of the nurseries where seedlings are produced, establishment of at least one multi-variety research trial and ten on-farm technology trials, and delivery of training on productivity improvement to 2,000 households in the municipalities of Aileu, Ainaro, Bobonaro, Ermera, Liquica, and Manufahi. Under output 2, the project will support annual coffee quality competitions, help to establish a grading system for quality-based classification of fresh and processed coffees, and improved marketing of Timorese coffees to consuming markets. Under output 3, the project will support the establishment of a farm information management system to track the condition of coffee farms and record delivery of training to farmers, help to facilitate the quarterly meetings of the taskforce for implementation of the NCSDP, and establish a platform for knowledge sharing and ongoing industry learning.

6. The project will be implemented for four years from 2020 to 2024 and has a total budget of $3.2 million of which $3.0 million will be financed through a grant from the Japan Fund for Poverty Reduction.

C. Exposure to Climate Risks

7. The project seeks to improve the productivity of smallholder managed coffee farms and the overall quality of coffee that is produced in Timor-Leste. Both the production and processing of coffee are influenced by climatic factors. In order to identify potential climate risks, the specific details of systems for coffee production and processing in Timor-Leste are described in more detail below.

1. Climate requirements for coffee cultivation and processing

8. Two species of coffee are grown commercially: Coffea Arabica, and Coffea Canephora (Robusta). Many varieties of C. Arabica that are produced commercially are descended from the Hibrido de Timor (HdT), a naturally occurring Hybrid of C. Arabica and C. Robusta that was discovered in Timor-Leste in 1927. These inter-species hybrids have the tetraploid genetic structure of C. Arabica but include genes that have been transferred from C. Robusta.

9. The coffee plant requires a specific climate to produce good quality coffee beans. C. Robusta and C. Arabica have similar rainfall requirements, but C. arabica requires a cooler climate for flowering and fruit set, has lower yields, and is more susceptible to pests and diseases. C. arabica's lower productivity is offset by the higher quality of its coffee, which commands a higher price due to the presence of fine flavors. Coffee production is very dependent on a sequence of rainfall events, matched with a suitable temperature. Flowering is induced by soaking rains after a significant (3 months or more) dry spell. Rainfall is required through the berry production period, and then a drier period is preferred leading up to harvest. Dryer weather at harvest makes the harvest of red cherry easier, facilitates transport of the fresh cherry and facilitates the timely drying of coffee after initial processing.

10. Rainfall requirements depend on the water retention properties of the soil, atmospheric humidity and cloud cover, as well as cultivation practices. The optimum annual rainfall range is 1200-1800 millimeters (mm) for arabica coffee. A similar range seems to be required for robusta, although it adapts better than arabica to intensive rainfall exceeding 2000 mm. For both species, a short dry spell, lasting 2- 4 months, corresponding to the quiescent growth phase, is important to stimulate flowering.

11. A cooler climate (optimum mean annual temperature of 18-21 C) is optimal for arabica coffee. Temperatures above 23ºC, during the development and ripening of fruits , speeds up the rate of development and leads to loss of quality. A relatively high temperature during blossoming, especially if associated with a prolonged dry season, may cause abortion of flowers. However these are not hard and fast rules. There is evidence that the intragression of robusta genes seen in C. Arabica varieties descended from the HdT results in improved tolerance to high temperatures and helps to safeguard quality.[1] There are also examples where careful management of selected cultivars have allowed arabica coffee plantations to be spread to marginal regions with average temperatures as high as 24-25ºC.

12. For C. Robusta, estimates of the optimum annual mean temperature ranges from 22- 26ºC or 24-30ºC. However, in dry weather, high temperatures can be damaging. In Timor-Leste's current climate, C.Robusta can be grown between sea level and 800 meters above sea level

[1] Sobreira. F., Oliveira. A., Pereira., A., AND Sakiyama, N. 2015. *Potential of Híbrido de Timor germplasm and its derived progenies for coffee quality improvement.* Australian Journal of Crop Science.

(masl), whereas C.Arabica grows best at higher altitudes. Table 1 summarizes the main climatic requirements for C. Arabica and C. Robusta and summarizes how they are met in Timor-Leste.

Table 1. Summary climate requirements for C.Aabica and C.Robusta

Requirement	Suitability of current climate in Timor-Leste
1. A dry period of three months to stress trees in order to flower	**1.** The longer dry season in most of the north facing coffee areas may place excess stress on the coffee plants.
2. A good soaking to initiate flowering	**2.** Generally met, except when the wet season has a false start in September
3. Regular rainfall throughout berry development. Annual rainfall 1,800-2,000 mm	**3.** Generally met but may be cut short in EL-Niño years that have a reduced length of wet season.
4. A drier period coming up to harvest	**4.** Generally met.
5. A dry period for harvesting	**5.** Generally met.
6. C.Arabica: Optimum temperature 21ºC	**6.** Average temperature of 22ºC is achieved at elevations above 800masl
7. C.Robusta: Optimum temperature from 22-26ºC	**7.** Average annual temperature is between 26ºC from 0-800masl.

13. Dry weather helps to facilitate harvest and post-harvest processing. Following picking, coffee can be processed using a variety of techniques. These techniques can be divided into three broad categories: i) natural process; ii) pulped natural process; iii) washed process. The natural process involves drying the freshly picked coffee cherries whole, like raisins. Once dried, they are milled to remove the dried outer skin and flesh and separate the coffee bean. The pulped natural process involves pulping the coffee cherries to remove the outer skin and some of the flesh, and then drying the coffee without removing its mucilage. Fermentation of the sugars in the mucilage occurs during the drying process and may contribute to desirable flavor characteristics if managed carefully. Finally, the washed process involves pulping the coffee, then using controlled fermentation to break down the sugars in the mucilage coating the coffee bean and finally removing all of the mucilage by washing the beans in water prior to drying. The washed process requires significant amounts of water. In contrast, the natural and pulped natural processes can be carried out with little or no water. However, both the natural and pulped natural processes require careful control of the drying process. They are generally not suitable for situations where there is rainfall, heavy cloud cover, or high levels of ambient humidity.

2. Climatic conditions for coffee production in Timor-Leste

14. It is no surprise that the areas where coffee is currenty grown in Timor-Leste meet the climatic requirements for coffee production that are described in the literature. Annual rainfall at the coffee producing areas of Aileu, Ermera and Ainaro are in the range or just above the optimal range of 1200-1800mm (Table 2).

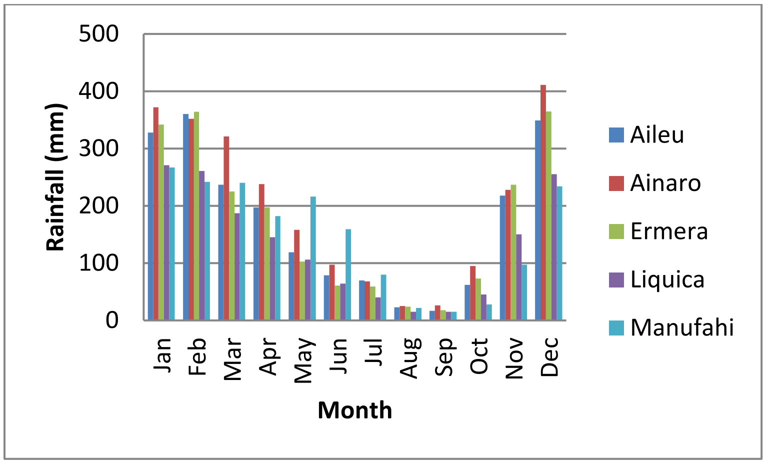
Table 2. baseline annual total rainfall for selected locations in Timor-Leste

Location	Annual Rainfall (mm)
Aileu	2059
Ainaro	2391
Ermera	2068
Liquica	1554
Manufahi	1782

Source: CLIMsystems report.

15. The pattern of rainfall over the year is also most suitable for coffee production. After a few months of dry weather (August-October) the opening rains of the wet season occur at the end of October to November lead to regular rain until March and April. As the coffee cherry ripens, rains reduce and lowest monthly rainfall is recorded for the harvest season May-September (Figure 1).

Figure 1: Monthly precipitation historical and projections for coffee growing

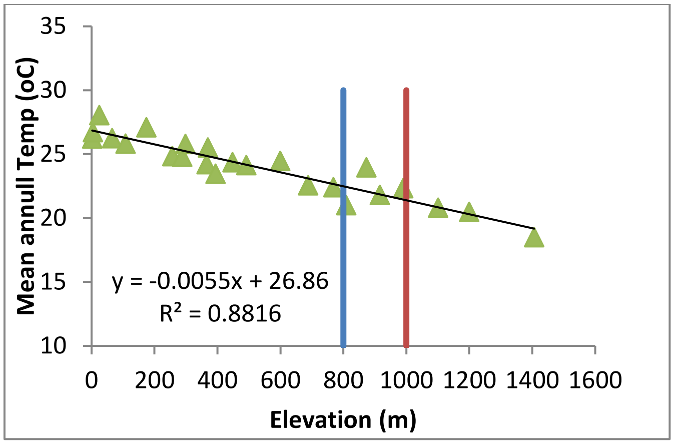


16. Annual mean temperature drops with elevation in Timor-Leste (Figure 2). The rate of decline is 0.55ºC per 100 m elevation. The optimal temperature for robusta coffee (22-26 ºC) occurs from sea level to 850 meters above sea level (MASL). The optimal annual temperature for arabica (18-21ºC) occurs in the elevation range from 1,000 to 1,550 MASL. Even though the elevation range of optimal temperatures for robusta and arabica coffee do not overlap, their range of adaptation does overlap in the elevations of 800 to 1,000 MASL. As a result, in the elevation range between 800 and 1,000m above sea level, robusta and arabica coffee are both grown. The average temperature in this elevation ranges from 21-22.5ºC.

3. Coffee production systems in Timor-Leste

17. Coffee in Timor-Leste is grown under the shade of larger trees that form continuous areas of forest and is often planted on steeply sloped land that would not be suitable for other annual crops. This agroforestry system provides a range of important ecosystem services. The shade trees stabilize soils, increase the infiltration of rainfall to aquifers, sequester carbon, and provide a habitat for diverse flora and fauna. They can also help to improve soil fertility by fixing nitrogen and provide a source of timber and edible fruits. Other economic crops, including foods like banana, taro, and arrowroot, and spices such as ginger, turmeric, pepper, vanilla, and cloves can also be grown alongside coffee.

Figure 2: Annual temperature for locations across Timor-Leste versus elevation



18. A range of tree species are used for shade. The two most common are Paraserianthes falcataria and Casuarina junghuhniana. Since the early 2000s, there have been some efforts to evaluate alternative quick growing shade trees and there is potential to expand the range of shade trees used in Timor-Leste. A manual of agronomic practices for coffee production in Timor-Leste that was produced under a European Union funded project lists a range of alternative shade trees including Toona sureni (Ai-Saria), Pterocarpus indikus (Ai on, ai naa), Grevillea robusta (Ai Grevillea), Erythrina subumbrans (Ai-eritrina or Ai-diik), Hevea brasileinsis (Ai-boraxa), Artocarpus spp (Kulu), Zyzigum aromaticum (cengkeh, cloves) and Cinnamon (Kanela).

19. Many of the C. Arabica varieties that are grown locally are descended from the Hibrido de Timor but the local varieties are not clearly defined or delineated. While some new varieties of C. Arabica and C. Robusta have been introduced since 2000 there is very little systematic data on the performance of specific varieties when grown under the range of conditions seen in Timor-Leste. ADB is currently supporting genetic analysis of local varieties, including those being propagated in government-managed and private nurseries. This analysis will help to clarify which varieties are growing in existing plantations and being distributed to farmers for new plantings. However, further research will be needed to confirm the performance of existing and new varieties under different climate and growing conditions.

20. Many coffee farmers in Timor-Leste do not make use of simple practices to ensure reliable production of coffee, choosing instead to minimize their labor input. This means that coffee farms are often very overgrown. Lack of management of shade trees may result in excessive shading that reduces coffee production. As shade trees grow larger there is also a heightened risk that they will either fall or be blown over in high winds thus threatening property and life. A lack of regular pruning means that coffee trees often grow well beyond the recommended size, making them less productive and more difficult to harvest. The density of coffee plants may also vary significantly from the recommended levels as farmers often don't follow recommended spacings.

21. Many coffee producers sell freshly harvested coffee cherries to other individuals, businesses, or cooperatives, that then manage the processing, and eventual sale. The aggregation of fresh cherries into relatively centralized locations can facilitate efficient processing and drying. However, many smallholder coffee producers also choose to process part or all of their coffee by themselves, or in cooperation with other nearby farmers. The equipment that is used for home processing is typically quite simple and may include a mechanical pulper to remove the outer skin and pulp, and simple tools for sorting and drying the coffee. For farmers who are

using the washed or pulped natural (honey) process, the availability of clean water at the processing site can be a challenge. For farmers who elect to use the natural processing method, cloud cover, rainfall, and high ambient humidity can slow down the initial phase of drying and lead to uncontrolled fermentation and mold growth that sharply reduces quality.

4. Pests and Diseases

22. Coffee production can be affected by a wide range of pests and diseases. The most common pests and diseases in Timor-Leste are Coffee leaf rust (a fungal infection caused by *Hemileia vastatrix*), coffee berry borer, and coffee stem borer. Phytosanitary controls can help to prevent new pests and diseases from entering a country. Where pests and diseases are already present, the emphasis is on use of naturally resistant crop varieties and/or control of the pests and diseases through appropriate farm management practices.

23. Field work in the early 2000s reported a devastating fungal disease on the P. faccataria shade trees, with 67% of plantations infected and on-plantation infection rates of 90%, suggesting a very limited resistance to the rust. At that time there was quite a bit of pessimism about the survival of the shade trees, and a 2003 report concluded “P. falcataria currently growing in East Timor seems to be very susceptible to rust and the prognosis must be for widespread tree death”. Although this prognosis was pessimistic in hindsight, it does highlight the importance of continued work to evaluate different shade trees.

24. Poor farm management can increase the risk of outbreaks of pests and diseases such as coffee leaf rust and coffee berry borer. Conversely, production systems that mimic the natural environment and have higher levels of biological diversity may help to reduce the risk of pest outbreaks. For example, a study of 22 coffee growing sites in Ecuador found that the incidence of coffee berry borer was negatively correlated with tree diversity, relative humidity, and canopy cover and positively correlated with temperature and coffee tree density.[2]

25. Climate change may exacerbate the risk of pest and disease outbreaks through two distinct channels: i) increased climate related stress may reduce plant health and increase plant susceptibility to pests and diseases; ii) changes in climate conditions may favor the expansion of specific pests and diseases. Climate change, and more specifically, reduced diurnal temperature range and earlier onset of rains, may have contributed to devastating outbreaks of coffee leaf rust in Central America during 2011-2014.[3] There is also some evidence that moderate increases in temperature may accelerate the growth and reproduction of the coffee berry borer.[4] However, the cumulative impact of climate change on the incidence of specific pests and diseases is difficult to predict with any certainty.[5]

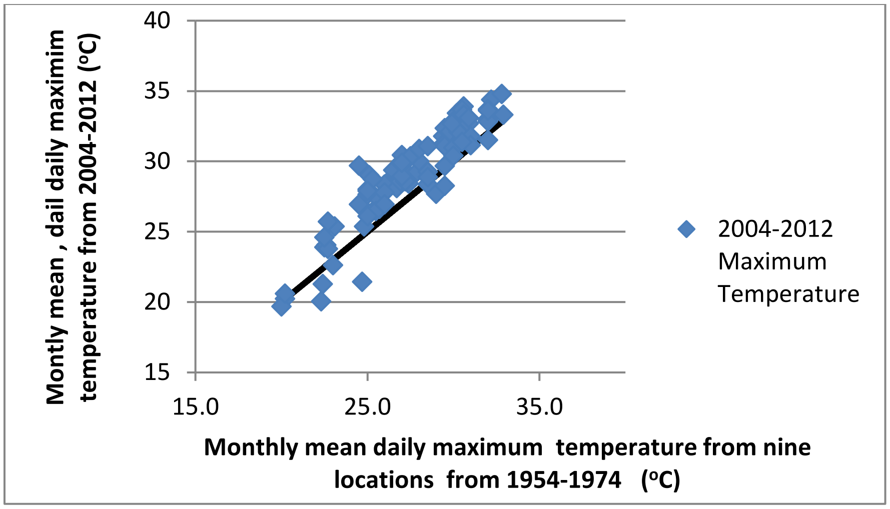
D. Recent and Projected Climate Change

26. There are indications that the current climate of Timor-Leste is different from the climate before 1975 when most coffee was planted. An analysis of Portuguese weather data compared

[2] Teodoro A, Klein AM, Tscharntke T (2008) Environmentally mediated coffee pest densities in relation to agroforestry management, using hierarchical partitioning analyses. Agr Ecosyst Environ 125: 120–126.
[3] Baker P 2014. The “Big Rust”: An update on the coffee leaf rust situation. Coffee Cocoa Int 40: 37-39.
[4] Jaramillo J, Chabi-Olaye A, Kamonjo C, Jaramillo A, Vega FE, et al. (2009) Thermal tolerance of the Coffee berry borer Hypothenemus hampei: predictions of climate change impact on a tropical insect pest. PloS ONE 4: e6487.
[5] Groenen, D. 2018. *The Effects of Climate Change on the Pests and Diseases of Coffee Crops in Mesoamerica.* Journal of Climatology and Weather Forecasting.

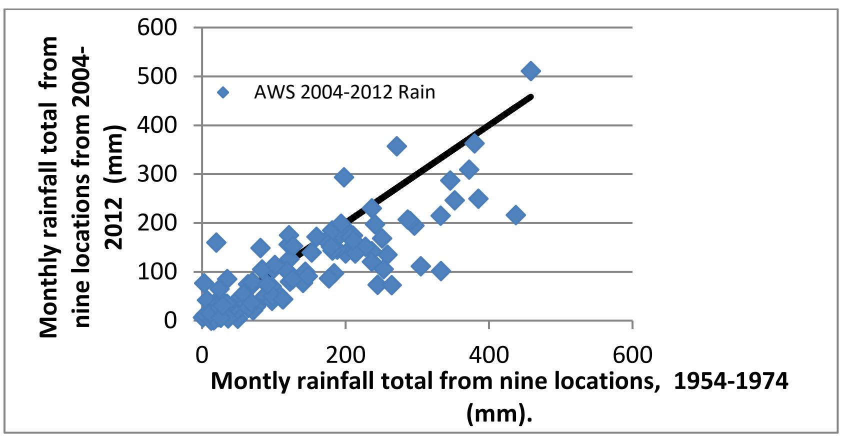
to that recorded from 2004-2012 was reported in 2013.[6] The comparison was made at nine locations where data was available from 1954-1974 and again from 2004-2012. The nine locations were spread from sea level to 1,406m elevation. In this data set, the monthly average, maximum temperatures had increased by 1.7 °C and minimum temperature had increased by 0.5°C. The increase of 0.8°C overall were recorded at almost all stations and all months of the year.

Figure 3. Monthly daily-maximum temperature from 1954-1974 compared with current climate 2004-2012.



27. Rainfall at the nine locations were shown to have reduced slightly in the period from 1954-1974 to 2004-2012. Monthly rainfall in 2004-2012 was 30 mm/month lower than the 1954-1974 period, an overall reduction of 22%. The reduction in rainfall was evident at most locations and most months. On average annual rainfall from 2004-2012 was 20% less than 1954-1974.

Figure 3. Monthly rainfall total from 1954-1974 compared with current climate 2004-2012.



[6] Isabel Soares Pereira et al. 2013. *Oinsa Lalaok Mudansa Klimatika Hahu Husi Tempo Português To'o agora?* Proceedings of the Timor-Leste Studies Association

28. The length of data records does not allow the conclusion that the rainfall has reduced over the last 50 years. The observation is that at the nine locations, the period from 2004-2012 had less rainfall than the period of 1954-1974. However, it is possible that the period from 2004-2012 is not representative of the current climate in terms of rainfall.

29. Climate projections have been made for Timor-Leste until 2055, using the average output of 40 global circulation models (GCM) and 10 regional circulation models (RCM). The projections are based on a CO2 concentration projection coded as RCP 8.5 (Representative Concentration Pathway 8.5). The RCP8.5 combines assumptions about high population and relatively slow income growth with modest rates of technological change and energy intensity improvements, leading in the long term to high energy demand and GHG emissions in absence of climate change policies. Compared to the total set of Representative Concentration Pathways (RCPs), RCP8.5 thus corresponds to the pathway with the highest greenhouse gas emissions.

30. Climate change projections until 2055 is for an increase of 2.1^{o}C over all of Timor-Leste. This is consistent with an observed warming of 0.7^{o}C from the period 1954-1974 to 2004-2012 at nine locations. There is high level of confidence of this temperature increase. There is no indication of different impacts at different months or season. There is no clear projection of changes in rainfall in the target area until 2050 due to the large uncertainty between the models. There is a range of projections from small increase to small decrease in annual rainfall, producing a median of a decease by a small percentage. Although the future trend of rainfall is not reliably projected, year to year variability will be an ongoing feature of the rainfall pattern in Timor-Leste. Rainfall variability is associated with variations in the southern oscillation index (SOI), and the projections have high confidence that the SOI will remain the dominant mode of year to year rainfall variation. The projections give no indication of likely changes on the future seasonality of rainfall, but suggest that seasonality will change with SOI as in the past.

31. Farmers have identified strong winds as having potential negative impacts on coffee production, indirectly on shade trees and directly on fruit fall prior to harvest. Strong winds are mostly associated with localised storms that pass through the region. Another source of damaging winds is cyclonic winds produced by tropical low-pressure systems in the Timor sea. Cyclonic wind activity can last a number of days and have devastating impacts. Strong winds during the peak of the wet season can cause trees to fall, and increased wind prior to harvest can cause severe yield loss as fruit is knocked to the ground. The projections of cyclonic activity suggest that cyclonic winds will be less severe than in the past

E. Farmers Perceptions of Climate Change

32. Collecting information from farmers in producing areas can help to identify and understand climate related risks.[7] Three farmer consultations were conducted to hear from farmers their experience of key coffee issues over the last 20-30 years. Consultations were conducted at Leorema, Ermera and Maubisse. At each location farmers were asked as a group their experience of change in the coffee production from pre 1975 to now. The issues covered included the climate, production, management and other issues.

33. As demonstrated in the previous section, the weather records show the climate pre-1975 was cooler and wetter than the climate from 2004-2012. The aim of this section is to match the

[7] Coffee and Climate. 2015. *Climate Change Adaptation in Coffee Production – A Step by Step Guide to Supporting Coffee Farmers in Adapting to Coffee Production.*

climate observations with farmer's experience, and their response to perceived changes in their lifetime. The discussion was conducted in a single group, with follow-up questions with individual farmers during breaks and after the group sessions.

34. In general farmers saw no major changes in climate and productivity from pre-1975 to current-day on most issues. At all three locations, each group reported that yields are similar now to earlier times. No growers reported changing varieties/species in response to changes around them. Two of the farmer groups mentioned that the dry season is less reliable than it used to be. This has had implications on increasing difficulty to harvest and process picked coffee. The farmers recognised that rain during the dry season (June-August) is not good for coffee yields the following year. The farmers realise that a long dry season brings on goods yields the next season.

35. Although farmers reported increase in dry season rainfall, no changes were detected in an analysis of rainfall data from 2004-2012 compared to pre-1975 data. However, there is a possibility the observation is generally true, but may be biased from wet weather just before the consultations.

Table 3. Summary responses from farmers on changes in climate, production and management of coffee plantations in their lifetime.

Variable.	**Leorema**	**Ermera**	**Maubisse**
Production	No change	No change	No change
Temperature	No change	Hot season hotter, cool season cooler.	No change
Rainfall	The dry season is less reliable. This year rain in July/August.	More rain now in June/August.	Dry season (June/Aug) is less reliable. Rain occurs in June-August. Start of wet season more variable.
Damaging winds	No Change	Higher winds in the past. Biggest wind was in Jan/Feb 1985.	No Change
Shade trees	No change	Seen new options of Leuceana, but does not fertilise the ground enough	No change
Coffee borer beetles	Worse now		
Weeds	New weed (Mist flower)	Mist flower is killing coffee and difficult to control.	
Leaf disease	No change	No change	No change
Management	Some people are pruning, but not keen.	Pruning: Can kill old trees that are dry inside.	Some prune trees
Variety	No change	No change	No change

36. Only at Ermera was there a comment on changing temperature over the last few decades. The comment at one group was that the hot season was hotter and cool season was cooler. Leorema farmers also mentioned that damaging winds was more a problem in the past than now. They recalled the most damaging wind occurred for a week in Jan/Feb 1985, when many houses and buildings were damaged. Strong winds are often associated with localized thunderstorms that last less than a few hours. The report of a week of strong winds in the peak of the wet season, suggests another source of damaging winds. The damaging winds of 1985 could have been due

to Cyclone Jacob that developed off the east coast of Timor-Leste and travelled west, on the south side of the island Feb 1985.

37. Farmer groups had mixed response to the incidence of coffee bean borer in their coffee. Coffee berry Borer (CBB) is a small beetle native to Africa. It is among the most harmful pests to coffee crops across the world. At Leorema they reported that coffee borer beetle is worse now than decades earlier. Coffee berry borer is described as a weevil (Tetun Fuhuk) by local growers, as it eats the inside of the coffee bean.

38. Weeding has been made harder over the last few years with the invasion of a new weed. The new weed is mistflower, or just called "new weed" (Tetun duut foun). In Leorema and Maubisse. In Hatobuilico the weed is called Weed 2000, (Tetun duut dua ribu). Mistflower (Ageratina riparia) is a low growing, sprawling perennial herb that grows up to 40x60 cm high. Its stems produce roots at joints that touch the ground. The serrated leaves on average reach 7.5 cm long and 2.5 cm wide and taper at each end. The flowers are white with dense heads at the ends of the branches

Figure 7. Mistflower characteristics, a new invasive weed in coffee areas.

39. Farmers reported that mist flower appeared 4-5 years ago and is invading coffee farms. The weed is hard to remove due to dense roots, that make the soil very hard and resistant to cultivation. The weed is slashed for control, but grows back quickly from the root system. There are some reports that mistflower can kill coffee trees, both newly pruned trees and older established trees. It is not clear if the spread of mist flower is linked to recent changes in climate.

F. Identification of climate risks for coffee production in Timor-Leste

40. The projected changes in climate pose a threat to future coffee production. This threat is the result of a series of distinct risks and vulnerabilities that arise from the interaction between current production practices and the projected changes in climate.

41. **Temperature.** Higher temperatures across Timor-Leste will potentially have considerable impact on the coffee growing areas. Higher temperatures may lead to some areas ceasing to be

suitable for cultivation of C. Arabica. They may result in faster water use by plants, resulting in drought stress and faster ripening of coffee cherries, resulting in lower cup-quality. Higher temperatures may also contribute to greater incidence of pests and diseases, either by weakening plants and making them more susceptible to disease, or by creating more conducive conditions for specific pests. The impacts of temperature increases will be seen across the full range of altitudes at which coffee is grown, but may be more acute at the lower end of the altitude range for C. Arabica. The 800-1100 MASL range marks the upper boundary of robusta coffee and the lower boundary for of arabica production.

42. **Rainfall.** The climate projections for Timor-Leste do not consistently project reduced rainfall. However, the projections suggest that annual rainfall variability will continue, and there may be more intense rainfall events in the future. Year to year changes in rainfall can have a significant impact on production. While a prolonged dry period is needed for flowering and fruit-set, drought conditions can also strain plant health and can even lead to plant death. More intense rainfall or unseasonal rainfall can contribute to crop damage and soil erosion, and can impede coffee processing, harvesting and drying.

43. **Wind.** High winds associated with storms pose a direct risk to coffee production. While winds may cause coffee fruit to drop, a more pressing risk is that high winds will cause shade trees to fall, thus creating a risk of injury and damage to coffee plants. This risk cannot be eliminated but it can be mitigated through improved management of shade trees. This begins with the selection of shade tree species and continues through to pruning and pre-emptive felling of large shade trees.

G. Analysis of Mitigation Strategies

i. Temperature

44. In the absence of adaptation measures, the projected 2.1 ^{o}C temperature increase would increase the lowest altitude suitable for arabica coffee by 380m. However, the experience from the temperature increases seen since 1975 suggests that it may be possible to continue growing C. Arabica within most if not all of its current range by taking appropriate actions to mitigate risk and adapt to higher temperatures. Risk mitigation strategies for temperature increases are summarized in table 4 below.

Table 4. Temperature related risks and mitigation actions

Risk	Mitigation Actions
Higher temperatures will reduce the viability of C. Arabica at lower altitudes.	Consider replanting with C. Robusta in the most marginal areas. In areas where risks are less acute, promote gradual replanting and replacement of existing C. Arabica with varieties with higher temperature resilience.
Higher temperatures will affect cup quality	Build capacity to assess links between temperature and cup quality. Ensure that varieties which are promoted to farmers can produce good quality in current and expected conditions.
Increased incidence of leaf diseases (e.g. coffee leaf rust)	Promote the use of varieties with high levels of resistance to coffee leaf rust and other leaf diseases.
Increased incidence of pests such as coffee stem borer and coffee cherry borer	Promote the use of integrated pest management and good crop hygiene.

45. Advice to farmers and protocols for nursery management should reflect anticipated temperature increases. Selecting appropriate varieties of coffee for replanting is the single most

important action to manage climate risks in the medium to long term. However, there is currently no clear evidence about the flavor profiles and temperature and water-stress tolerance of different coffee varieties in Timor-Leste. Such evidence can be generated in the medium term through well-designed research. In the short term, the most effective adaptation strategy is likely to involve using local planting material that is performing well at slightly lower altitudes.

46. In the transition zone from 800-1,100 MASL, advice to farmers should take into account local micro-climates and the current performance of C. Arabica and C. Robusta coffees. While progressive re-planting with C. Robsuta is a suitable, and relatively conservative adaptation strategy, evidence from other countries suggests that C. Arabica production can remain viable with careful management. Other temperature risks relating to pests and diseases can be managed through integrated pest management.

ii. Rainfall

47. The main mechanisms for mitigating rainfall related risks are varietal selection, soil and crop management, and adoption of suitable processing technologies. Drought tolerance in coffee plants is largely determined by the structure of the plants' root systems and may vary significantly between varieties. Since the rainfall variability is expected to continue, using locally adapted varieties that are shown to perform well in local conditions is an important adaptation strategy. Soil conservation techniques can help farmers to adapt to dry conditions and periods of intense rainfall. Since the application of these techniques is site-specific, the overall approach to adaptation and risk mitigation should be to help farmers to understand and apply soil and water conservation techniques that are appropriate to their farm.

48. Over time, a well-designed research program may help to identify varieties that are better able to withstand drought, intense rainfall, and year to year rainfall variability. Given the nature of coffee production and the available risk mitigation strategies, there is no basis for 'precautionary principle' based approach in which mitigation targets the most extreme projection rather than the average projected change. A summary of mitigation actions for rainfall related risks is shown in Table 5 below:

Table 5 – Mitigation Actions for Rainfall Related Climate Risks

Risk	Mitigation Actions
Extended drought / dry period damages plant health	Implement soil and water conservation techniques to increase the water retention capacity of the soil.
Period of intense rainfall leads to erosion and loss of soil fertility	Implement soil and water conservation techniques such as terracing, contour-line planting, and planting with ground cover crops.
Extended drought / dry period damages plant health	Promote replanting with varieties that are more tolerant of levels and patterns of rainfall that sit outside current norms, with emphasis on drought tolerance.
Extended dry periods reduce water availability, thus limiting options for home and community managed processing.	Support the identification and adoption of low-water processing techniques including increased use of natural and pulped-natural processes and the use of low-water 'eco' pulpers.
High ambient humidity or unseasonal cloud cover impedes drying of processed coffee at the household or community level.	Support the development of business models and technologies for successful drying of coffees

	including use of covered drying houses, raised drying beds, etc.

iii. Wind

49. As with rainfall, there is no basis for application of a precautionary principle in which mitigation is based on the most extreme projections. The main action to mitigate wind related risks is improved management of shade trees. Pruning large trees and selecting shade tree species that are less prone to wind damage will help to reduce risks.

H. Recommended Project Risk Mitigation Actions

50. The project design centers on establishing a research and variety improvement program, training coffee farmers on good agricultural practices for coffee production, and implementing actions to strengthen industry coordination and management. The project's activities and outputs were reviewed to assess climate risks and risk mitigation actions were identified for each output that may be affected by climate change. These actions are summarized in table 6 below.

51. Improving the suitability of varieties is arguably the single most important action for reducing long term climate risks. Some time may be needed to fully profile existing varieties and validate the suitability of new varieties. In the meantime, risk mitigation should focus on ensuring that protocols for seed selection, plant propagation, and nursery management are cognizant of climate risks.

52. Agronomic practices are a key tool for managing climate risks. The productivity improvement training that is delivered through the project should therefore focus on 'climate smart' techniques and practices that can help to improve production under current conditions while also increasing the resilience of the coffee production system in the face of expected changes. Recommended climate smart practices include stump pruning, maintenance pruning, spaced planting, contour line planting, use of weeding and cover crops, shade management, integrated pest management, composting, etc.

53. The research and demonstration plots that will be established by the project provide a valuable opportunity to formally assess the performance of different varieties and production practices in a range of climatic conditions. In order to maximize the contribution that these plots make to providing actionable knowledge about climate risk management, the plots should be located across the full range of agro-ecological zones in which coffee is grown in Timor-Leste. If possible, they should be located at, or close to, sites where there is ongoing recording of weather data. Alternatively, weather monitoring should be incorporated into the plot design. Finally, since Timor-Leste is understood to be home to some as-yet undocumented coffee varieties, local varieties should be trialed in the plots alongside newly introduced varieties.

54. The project activities relating to industry management and quality provide additional opportunities to address climate risks. The knowledge sharing platform that will be established under output 3 could be used to access know how on new technologies for processing and drying coffee that can help to reduce the water requirements and increase the reliability of the drying process. Similarly, the farm information system may help to track farm conditions and the incidence of pests and diseases that are associated with climate change.

Table 6. Recommended actions to mitigate climate risks.

Project Output	Performance Indicator	Recommended Actions for Risk Mitigation
1. More productive coffee and agroforestry production systems established	1a. Genetic profiling and suitability analysis of existing varieties completed and updated protocols for nursery management developed and implemented.	• Ensure that protocols for nursery management include farmer and community managed nurseries. • Aim to identify recommended varieties for each major agro-ecological zone.
	1b. During 2019-2023 at least one multi-variety research trial and 10 on farm technology trials are established as part of a national network with at least 1 on female-managed farms.	• Ensure that the multi-variety research trial includes local varieties. Ensure that the on-farm trial plots are spread across the full range of agro-ecological zones. • If possible, locate the on-farm plots close to weather monitoring stations or include weather monitoring capabilities in the plot design.
	1c. By 2023, at least 2,000 households have received regular training on productivity, quality improvement, and financial inclusion with at least 60% of active female farmers participating in coffee related training and women accounting for at last 50% of participants in financial inclusion training	• Ensure that the suite of recommended practices are 'climate smart' and include shade management, water conservation, soil management, etc.
3. Sector management and coordination improved	3a. By the end of 2020, a farm information management system is in place to monitor farm conditions and sex-disaggregated delivery of training and extension services.	• Incorporate climate risk relevant information in the system.
	3c. During 2019-2023 ACT provides a platform for knowledge sharing and ongoing industry learning	• Use the platform to share knowledge and information on methods for improving coffee processing through reduced water usage and improved drying.