TECHNICAL REPORT

INDONESIA: COSTS OF CLIMATE CHANGE 2050

May 2016

This document was produced for the United States Agency for International Development. It was prepared by Dr. Joy E. Hecht, consultant to Chemonics International, through the ATLAS Task Order.

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This document and the associated spreadsheet may be accessed online through
www.climatelinks.org/projects/atlas

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Cover Photo: Jakarta, tropical storm moving in. Photo by Joy Hecht

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Prepared for:

United States Agency for International Development
Climate Change Adaptation, Thought Leadership and Assessments (ATLAS)

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ACRONYMS

BIG	Badan Informasi Geospasial (Geospatial Information Agency)
BPS	Badan Pusat Statistik (National Statistical Agency)
CBD	Central business district
DALY	Disability-adjusted life-year
DHF	Dengue hemorrhagic fever
GIS	Geographic information system
LU/LC	Land use/land cover
MMAF	Ministry of Marine Affairs and Fisheries
SLR	Sea level rise
SRTM	Shuttle radar topography mission
USAID	United States Agency for International Development
YLD	Years lived with disability
YLL	Years of life lost

EXECUTIVE SUMMARY

This study provides an estimate of the costs imposed by climate change on Indonesia if the country does not make a concerted effort to protect itself through effective adaptation programs. It focuses on agriculture, health, and long-term sea level rise (SLR), estimating the costs that would be incurred in the year 2050 due to changes in climate or to loss of land from gradual SLR. The study relies on data available at the provincial level, making it possible to compare the estimated impacts both across areas of impact and across provinces or regions of the country. The results of this study are presented through three documents:

- This technical report, which presents the methodology behind the calculations.
- An Excel spreadsheet in which most of the calculations were made (those done in a GIS were imported to the spreadsheet), and which should be used in conjunction with this technical report.
- A policy brief, which presents the main findings for policy makers.[1]

WHY MONETARY VALUE?

Use of monetary value of impacts as a common metric across sectors and provinces (or other sub-national spatial area) makes it possible to compare impacts of climate change across provinces and sectors, and with the costs of adaptation in each province and sector.

The approach of this study is offered as a complement to, rather than a replacement for other approaches. The use of monetary values and the focus on costs of climate change, rather than costs of adaptation, are useful for several reasons. First, while monetary values certainly do not capture everything of importance to humans, they offer a standard, relatively objective unit of measure that permits comparison of impacts across both places and areas of impact. Second, in a context where public officials manage scarce resources, the use of monetary valuation provides an understanding of what will be lost if they do not factor adaptation into their plans. While this study is not a comprehensive cost-benefit analysis of climate change impacts – such an analysis goes well beyond the scope of this work – it does shed light on the costs that will be incurred if Indonesia does not invest in adaptation. International and Indonesian policy analysts and decision makers in government, civil society, and the private sector can use this information to inform decisions or identify issues for more detailed analysis that will refine the understanding of the economic implications of climate change.

While this represents only one projection among many possibilities, the three areas of impact discussed here represent major aspects of the Indonesian economy and society. The five crops analyzed account for a significant share of the value of food production, while the two diseases studied include those expected to be most affected by climate change. The climate change

[1] All three of these documents can be found online at www.climatelinks.org/projects/atlas

scenario used is an average of all international climate models for middle-of-the-road assumptions about greenhouse gas emissions.

The overall approach of this study involves combining data and analytical results from a number of other fields in a kind of "chain" to predict how climate change will affect the areas of interest. First, the impacts of climate change on Indonesia were identified based on global and national models of temperature, rainfall, and SLR. In each area of focus, it was determined what is now prevailing: how much agricultural production, how many cases of disease, et cetera. From the research literature, studies were identified showing how changes in temperature or rainfall will affect agricultural productivity and the incidence of disease. These inputs were combined to predict agricultural output and disease rates in 2050. Finally, monetary values were assigned to those impacts based on current prices or incomes.

Agriculture: The analysis of agriculture focuses on five crops: soybeans, corn, sugarcane/sugar, irrigated rice, and rainfed rice. These are the only ones for which estimates of the impact of climate change on yield are available. The agriculture sector accounts for the largest share of overall costs of all three areas of impact, at 53 percent, but this varies considerably across provinces, with some experiencing overall gains rather than losses. These gains result from the expected increase in rainfall, which leads to increases in yields of corn and rainfed rice that in 11 provinces outweigh decreases in the other three crops due to higher temperatures. Nevertheless, despite increases in these crops in these specific provinces, the overall national impact on agriculture is significantly negative, principally from losses associated with irrigated rice. To ensure that the opportunities for increased agriculture value are realized, it is essential to conduct additional research on how climate change will affect agriculture in specific different locations within Indonesia.

The fact that agriculture dominates the impact of climate change in every province except Jakarta means that these impacts may be fairly widely distributed across the population, at least to the extent that agriculture in those provinces is characterized by small farmers rather than large agribusiness. Since this agricultural analysis does not take into account large-scale oil palm plantations, the agriculture output dominating the impacts of climate change here may indeed primarily affect smallholders.

Health: The analysis of health impacts focused on dengue fever and malaria, because for these two diseases quantitative links can plausibly be made between changes in weather and changes in the probability of disease. For each of them, the study looked at forgone incomes due to illness or premature death and direct medical expenditure. The monetary analysis is based on years of life lost to illness or disability – the World Health Organization's so-called disability-adjusted life-years or DALYs – multiplied by 2012 provincial income per capita to estimate forgone incomes. The results show the costs of dengue fever to be much higher than those of malaria. Also, the residents of Jakarta incur much higher costs than any other province, both because dengue fever is more prevalent in Jakarta and because incomes (and thus forgone income) are higher there than elsewhere. On the other hand, in three provinces, dengue fever is expected to decline rather than rise, because rainfall is expected to decrease by

2050. While the overall negative impacts of health problems are second to those of agriculture – 45 million million (or trillion Indonesian rupiahs (Rp) in losses for health compared with Rp 70 trillion in net losses in agriculture – these are still major costs and represent significant negative effects on the quality of life or on life itself.

Sea Level Rise: The analysis of coastal impacts focuses on long-term gradual SLR, and how it will affect coastal property and economic activity. It includes estimates of forgone earnings from agriculture, forgone earnings from aquaculture, and forgone annual value of industrial, office, and residential properties submerged. Estimates of the losses due to extreme storms were not possible because information was not available on the probability of such storms in different parts of Indonesia. The study also did not assess the macroeconomic or multiplier implications of lost roads, ports, or other key infrastructure, as this goes beyond the scope of this rapid assessment. Both of these issues are very important and will probably impose greater costs than gradual SLR, and will have to be the subject of other studies.

Unsurprisingly, the lost income from urban properties accounts for most of the losses due to SLR; Rp 14,406,695 million out of a total of Rp 17,198,244 million, or 84 percent. Equally unsurprising is that property losses in Jakarta account for Rp 13,844,737 million: 96 percent of the urban property losses and 81 percent of all losses due to SLR. Jawa Barat province, which is projected to be entirely urban by 2050, comes a very distant second in losses of property income, at Rp 375,123 million. After property losses, the biggest losses from flooding come from decreased production of rice, some Rp 1,843,123 million. At the national scale, these losses are still small compared to the much greater losses in the value of agricultural output due to rainfall and temperature changes.

Provincial Comparisons: A comparison of total and per capita impacts across provinces, shown in Figures 1 and 2, respectively, makes it clear which provinces are most positively affected – Lampung and Gorontalo – and which are most harmed: Jakarta and other provinces on Java Island. These figures also clearly show the extent to which agriculture dominates the impact in all provinces except Jakarta.

A similar comparison of impacts per capita shows Jakarta still hardest hit in the country, but the impacts on Gorontalo, Sulawesi Utara, and Papua Barat provinces are much greater in per capita than in total terms. This is the result of their relatively small projected populations in 2050. From the perspective of potential burden or benefit to the province from climate change impact, this cost or benefit per capita is likely to be more important than the total impact. The impacts on Jakarta are, of course, quite different from those on other provinces. Agriculture is obviously of little importance; indeed, it is not likely that there will be any agriculture within the city limits by 2050, though this analysis continues to show a modest amount. Dengue fever is expected to impose the greatest climate-related costs on Jakarta, as discussed above.

Figure 1. Total impacts of climate change by province and source of impact (in millions of rupiahs)

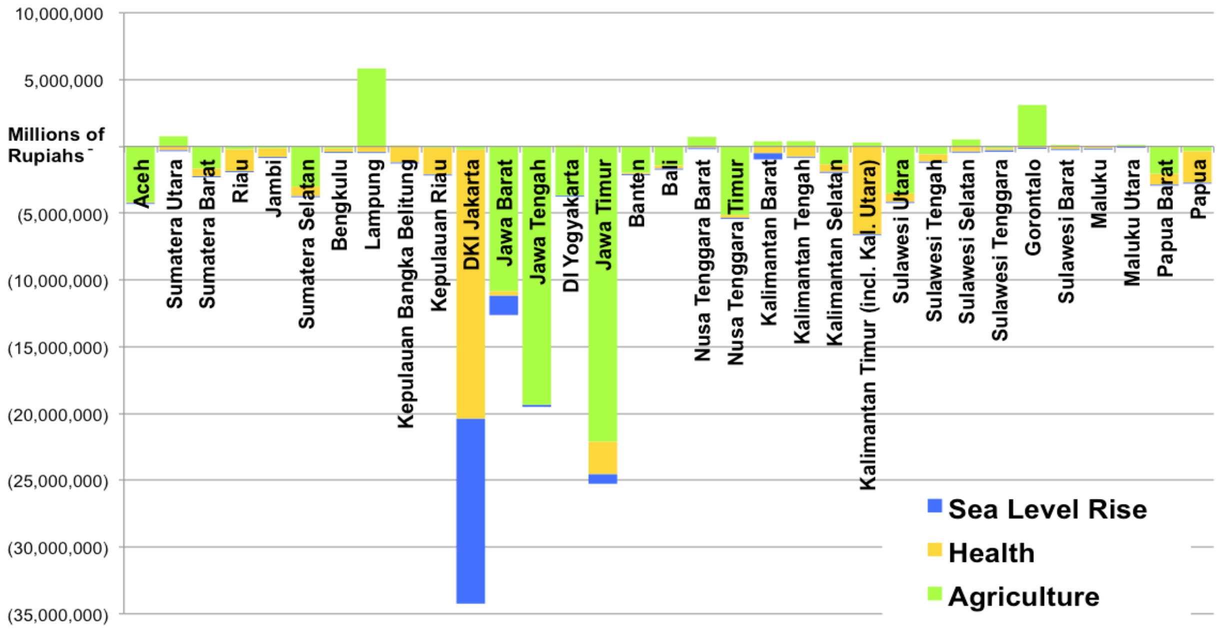
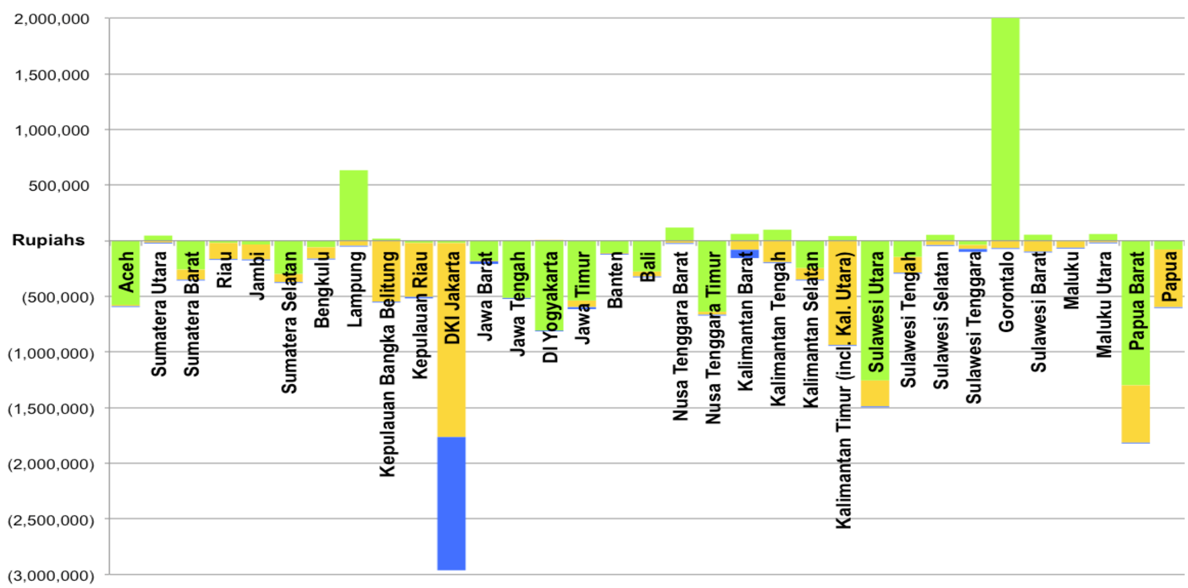


Figure 2. Per capita impacts of climate change by province and source of impact (in rupiahs)



Analysis of the impacts of climate change on Jakarta should take into account the impacts of extreme storms, considering not only the direct loss of property but also the repercussions of those losses for the country as a whole. Economic research has shown that some impacts, such as flooding of the international airport or destruction of the seaport, would impose costs far beyond the investments required to prevent them. In many other areas, more detailed analysis is needed to identify priorities for investments to prevent harm from extreme storms. This should be a priority in Indonesian work to establish priorities for climate change adaptation.

This study makes several key recommendations:

- In general, the GOI should discuss these results with provincial authorities to inform local planning and budgeting. Climate change will have implications for agriculture, health, infrastructure, and general development in both expenditures and revenues.

- When considering adaptation strategies for these sectors the benefits and costs of various actions should be considered in the context of the costs shown here.

- In each province, policy makers and agriculture interests should look for opportunities to benefit from climate change, encouraging growth of crops that will do well under the new conditions and investing in water control and irrigation infrastructure to take advantage of where rainfall may increase. This study alone may not be sufficient to say that policy makers should immediately encourage corn production in Lampung and Gorontalo provinces, but at both the national and provincial level, understanding where the opportunities will emerge is important, especially given that the climate will not change equally everywhere.

- The responsible authorities should plan now to avoid or alleviate the clear significant negative consequences for Jakarta associated with dengue fever. Similarly, in many provinces the conditions for malaria will worsen and authorities should be planning or initiating programs for this. More research should be carried out on links between disease and climate, including not only of the expected increased incidence but also of the possibility that some changes in climate may actually hinder the spread of certain diseases in some locations. More detailed research on malaria along the lines of the study used to analyze dengue fever would be particularly important.

- Actions against gradual SLR must be chosen carefully: The study shows negative effects of SLR nationwide, but the costs foreseen are almost all incurred in urban areas where property is much more valuable and adaptation will be most costly. Both policy makers and private investors working on shoreline development should be extremely interested in this. It is unlikely that large-scale protective infrastructure would be cost-effective anywhere except possibly in Jakarta or other very large and economically valuable urban areas. Such a cost-benefit analysis was done before the decision was made to build the National Capital Integrated Coastal Development (NCICD) sea wall for Jakarta that is now under construction.

- Extreme storms and weather pose a great economic threat: Analysis of the probability of extreme storms in different parts of the country would be very valuable in identifying the costs they will impose and setting priorities for investments in adaptation. To the extent that the fields of climatology and oceanography can shed light on this issue, investments in further research will be essential. Policy makers must order more detailed analysis of the impacts of extreme storms on large urban areas, particularly Jakarta. In particular, work that can consider the macroeconomic or multiplier implications of the loss of key urban infrastructure will be essential to set priorities for investments in adaptation or strategies to minimize the harm caused by such storms. The private sector must anticipate these problems as well; every company whose business relies on transportation through the harbor or airport should create plans for continuity of its operations in the face of such extreme storms.

- To identify optimal implementable policy responses much more information is needed on certain aspects. In particular, more work is crucial on links between climate change and agricultural yields given the huge monetary impacts involved. The wide range of impacts on agriculture found here are dependent on a single piece of research. It is essential for Indonesia to invest in more research on links between climate and agriculture, considering a wider range of crops and more areas of the country. Moreover, the research and this study point to the varying effects in different locations; a more comprehensive understanding of this geographic variation across this vast country would be valuable to design provincial or local adaptation responses.

- Work on the probability of extreme storms and the costs they would impose in different parts of the country is also very important, particularly the macroeconomic implications of flooding on nationally important transportation infrastructure in Jakarta. More generally, flooding and drought have direct costs and multiplier effects throughout the economy and these should be studied.

- Indonesia cannot wait until 2050 to act: This study projects the situation in 2050 in specific areas of impact under specific parameters. As climate change is gradual, it may be assumed that the conditions described for 2050 will evolve between now and then, and that Indonesia will increasingly and inexorably experience the costs and benefits each year. This means that policy makers should not wait until the future to implement changes that either lessen or take advantage of the impacts.

CHAPTER 1. INTRODUCTION AND APPROACH

This study provides an estimate of the costs imposed by climate change on Indonesia if the country does not make a concerted effort to protect itself through effective adaptation programs. The study focuses on three major areas of impact: agriculture, health, and long-term sea level rise (SLR), under one widely accepted scenario. It estimates the costs incurred in the year 2050 alone, partly due to forgone income and partly due to loss of assets as the sea level rises. It works with data available at the provincial level, enabling comparison of the estimated impacts both across areas of impact and across provinces or regions of the country.

The spreadsheets developed to do the calculations for this study are available online. This technical report describes the methodology used. It is intended to be read in conjunction with a review of the spreadsheets themselves. Analysts interested in modifying some aspects of the analysis, such as varying temperature or rainfall patterns, or additional data previously unavailable, are welcome to do so; one of the goals of this study is to facilitate further analysis by others, building on this work.[2] This technical report and the policy paper that accompanies it are also available on the Climatelinks website.[3] Where specific data sources are not provided in this report, they are available in the spreadsheets.

1.1 WHY STUDY THE COSTS OF CLIMATE CHANGE?

Most studies of the impacts of climate change focus on several issues:

- Identifying the mechanisms through which climate change will affect different areas of activity;
- Identifying the mechanisms through which climate change will affect specific locations, ranging in scale from individual villages to the country as a whole;
- Quantifying the vulnerability of the country to climate change impacts, typically using subjective indicators or indices of vulnerability based at least in part on residents' assessments of which problems are the most serious;
- Identifying strategies to head off those impacts or adapt to them;
- Calculating the costs of those adaptation strategies.

This study differs from conventional vulnerability assessments in two key ways:

[2] The spreadsheets are not protected; analysts using them will have to be careful to keep track of their own modifications and ensure that they do not introduce errors through undocumented changes.

[3] https://www.climatelinks.org

- It quantifies the impacts of climate change in monetary terms rather than subjective measures of vulnerability.
- It does not consider adaptation strategies or the cost of adaptation.

The approach of this study is offered as a complement to rather than a replacement for more conventional approaches. The use of monetary values and the focus on costs of climate change rather than costs of adaptation are useful for several reasons. First, while monetary values certainly do not capture everything of importance to humans, they offer a standard, relatively objective unit of measure that permits comparison of impacts across both places and areas of impact. The availability of a wide range of published provincial data in Indonesia on agriculture, health, aquaculture, and other topics makes it possible to compare impacts in ways that should help both national and provincial governments set priorities for adaptation.

Second, in a context where public officials may be reluctant to spend money on adaptation to climate change, the use of monetary valuation provides an understanding of what will be lost if funds are not made available. While this study is not a comprehensive cost-benefit analysis of climate change adaptation – such an analysis goes well beyond this scope – it does shed light on the costs that will be incurred if societies do not invest in adaptation.

1.2 BASIC METHODOLOGY

While the methodology differs for each component of this study, some elements are common to the study as a whole. Broadly, the overall approach involves combining data and analytical results from a number of other fields in a kind of "chain" to predict how climate change will affect the areas of interest. This is done in several steps:

1. Identify the impacts of climate change on the country based on internationally accepted global models, with a focus on temperature, rainfall, and SLR.

2. In the areas of focus, locate information on the prevailing situation: how much agricultural production, how many cases of disease, how many people living in areas at risk from coastal flooding, what infrastructure is at risk of coastal flooding, et cetera.

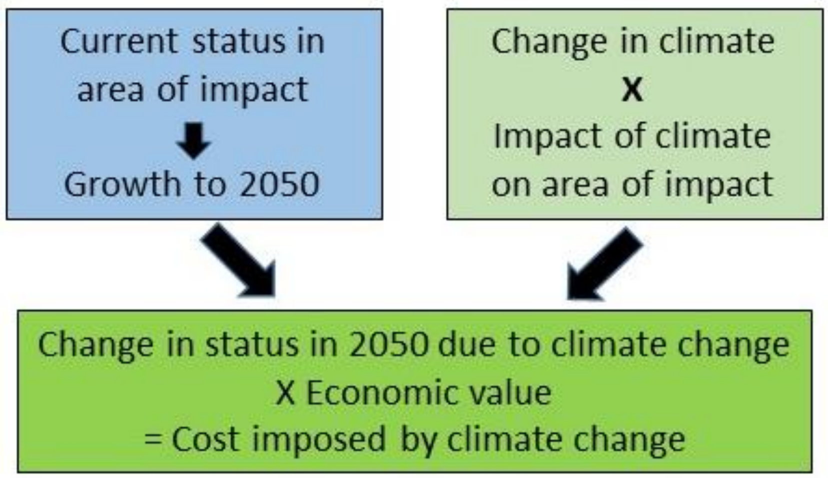
3. By searching the relevant literature, identify studies that shed light on how changes in temperature or rainfall will affect the areas of focus, particularly agricultural productivity and the incidence of disease. This is the most challenging part of the study because it concerns how climate change affects very complex physical and biological systems, such as the ecosystem in which an anopheles mosquito transmits disease, or the complex currents and winds surrounding Indonesia's 17,000 islands. In some respects, agricultural impacts may be the simplest of these topics because agriculture occurs in a relatively controlled biological system where research is possible and the subjects of study – plants or animals – are visible to researchers. Impacts on capture fisheries are the most complex because oceanographic systems are complex and the objects of study – fish – are free to move in three dimensions,

often unseen. Useful literature on agriculture and health was available, but analytical results on capture fisheries were not, though these were originally to be included in the study.

4. Combine predictions of climate change with information from the literature to predict the state of the areas of focus in 2050: agricultural output, number of cases of disease, structures flooded, et cetera. Where impacts are directly related to population, they are based on projections of the 2050 population of each province. The year 2050 was chosen because climate models use this as a principal projection date and it fits with most long-term policy plans. It is also a very "graspable" date for most people, one that is within the foreseeable lifetimes of most.

5. Use current price data to put a monetary value on the changes attributable to climate change, as in Figure 3.

Figure 3. Overall approach to the study



The study uses current prices for all valuations, without discounting future costs to the present, increasing them to account for inflation, or anticipating structural shifts in the Indonesian or global economy that would change relative prices of goods or the relation of prices to income. Clearly, this is not perfectly realistic, as much will change between now and 2050. However, predicting future prices would require modelling the evolution of the Indonesian economy 35 years into the future, a task that would be highly speculative and far beyond the scope of this study. Moreover, since one use of these results will be to compare climate change costs with the costs of adaptation measures, and those policy decisions are being made now, current costs may not be entirely unrealistic. In addition, for comparing costs across areas of activity or provinces, the changes due to inflation or discounting will affect all areas in the same way, and therefore are not important. Of course, the same is not true of structural change in the economy or relative prices; this is unavoidable, however.

The years 2012 or 2013 were used as the base years for the price, population, production, and other data for the analyses, depending on the available data. At that time Indonesia had 33 provinces. The province of Kalimantan Timur was subdivided into Kalimantan Timur and Kalimantan Utara in late 2012, but the statistical data did not account separately for the new province until 2014. All of the analysis was therefore done with the country divided into 33 rather than 34 provinces.

1.3 WHY THE CHOSEN AREAS OF IMPACT?

The choice of areas of focus for this study was the outcome of several considerations. Before work began, the research team, in discussions with the United States Agency for International Development (USAID), decided to consider agriculture, health, fisheries, and SLR. It decided not to include other areas of interest and importance, particularly freshwater hydrology and biodiversity. These choices were based on the need to limit the scope of the work due to time constraints and the expectation that the issues would be sufficiently controllable to address in a study that builds on work carried out by other people.

As the study evolved, the areas considered narrowed somewhat. The extreme complexity of ocean systems in Southeast Asia meant that it was not possible to find usable predictions of the impacts of climate change on capture fisheries. While extensive research has been done in this area, particularly on the impacts of climate change on the tuna fishery, the results were too complex and hypothetical to build into the kind of simple framework used for this project. As such, capture fisheries were omitted from the work.

While the impacts of climate change on aquaculture may be simpler to analyze, the research team was unable to find any studies specifically addressing this issue. Such research would look at impacts of changes in air temperature, coastal or freshwater temperature, and coastal salinity on growth and viability of specific species. However, the published data on Indonesia do not include information on output or value by species, so even if research results were available, it would have been difficult to apply them. Moreover, the structure of the Indonesian aquaculture sector is evolving rapidly as opportunities to sell to regional markets are developed (SPIRE Research and Consulting, 2014). In that context, projections even a few years into the future would be highly speculative, at best. The study did include estimates of the impact of SLR on coastal aquaculture activities, as the available data made it possible to estimate how much infrastructure was located in areas that might be permanently flooded over time.

In the analysis of SLR, the initial intention was to include both the long-term rise in the average height of coastal seas and occasional flooding from extreme storms. As the work evolved, it became clear that including extreme storms, while clearly more important than long-term SLR for understanding climate change costs, would not be feasible in a study making comparisons across provinces and areas of impact. Most studies of the impact of extreme storms look at what would be flooded in a specific geographic area – typically a large urban area – if the water rose to a given level, and perhaps put a monetary value on what is damaged, or calculate how many people are at risk. Such studies do not place much emphasis on estimating the probability that this might actually occur in any given place.

Since this study looks at the whole country and compares impacts across provinces, it would be essential to build in estimates of the probability of such storms occurring in any given place. Otherwise, the cost estimates at the provincial and national levels would be grossly exaggerated, since they would essentially assume that every place would be hit with an extreme event all at once. However, estimates of the probability of extreme storms were not available, nor was there any basis for assessing how much of the coast could be affected by a given storm. Consequently, there was no realistic way of bringing the impact of extreme storms into this comparative analysis.

Another even more complex aspect of extreme storms was further beyond the scope of this study. Much of the major impact of such storms comes not from property directly damaged or destroyed but from the multiplier effects throughout the economy of losing key infrastructure. For example, if a major port is put out of commission for a few weeks or months by an extreme storm, the impacts are felt through the disruption to imports and exports, which affects all aspects of the economy. Similarly, if a key highway washes out, especially in a developing country where alternate routes may not exist, entire communities or regions may be cut off from the rest of the country, with wide-ranging impacts far beyond the immediate cost of repairing the road. To analyze these impacts, it is necessary to build complex spatial models of the economy, within which the impact of losing one transportation node could be calculated. While this kind of analysis is of considerable interest, it goes far beyond the scope of this study.

1.4 CLIMATE PROJECTIONS

This study used climate projections from several difference sources:

- Temperature projections to 2050 are from www.climatewizard.org, using its average values for the major climate models, for the A1B ("middle of the road") climate scenario.[4,5]
- Rainfall projections to 2050 are from www.worldclim.org/current, using the 30 arc-second ESRI grid data. These are downscaled global climate model data from CMIP5 (IPPC Fifth Assessment). The base data are an average of rainfall levels from 1950 to 2000. The base year for this data is 2013 in most cases. To estimate change in rainfall over the study's time period, the base year data were subtracted from 2050 data, divided by 50, and multiplied by 37 (2050-2013).[6]
- Projections of SLR to 2040 were provided by Dr. Ibnu Sofian, climatologist with the Indonesian Geospatial Information Agency (BIG, Badan Informasi Geospasial). These were extended to 2050 following the same rate of change as in his projections.

[4] BMKG, the Indonesian Agency for Meteorology, Climatology and Geophysics, developed its own temperature and rainfall projections using the A1B scenario; however these were not available for this study.

[5] The temperature projections used in the study are in the worksheet titled "CC proj. temp change" in the study spreadsheet.

[6] The rainfall projections used in the study are in the worksheet titled "CC proj. rainfall change" in the study spreadsheet.

1.5 POPULATION PROJECTIONS

Indonesia's national statistical office, Badan Pusat Statistik (BPS), projected population by province and by gender to 2035.[7] The BPS provincial projections were extended to 2050, ensuring that the total projected population in 2050 would be as close as possible to the United Nation's projections. This was done by projecting the 2020 to 2035 change in five-year growth rates for each province to the period 2040 to 2050, using those projections to calculate growth rates for the corresponding periods, and then using those calculations to project population in each province in 2040, 2045, and 2050.[8] BPS also projected the rural urban breakdown out to 2035. This study used similar calculations to extend them to 2050 as well.

[7] BPS (2013), p. 24 or data available at http://www.bps.go.id/linkTabelStatis/view/id/1274

[8] These calculations are in the worksheets titled "Pop proj based on growth-rate," "urban pop share," and "Pop 2010-12-13 & 2050" in the study spreadsheet.

CHAPTER 2. AGRICULTURE

2.1 GENERAL APPROACH

The analysis of impacts of climate change on agricultural output depends on various types of information:

- Current crop output
- Crop price
- Impact of climate change on crop yields

For the first, extensive data are available on about 30 products from the Ministry of Agriculture. For the second, the Ministry of Agriculture conducts surveys in urban markets to collect sale prices for nine of these products: rice, soybeans, chicken, beef, eggs, oil, sugar, chili, and shallots.[9]

For the third, the model developed by Handoko & Syaukat (2008) predicts the impacts of climate change on outputs of five crops: soybeans, maize (corn), rainfed and irrigated rice, and sugarcane.[10] While some variation exists among the analyses of different crops, the overall approach is similar for all of them. The study identifies several different mechanisms through which climate change may affect agricultural yields:

- Increases in temperature shorten the lifespan of the crops, decreasing their period of productivity and thus their yields. For each of the five crops, the Handoko & Syaukat (2008) study provides a figure for the percent change in yield per hectare between 2006 and 2050 and for the change in average temperature over the same period. From that, the study calculated the change in yield per year due to a 1 degree Celsius change in temperature. Handoko & Syaukat give different coefficients for Jawa Tengah, Yogyakarta, Jawa Barat, Banten, and "outside of Java or Bali." They also list Bali and Jawa Timur in their table but shows them with no temperature change and no change in agricultural yield. Since the data here show a change in temperature projected for Bali and Jawa Timur, the average of the annual percent changes in yield for Jawa Tengah, Yogyakarta, and Jawa Barat was applied to those two provinces.

- Increases in temperature change crops' evapotranspiration (ET) patterns, causing decreased yields. The Handoko & Syaukat (2008) study provides the same kind of data for this impact as for the impacts of temperature on plant lifespan. The same calculation was done here, converting their percent change in yield per hectare from 2006 to 2050 to an

[9] Crop output and prices are available in Center for Agricultural Data and Information Systems (2014).

[10] All of the coefficients from this model that were used in this study are in the five worksheets with "Handoko" in the title in the study spreadsheet.

annual percent change in yield per degree of change in temperature. The Handoko & Syaukat study provides coefficients for the same provinces and "outside of Java and Bali," and has no values for Bali and Jawa Timur. Again, the percent changes for Jawa Tengah, Yogyakarta, and Jawa Barat were averaged here and then applied to Bali and Jawa Timur.

- Increases in annual rainfall are expected to lead to increased crop yields. The Handoko & Syaukat (2008) study provides estimates of this impact for corn and rainfed rice but not for soybeans, sugarcane, or irrigated rice. The coefficients are for the impact of annual rainfall on crop yields but not for changes in the length of the rainy season or the concentration of that rainfall over time. It is often suggested, though, that climate change may lead to more concentration in rainfall patterns than changes in the overall level. Consequently, this study also looks only at the impact of changes in annual rainfall levels. The Handoko & Syaukat study's coefficients for both corn and rainfed rice show direct relationships between both increases and decreases in rainfall and agricultural yield. That is, when rainfall is observed to decrease, a decrease in yield is found, while when rainfall is observed to increase, an increase in yield is seen. This is quite important, because the climate change data used here show wide variation in the changes in rainfall. Had that study only observed the impacts of a decrease in rainfall, it might not be possible to conclude that increased rain would lead to commensurate increases in yield. The fact that their work shows both lends plausibility to the results found herein.

In the case of rainfall, the Handoko & Syaukat (2008) study provides coefficients for Jawa Tengah, Yogyakarta, Jawa Barat, and Banten provinces. While the study shows rainfall change for Bali and Jawa Timur, it does not provide coefficients for those provinces. For the study herein, the percent changes for Jawa Tengah, Yogyakarta, and Jawa Barat were averaged and then applied to Bali, Jawa Timur, and "outside Java or Bali."

The analysis here assumes that the area cultivated with each crop will not change between the baseline period and 2050. This is clearly unrealistic. Many complex factors will affect what is actually planted where. Some relate to climate change, as shifts in weather patterns will influence which is the most suitable crop to grow in each location. Other factors will play into this decision: evolution of prices and exchange rates; changes in the road network that affect access to markets; urbanization patterns that change the most lucrative use of specific land; and so on. Each farmer will decide what to grow based on a combination of these factors. Projecting future cropping patterns would involve building a complex model of farmers' decisions about what to grow, and projection of all of the determining factors to 2050 to assess how crops will be distributed in the future. Moreover, while climate change may reduce the yield of some crops grown now, it may increase the yield of other crops. It is possible that farmers will be better off once they adapt to a changing climate, assuming the new crops are more lucrative than those most suitable now.

These complex consequences of climate change are not part of the Handoko & Syaukat (2008) study, nor of most other studies of the impact of climate change on agricultural output. Instead, they focus on the direct impacts of weather changes on crops grown now, which are negative for temperature increases and positive for rainfall increases. Thus, they present a considerably simplified and perhaps more discouraging picture than appropriate of how climate change will affect food production or farmers' incomes. Unfortunately, since the agriculture experts are not building the complex models that would factor in the new crops that become suitable with climate change, or the broad calculus that determines what is grown in each place, this study cannot take that into account either. The only option is to use existing results to calculate the expected changes in future output with the current cropping patterns, and to put a monetary value on that production. Policy makers and farmers can then use this information to adjust crops or practices over time.

2.2 CROP ANALYSES

The calculations for soybeans, corn, rainfed rice, and irrigated rice were all made the same way:

1. Data were available for annual output of each crop from 2010 to 2014, by province (Center for Agricultural Data and Information Systems, 2014). Those five years of production data were averaged to establish a baseline, rather than using a single year, to smooth out any one-year anomalies due to weather. In the calculations, these were treated as if they were 2012 data.

2. The coefficients were calculated and applied based on the Handoko & Syaukat (2008) study[11] to calculate the annual change in total production: two temperature coefficients for each crop and rainfall coefficients for corn and irrigated rice. Since, as discussed above, the assumption is that the area cultivated with each crop is unchanged, one can multiply (output) x (change in temperature or rainfall) x (change in yield per unit of change in temperature or rainfall) to get the change in output attributable to each of the three impacts of climate change (crop lifespan, ET, and rainfall where relevant). These are then summed to get the overall impact of climate change on crop output per year and multiplied by 38 (2050-2012) to get what would be the change to the year 2050.

3. The calculations for output showed several anomalies related to the fact that the Handoko & Syaukat study coefficients were developed for marginal changes in temperature and rainfall, whereas the changes due to climate change are not marginal. Consequently, for some crops, the decreases in output due to higher temperatures or lower rainfall led to negative output in 2050, which is clearly impossible. For corn and rainfed rice, in provinces where rainfall is expected to increase substantially, the coefficients led to yield and output increases of several hundred percent, which is extremely unlikely. A more likely consequence of such substantial increases in rainfall is that fields will flood and nothing will ould grow. To address these anomalies, the possible increase or decrease in output was bracketed to 100 percent. So, output could drop to zero or double but could not become negative, nor could there be more than a 100 percent increase in output.

[11] These calculations can be seen in the worksheets for each of the five crops - soybeans, corn, sugarcane, irrigated paddy, and rainfed paddy - in the study spreadsheet.

4. Consumer price data were available for each crop from Ministry of Agriculture surveys conducted in certain urban markets and national data on both producer and consumer prices for each crop. Where it was possible to identify the urban market in which the crops were likely to be sold, urban market prices were used. Elsewhere, the national average price from 2010 to 2014 was used (again averaging to smooth out anomalies in any given year).

5. The expected change in output due to climate change was multiplied by the current price to get an estimate of the economic impact of climate change on farmers, and traders. As discussed above, no basis exists for estimating how prices may shift between now and 2050, so current monetary values were used throughout the study.

The calculations for sugarcane were slightly different from those of the other crops because the available price data are for sugar rather than sugarcane:

1. The first step was the same. Data on the annual output of sugarcane from 2010 to 2014 by province were averaged to establish a baseline rather than using a single year, to smooth out any one-year anomalies due to weather.

2. A conversion factor of about 0.07695, from a US Department of Agriculture study (Slette & Meylinah, 2013) of the Indonesian sugar industry in 2012–2013 was applied for the amount of sugar obtained from one ton of sugarcane to estimate the amount of sugar from each province's cane production in 2012.

3. Handoko & Syaukat (2008) only provide coefficients for the impact of changes in temperature on sugarcane output; the study shows that changes in rainfall will have no impact. As in the previous calculations, this formula was used: (sugar production) x (change in temperature) x (change in yield per unit of change in temperature) to get change in sugar production for each of the two impacts of temperature change (lifespan and ET). These are summed to get the overall impact per year of climate change on sugar production, and multiplied by 38 to get the change in impact in 2050.

4. Consumer prices of sugar from one main urban market in each province for 2010 to 2014 were averaged to get a single 2010-2014 price for each province.

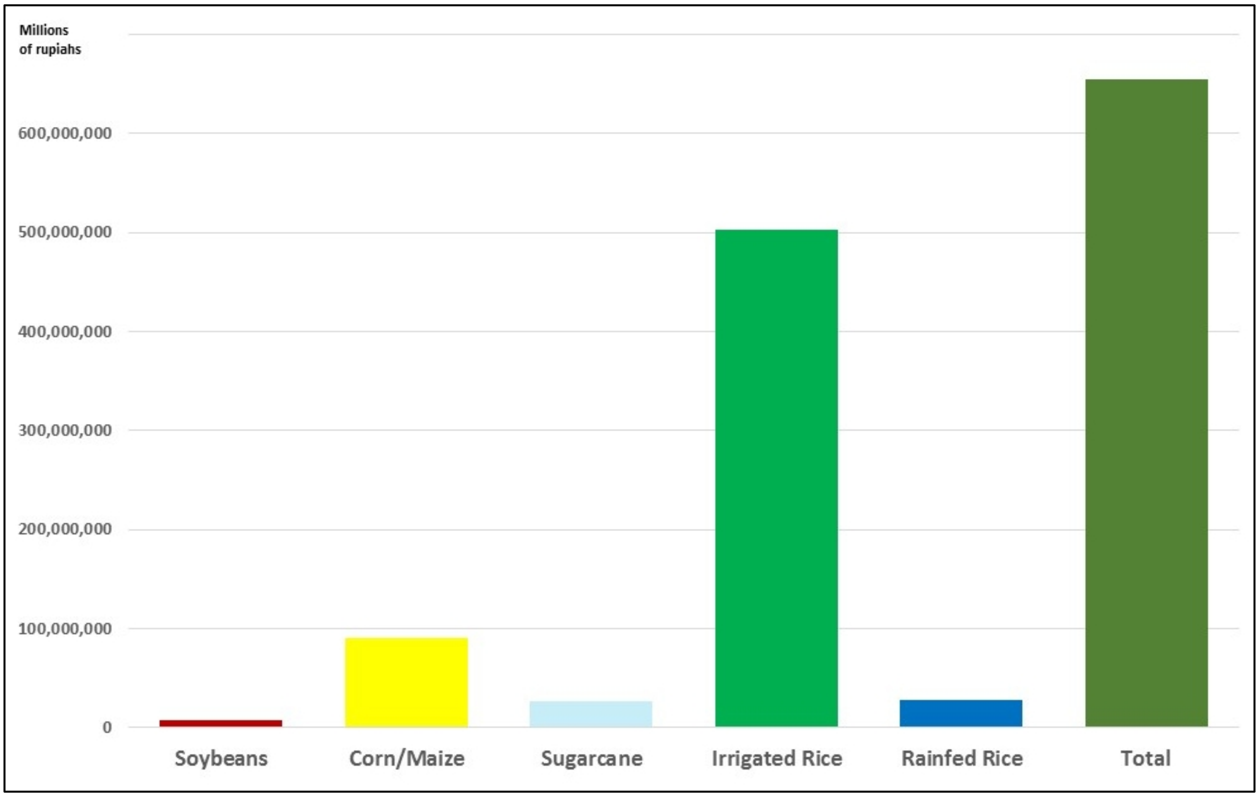
5. That price was multiplied by the expected change in sugar output to get the impact of climate change through the sugar value chain.

2.3 RESULTS

The analysis of impacts on agricultural output shows a great deal of variability from crop to crop and from province to province. Figure 5 shows the overall impact by crop while Figure 6 presents that impact at the provincial level; the data underlying Figure 6 can be seen in Table 1.

One of the most important causes of this variability is the impact of rainfall. As mentioned above, the Handoko & Syaukat model finds that changes in rainfall are positively correlated with yields of corn and rainfed rice, but do not affect yields of soybeans, sugarcane, or irrigated rice, whereas changes in temperature are negatively correlated with all five crops. The climate change models project increases in temperature everywhere in Indonesia. Consequently, for the three crops unaffected by rainfall, the analysis shows climate change leading to decreases in yield and output in all provinces.

Figure 4. Value of production of study crops in 2012
(in millions of rupiahs)



When both rain and temperature affect yields, however, the impacts vary. The climate change models project increases in annual rainfall in some provinces but decreases in others. Most of Kalimantan and Sumatera are expected to have significant increases in rainfall, while much of Sulawesi is expected to see less rainfall. In a number of provinces, the increased outputs of corn and rainfed rice resulting from increased rainfall far outweigh any decreases resulting from higher temperatures, leading to projections of a net increase in the value of agricultural production as a result of climate change in those provinces. However, these increases, while large for these provinces, do not make up for the losses elsewhere and the overall projected impact of climate change on the national value of agricultural production is more than 10 percent negative. However, while this change will involve variation from place to place and crop to crop, there is still much cause for concern everywhere about the impacts of climate change on food production and rural incomes.

Figure 5. Impacts of climate change on the value of agricultural output in 2050
(in millions of rupiahs)

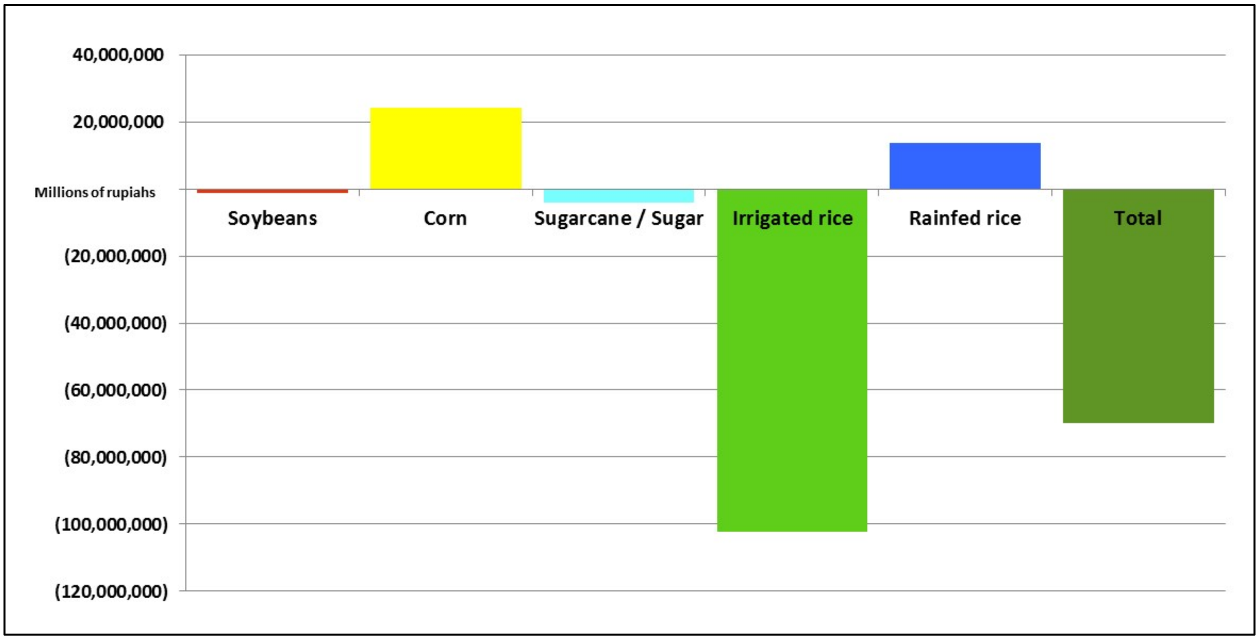


Figure 6. Impact of climate change on the value of agricultural output in 2050 by province
(in millions of rupiahs)

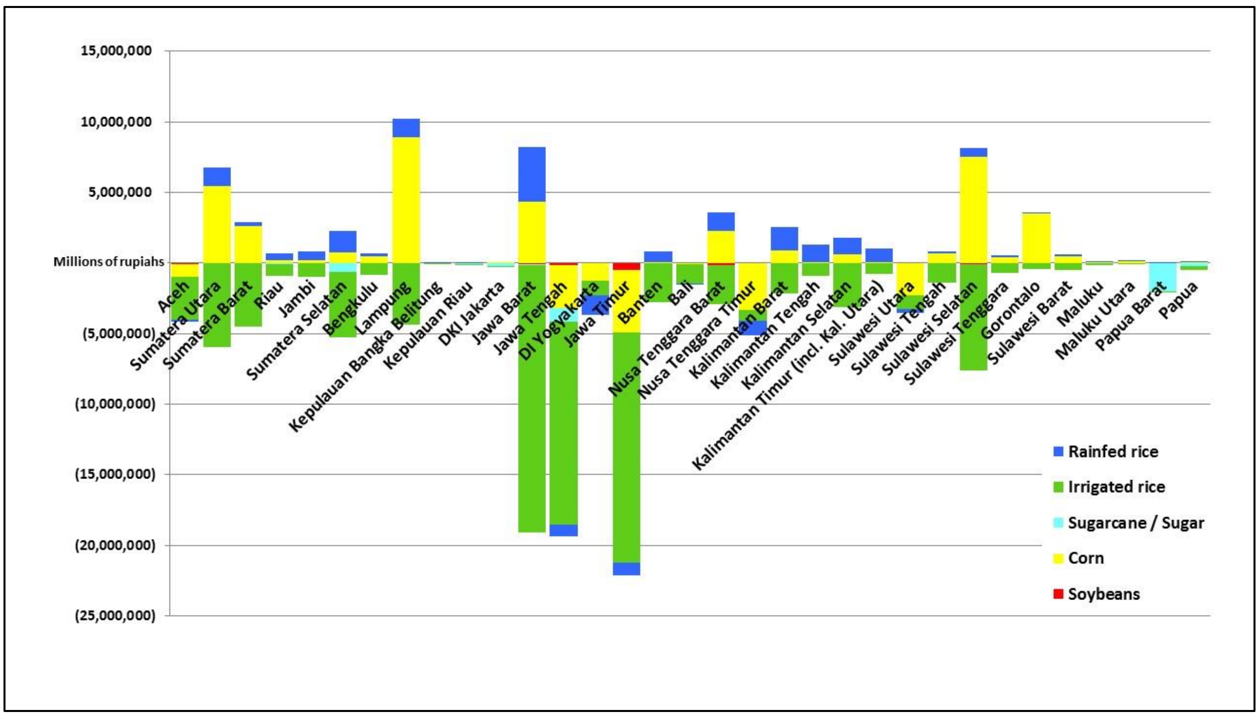


Table 1. Impacts of climate change on the value of agricultural output in 2050 by province

(in millions of rupiahs)

Province	Soybeans	Corn/Maize	Sugarcane / Sugar	Irrigated rice	Rainfed rice	Total, Agriculture
Aceh	(93,616.8)	(909,905.6)	-	(3,018,110.8)	(125,293.8)	(4,146,926.9)
Sumatera Utara	(11,909.9)	5,438,312.9	-	(5,958,230.1)	1,300,382.4	768,555.3
Sumatera Barat	(1,939.3)	2,619,863.7	-	(4,525,805.3)	253,473.0	(1,654,407.9)
Riau	(7,849.8)	174,090.9	(63,287.3)	(829,781.8)	503,239.1	(223,588.8)
Jambi	(8,325.1)	161,149.6	-	(973,569.7)	665,934.1	(154,811.1)
Sumatera Selatan	(18,819.9)	763,597.9	(631,086.6)	(4,592,855.1)	1,483,735.7	(2,995,428.0)
Bengkulu	(5,706.5)	458,640.5	-	(819,672.7)	217,371.9	(149,366.8)
Lampung	(17,032.9)	8,916,072.3	-	(4,374,994.6)	1,319,848.8	5,843,893.7
Kepulauan Bangka Belitung	(15.9)	4,833.1	-	(30,263.8)	67,119.5	41,673.0
Kepulauan Riau	(21.6)	1,260.1	(82,190.6)	(1,882.8)	37.2	(82,797.6)
DKI Jakarta	-	106.1	(225,020.2)	(17,000.5)	-	(241,914.6)
Jawa Barat	(104,042.5)	4,313,762.6	(12,993.6)	(18,969,628.2)	3,928,711.6	(10,844,190.1)
Jawa Tengah	(175,773.4)	(3,037,258.8)	(930,292.8)	(14,414,499.4)	(782,340.1)	(19,340,164.5)
DI Yogyakarta	(41,163.1)	(1,234,752.6)	-	(1,000,724.7)	(1,409,045.0)	(3,685,685.3)
Jawa Timur	(462,368.0)	(4,429,238.1)	-	(16,325,581.7)	(889,598.4)	(22,106,786.3)
Banten	(13,123.0)	80,173.4	-	(2,784,266.4)	755,909.6	(1,961,306.4)
Bali	(8,742.7)	(85,098.4)	-	(1,339,424.3)	(1,979.0)	(1,435,244.4)
Nusa Tenggara Barat	(153,211.2)	2,236,253.8	-	(2,728,641.6)	1,365,709.5	720,110.5
Nusa Tenggara Timur	(3,396.6)	(3,354,005.7)	-	(741,175.4)	(1,040,338.4)	(5,138,916.1)
Kalimantan Barat	(3,970.7)	856,690.3	-	(2,140,918.7)	1,673,435.8	385,236.6
Kalimantan Tengah	(3,647.4)	41,634.6	-	(881,216.5)	1,240,883.2	397,653.9
Kalimantan Selatan	(8,990.0)	590,291.8	-	(3,129,798.6)	1,210,177.2	(1,338,319.6)
Kalimantan Timur (incl. Kal. Utara)	(3,017.2)	46,590.8	-	(753,743.3)	1,007,599.3	297,429.6
Sulawesi Utara	(10,711.1)	(2,253,758.3)	(26,574.2)	(935,468.3)	(286,433.2)	(3,512,945.1)
Sulawesi Tengah	(18,128.9)	674,675.0	-	(1,365,382.6)	126,834.4	(582,002.2)
Sulawesi Selatan	(57,427.2)	7,490,557.9	(26,062.9)	(7,498,829.0)	621,187.4	529,426.2
Sulawesi Tenggara	(7,115.4)	372,150.2	-	(695,164.4)	181,476.8	(148,652.8)
Gorontalo	(5,911.2)	3,538,186.1	-	(450,993.0)	30,800.1	3,112,081.9
Sulawesi Barat	(4,827.1)	502,063.3	-	(489,746.1)	105,143.9	112,634.0
Maluku	(1,364.5)	78,543.2	-	(114,226.1)	26,145.1	(10,902.3)
Maluku Utara	(3,459.8)	131,438.2	-	(99,864.7)	87,316.7	115,430.4
Papua Barat	(1,160.3)	17,838.1	(2,031,006.7)	(58,918.4)	22,692.8	(2,050,554.4)
Papua	(7,704.3)	56,886.5	(218,387.8)	(253,978.1)	63,976.3	(359,207.5)
Indonesia	**(1,264,493.1)**	**24,261,645.3**	**(4,246,902.6)**	**(102,314,356.6)**	**13,724,113.6**	**(69,839,993.5)**

CHAPTER 3. HEALTH

3.1 GENERAL APPROACH

The links between climate change and disease are very complex. As discussed in the Indonesia Climate Change Roadmap paper on health, they may involve a number of different direct and indirect connections (Sofyan, Sukowati, & Slamet, 2010):

- Changes in temperature and rainfall may affect the life cycles of the organisms that cause the disease or the other species that transmit those diseases to humans. Such impacts could be of many types. They could affect their reproductive success, lifespan, the time required for them to reach an age at which they can transmit disease, their spatial dispersion, or other factors that can affect the likelihood of humans receiving the disease.
- Changes in temperature and rainfall will affect agricultural output, causing a risk of harvest failure and malnutrition, with consequent increases in the risk of many other health problems.
- Changes in rainfall and hydrology may affect water supply and sanitation, increasing the risk of water-borne diseases.
- Extreme weather events may destroy settlements or income-generating resources and facilities, leading to direct physical harm, loss of income and consequent well-being, psychological stress, and other direct and indirect human health consequences.

The climate change roadmap focuses on three diseases: dengue fever, malaria, and diarrheal diseases. This study considered the first two because there were plausible ways to establish quantitative links between changes in weather and changes in the probability of disease. Because diarrheal diseases will result primarily from extreme weather events rather than gradual change in temperature and rainfall, the quantitative change in disease incidence is difficult to predict. For that reason, they were not included in this analysis.

The study analyzes two aspects of disease: direct expenditures for medical care and prevention, and forgone income due to illness or death. Estimates of direct costs attributable to climate change were based on data found in the literature on current expenditures related to dengue fever and malaria in Indonesia, and then applied to the number of cases of each disease that could result from climate change.

The estimates of forgone income use the so-called disability-adjusted life-year (DALY) to measure the consequence of illness. This standard measure, developed initially by the World

Health Organization,[12] is the sum of the number of years of life lost by those who die of a disease plus a weighted sum of the number of years that people live with that disease. The weights are set to reflect shared views on the burden imposed by living with different medical conditions. Thus, for example, the weight for living with a spinal cord lesion that causes paralysis from the waist down is 0.296. If each year of life is weighted equally, a man with a life expectancy of 60 years who dies in an accident at age 20 will generate 40 DALYs. If his twin sister (with the same life expectancy) were in the same accident and lived with paralysis until age 60, she would generate 40 x 0.296 = 11.84 DALYs. If she died at age 40 due to complications of her paralysis, she would generate (40-20) x 0.296 + 20 = 25.92 DALYs.

The weights used to calculate DALYs for different diseases were established through extensive global survey research (Salamon et al., 2012). A key issue in that work was whether people at different income levels, or living in different countries and cultures, feel differently about living with disease or disability. Somewhat counter to expectations, researchers found considerable consistency across social conditions. This means that the same weights can be used worldwide and comparisons across countries and income groups will be meaningful.

3.2 DENGUE FEVER AND DENGUE HEMORRHAGIC FEVER[13]

Arcari, Tapper, & Pfueller (2007) analyzed the variation in dengue fever and dengue hemorrhagic fever (DHF) in different provinces of Indonesia in response to changes in weather. Their study selected eight provinces considered representative of the climate regions of the whole country and analyzed links between dengue fever and five climate parameters:

- average monthly temperature
- total monthly rainfall
- average relative humidity during the month
- presence of rainfall anomalies during the month (extreme rainfall or drought)
- average value of the Southern Oscillation Index (SOI)

The data here on the impacts of climate change include projections of temperature and rainfall, but do not include projections of relative humidity, rainfall anomalies, or SOI values. The analysis of the impacts on incidence of dengue fever/DHF is therefore limited to those two variables.[14] Table 2 shows the coefficients for these two variables for the eight provinces in the Arcari et al. (2007) study. It also shows for each of the country's 33 provinces which of the eight study provinces can be used to represent its climatic conditions. The 33 provinces were

[12] This work is now being piloted by the Institute for Health Metrics and Evaluation at the University of Washington. The DALY calculations for each disease and each country worldwide can be downloaded from their Global Data Exchange website, http://ghdx.healthdata.org.

[13] Dengue hemorrhagic fever (DHF) is a sometimes-fatal extreme variant of dengue fever that can develop as the fever from the milder version is waning. It emerged in the 1950s in the Philippines, and since then has spread through Southeast Asia and elsewhere in the world. The DALY data from the Arcari et al. (2007) study and the analysis here include both dengue fever and DHF.

[14] Analysis of dengue/DHF can be found in the worksheet entitled "Totals - Dengue" in the study spreadsheet.

assigned to the provinces included in the Arcari et al. study based on their map of climate regions, shown in Figure 7.

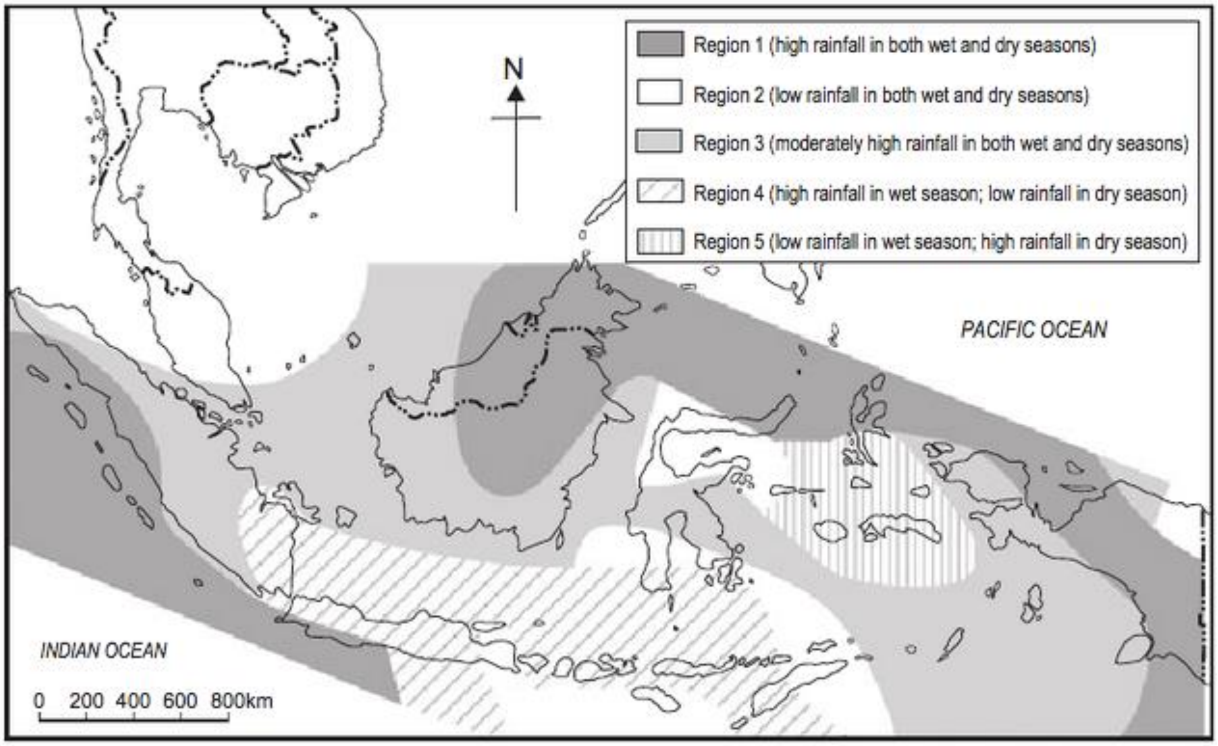
The data on dengue fever come from two sources. The 2013 DALY data come from the Institute for Health Metrics and Evaluation (IHME) Global Burden of Disease work (IHME, 2015), as discussed above. Two separate figures from those data were used: the years of life lost (YLL) by those who die from dengue fever/DHF or its later complications; and the years lived with disability (YLD) after the person is no longer sick with dengue fever/DHF. They sum to the total DALY figure for dengue fever/DHF in Indonesia.

Table 2. Coefficients for impact of change in temperature and rainfall on dengue fever /DHF cases (per 100,000 people)

PROVINCE	PROVINCE IN ARCARI ET AL. (2007) STUDY WHOSE COEFFICIENTS ARE USED	TEMPERATURE COEFFICIENT (A)	RAINFALL COEFFICIENT (B)
Aceh	Aceh	0.051	0.001
Sumatera Utara	Aceh	0.051	0.001
Sumatera Barat	Kalimantan Barat	0.982	0.000
Riau	Kalimantan Barat	0.982	0.000
Jambi	Kalimantan Barat	0.982	0.000
Sumatera Selatan	Kalimantan Barat	0.982	0.000
Bengkulu	Kalimantan Barat	0.982	0.000
Lampung	Jawa Tengah	0.000	0.008
Kepulauan Bangka Belitung	Kalimantan Barat	0.982	0.000
Kepulauan Riau	Kalimantan Barat	0.982	0.000
DKI Jakarta	DKI Jakarta	4.83	0.015
Jawa Barat	Jawa Tengah	0.000	0.008
Jawa Tengah	Jawa Tengah	0.000	0.008
DI Yogyakarta	Jawa Tengah	0.000	0.008
Jawa Timur	Jawa Tengah	0.000	0.008
Banten	Jawa Tengah	0.000	0.008
Bali	Jawa Tengah	0.000	0.008
Nusa Tenggara Barat	Nusa Tenggara Barat	0.694	0.000
Nusa Tenggara Timur	Jawa Tengah	0.000	0.008
Kalimantan Barat	Kalimantan Barat	0.982	0.000
Kalimantan Tengah	Kalimantan Barat	0.982	0.000
Kalimantan Selatan	Kalimantan Barat	0.982	00.00
Kal. Timur (incl. Kal. U.)	Kal. Timur (incl. Kal. U.)	1.768	0.000
Sulawesi Utara (2), (3)	Kal. Timur (incl. Kal. U.)	1.768	0.000
Sulawesi Tengah (2), (3)	Sulawesi Tengah (2), (3)	0.603	0.000
Sulawesi Selatan (2011)	Kalimantan Barat	0.982	0.000
Sulawesi Tenggara	Kalimantan Barat	0.982	0.000
Gorontola	Sulawesi Tengah (2), (3)	0.603	0.000
Sulawesi Barat	Kalimantan Barat	0.982	0.000
Maluku	Maluku	0.939	0.000
Maluku Utara	Maluku	0.939	0.000
Papua Barat (2), (3)	Jawa Tengah	0.000	0.008
Papua (2011)	Jawa Tengah	0.000	0.008

(A) Change in cases of dengue fever/DHF per 100,000 people for a 1 degree C change in average temperature.
(B) Change in cases of dengue fever/DHF per 100,000 people for a 1 mm change in total rainfall.
Note: Values of 0 are statistically significant; they do not mean that no relationship could be established.
Source: Arcari et al. (2007). (2) and (3) refer to climate regions in Arcari et al map in Figure 7.

Figure 7. Climate regions of Indonesia



Source: Arcari et al. (2007, Figure 3, p. 256).

Those data are national. To allocate them to provinces, Ministry of Health data on the number of DHF cases and the number of deaths for each province were used. The national YLL figure was assigned to provinces based on the share of each province in total deaths from DHF. This could be somewhat inaccurate, as the Ministry's death statistics only include those who died during the DHF incident that year, and not those whose death later in life was hastened because they had had DHF. However, given the way the statistics are calculated, it is quite possible that the DALY data also do not capture later deaths. In any case, this possible inaccuracy is unavoidable. The YLD figure is allocated based the number of non-fatal cases of DHF in each province.

The Ministry of Health data are only for DHF, whereas the DALYs are for both dengue fever and DHF. In using the Ministry data to allocate DALYs to provinces, the assumption is that the ratio of dengue fever to DHF cases is constant across provinces. The rest of the calculations are done using the DALY data, so there is no risk of combining calculations on DHF alone with calculations on dengue fever plus DHF.

For each province, the following steps were taken:

1. Calculate the DALYs allocated to the province, as described above.
2. Divide provincial DALYs by 2012 population, to get DALYs per 100,000 people.

3. Multiply the projected change to 2050 in either temperature or rainfall by the appropriate coefficient to get the impact of that independent variable on cases of dengue fever per 100,000 residents.
4. Sum the results for temperature and rainfall to get the overall change in DALYs per 100,000 people that are attributable to climate change.
5. Multiply annual change in DALYs per 100,000 people by the projected population in 2050 to get total DALYs expected to result from climate change.

Provincial per capita income from Indonesia's provincial accounts (the provincial equivalent of the national income accounts) was used to put a monetary value on a DALY. Per capita income for 2012 was used because projecting trends in the Indonesian economy to 2050 goes far beyond the scope of this study. Income per capita varies widely across the provinces of Indonesia, so aside from the provincial variation in the rate of dengue fever/DHF, this creates very large differences in the economic impacts of dengue fever in different parts of the country. The results of these calculations are presented in Table 3.

The direct costs imposed by dengue fever for medical care were also analyzed. This is based on Shepard, Undurraga, & Halasa (2013), who estimated the direct and indirect costs of dengue fever across Southeast Asia.[15] Their indirect costs pertain to forgone income, which were analyzed here through use of the DALYs. However, their direct costs are useful, distinguishing between the costs of cases that include hospitalization and those that do not (ambulatory costs). They give the total average annual cost between 2001 and 2010 and the annual average DALYs over that period. Those figures were used here to estimate the direct cost per DALY, including costs for those who are hospitalized and those who are not. This comes to US$982 per case. The United States inflation rate was used to convert that to 2012 dollars, and the 2012 exchange rate to convert it to Indonesian rupiahs. That was multiplied by projected 2050 climate change-induced DALYs from dengue fever/DHF to estimate the direct medical costs that may be imposed by dengue fever because of climate change. These results are also included in Table 3.

The results show that Jakarta far exceeds any province in the costs imposed by dengue fever, for three compounding reasons. First, dengue fever rates are high in Jakarta because the disease flourishes in urban areas with many small pools of water where mosquitoes can breed. Second, as shown in Table 3, the Arcari et al. (2007) study finds that the impact of change in temperature on dengue fever cases is very strong in Jakarta, with a coefficient of 4.83, compared to coefficients of less than one for the rest of the country. Thus the impact of climate change-related temperature increases is much greater in Jakarta than elsewhere in the country. Third, per capita income is higher in Jakarta than in most of the rest of the country, so the forgone income from a single case of dengue fever is greater there than elsewhere. As a result of all of these factors, Jakarta accounts for about three-quarters of the total costs imposed by climate change through spread of dengue fever.

[15] The Shepard et al. (2013) values may be found in the worksheet entitled "Medical costs - Dengue" in the study spreadsheet.

Table 3. Costs imposed by climate change in 2050 due to impacts of dengue fever/DHF by province
(in millions of rupiahs)

PROVINCE	FORGONE INCOME	MEDICAL EXPENDITURES	TOTAL
Aceh	(7,850)	(3,108)	(10,958)
Sumatera Utara	(94,638)	(29,248)	(123,887)
Sumatera Barat	(421,256)	(154,116)	(575,372)
Riau	(1,337,241)	(135,425)	(1,472,666)
Jambi	(444,336)	(119,836)	(564,172)
Sumatera Selatan	(546,086)	(159,957)	(706,043)
Bengkulu	(141,323)	(66,959)	(208,282)
Lampung	(287,807)	(115,733)	(403,540)
Kepulauan Bangka Belitung	(822,888)	(224,330)	(1,047,218)
Kepulauan Riau	(1,650,170)	(197,813)	(1,847,984)
DKI Jakarta	(18,850,295)	(1,305,419)	(20,155,714)
Jawa Barat	(217,785)	(82,871)	(300,656)
Jawa Tengah	8,741	3,676	12,417
DI Yogyakarta	11,841	5,237	17,078
Jawa Timur	(1,889,658)	(554,485)	(2,444,143)
Banten	(80,860)	(25,749)	(106,609)
Bali	(172,332)	(56,287)	(228,619)
Nusa Tenggara Barat	(31,603)	(20,460)	(52,063)
Nusa Tenggara Timur	13,477	11,504	24,981
Kalimantan Barat	(303,687)	(124,657)	(428,345)
Kalimantan Tengah	(518,738)	(158,330)	(677,068)
Kalimantan Selatan	(404,736)	(138,017)	(542,753)
Kalimantan Timur incl. Kalimantan Utara	(5,846,528)	(385,198)	(6,231,726)
Sulawesi Utara	(291,005)	(102,222)	(393,226)
Sulawesi Tengah	(224,721)	(85,012)	(309,733)
Sulawesi Selatan	(260,453)	(90,510)	(350,963)
Sulawesi Tenggara	(60,472)	(21,089)	(81,561)
Gorontola	(31,389)	(16,581)	(47,970)
Sulawesi Barat	(56,194)	(28,929)	(85,123)
Maluku	(65,986)	(41,164)	(107,151)
Maluku Utara	(2,981)	(1,618)	(4,599)
Papua Barat	(8,671)	(1,420)	(10,091)
Papua	(73,221)	(18,566)	(91,787)
Total in Rps 10^6	**(35,110,852)**	**(4,444,691)**	**(39,555,543)**

Table 3 also shows that dengue fever will decline, with resulting economic benefits, in three provinces; Java Tengah, DKI Yogyakarta, and Nusa Tenggara Timur. In all three, rainfall is expected to decrease with climate change, which results in the decrease in dengue fever.

Rainfall is also projected to decrease in Aceh, but the coefficient for the impact of change in rainfall in Aceh is only 0.001, compared with 0.008 in the other three provinces. In Aceh, therefore, the decrease in dengue fever resulting from a drop in rainfall is outweighed by the increase from the rise in temperatures.

Because the analysis multiplies the change in DALYs per 100,000 people by future population, the resulting change in the number of DHF cases is actually the result of a combination of two factors: change in disease incidence as a result of climate change and change in population. If the new weather conditions were applied to the lower 2012 population, the number of actual cases of dengue fever and of DALYs would increase, but not nearly as much as these results show.

3.3 MALARIA

A great deal of research has been carried out on the impacts of climate change on the incidence of malaria. However, studies that provide quantified measures of the impact of temperature or rainfall changes on dispersion of anopheles mosquitoes or the malaria virus itself are largely focused on Africa, where malaria is a much greater problem and climate change impacts are likely to be greater than in Indonesia.[16]

In the absence of studies that provide transferable coefficients on the impacts of temperature or rainfall change on incidence of malaria, the analysis is based on rules of thumb from the literature on the limiting temperature and rainfall ranges that determine whether malaria can be transmitted.[17] The ranges provided in the data library of the International Research Institute for Climate and Society of Columbia University's Earth Institute were used.[18] They define the limits of suitability as a combination of average temperature between 18°C and 32°C, monthly rainfall of at least 80 millimeters (mm), and relative humidity of at least 60 percent. Projections for humidity are not available so this analysis is based only on temperature and rainfall.

For each province, the following steps were taken:

1. Projections to 2050 for average monthly temperature and rainfall to 2050 were available, as described above.

2. For temperature, it was necessary to factor in diurnal variation in temperature, which is about 8°C in Indonesia. To ensure that average temperature was above 18°C throughout the day and night, 4°C were subtracted from the projected average temperature on the assumption that if temperature averages only 14°C at night it will not be suitable for

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[16] This is the case because far greater climate variability currently exists in Africa than in Indonesia, so many more new areas will become suitable for malaria than in Indonesia, where climate is fairly uniform compared to Africa.

[17] Analysis of the impact of climate change on malaria may be found in the worksheet entitled "Totals - Malaria" in the study spreadsheet.

[18] http://iridl.ldeo.columbia.edu/maproom/Health/Regional/Africa/Malaria/CSMT/index.html

mosquitoes. Another 2°C were subtracted from the average to account for deviation from the average, on the assumption that if it is colder than average, mosquitoes will not survive.

3. For rainfall, the monthly projections were used without modification.

4. For each month, the research team combined in a GIS (geographic information system) the raster images of temperature of minus 6°C and monthly rainfall to identify those places (pixels) for which both temperature and rainfall would be suitable for malaria. This was done for historic temperature and rainfall data and for temperature and rainfall projected to 2050. Pixels suitable for malaria in each time period were valued at 1 and those not suitable were valued at 0.

5. For each of the two time periods (historic and projected), the 12 monthly suitability images were summed to find how many months of the year that place (pixel) was suitable for transmission of malaria.

6. Each of the two resulting "months of suitability" images was overlaid with provincial boundaries and an average "months of suitability" was calculated for each province.

7. The historic "months of suitability" for each province was multiplied by the 2013 population to calculate person-months of exposure to malaria for each province. The same was done for 2050, based on projected "months of suitability" and the projected 2050 population.[19]

The results of these calculations are shown in Table 4. For most of the country the length of the malaria season will stay the same or get longer, but in four provinces it will be shorter in the future: Nusa Tenggara Timur, Kalimantan Tengah, Kalimantan Selatan, and Maluku Utara. This is related to the shortening of the rainfall season, even if total annual rainfall may not increase. Nusa Tenggara Timur and Maluku Utara will have fewer months with an average of 80 mm of rain. In the two Kalimantans, the average will still be above the cutoff for the province as a whole (though barely, in the case of Kalimantan Selatan), but in some areas it will drop, so the average months of suitability for the province as a whole will still drop relative to the historic period.

(Note on representing the health costs in tables, figures and charts in this report: While expenditures may in themselves be considered positive, to be able to add them to the forgone income – a negative – and to the changes in value for agriculture and losses from sea level rise, we have chosen to show all health costs as negative.)

[19] The "months of suitability" for malaria by province, historic and projected, may be found in the worksheet entitled "Malaria suitability" of the study spreadsheet.

Table 4. Person-months of suitability for malaria, 2012 and 2050

PROVINCE	AVERAGE OF SUITABILITY - MONTHS 2012	PERSON-MONTHS EXPOSURE 2012	AVERAGE OF SUITABILITY - MONTHS FUTURE	PERSON - MONTHS EXPOSURE 2050	CHANGE IN PERSON-MONTHS OF SUITABILITY
Aceh	9.81	46,247,046	11.20	80,545,144	1.39
Sumatera Utara	9.75	130,738,345	11.93	196,269,675	2.17
Sumatera Barat	11.27	56,334,418	11.86	75,643,579	0.59
Riau	12.00	70,566,000	12.00	135,081,889	-
Jambi	11.56	37,292,362	11.92	55,626,564	0.36
Sumatera Selatan	11.73	90,466,820	12.00	120,206,349	0.27
Bengkulu	11.29	20,141,967	12.00	30,541,829	0.71
Lampung	11.34	88,828,624	12.00	110,550,652	0.66
Kep. Bangka belitung	12.00	15,441,600	12.00	26,328,634	-
Kepulauan Riau	12.00	21,662,400	12.00	49,941,285	-
DKI Jakarta	11.00	108,460,733	12.00	138,732,741	1.00
Jawa Barat	9.65	430,653,444	11.03	667,085,625	1.38
Jawa Tengah	9.57	315,668,076	10.08	379,204,827	0.51
DI Yogyakarta	8.00	28,419,467	8.00	36,556,849	-
Jawa Timur	8.06	306,903,018	8.61	354,149,828	0.56
Banten	11.78	131,873,691	12.00	213,152,956	0.22
Bali	9.02	36,158,323	9.02	46,762,256	-
Nusa Tenggara Barat	7.12	33,067,397	8.55	51,870,483	1.44
Nusa Tenggara Timur	6.57	31,989,894	5.87	47,249,764	**(0.70)**
Kalimantan Barat	11.87	54,161,245	12.00	74,687,190	0.13
Kalimantan Tengah	11.87	27,668,275	11.83	47,181,941	**(0.05)**
Kalimantan Selatan	11.93	45,146,359	11.25	61,216,135	**(0.68)**
Kalimantan Timur	10.87	41,014,152	11.88	83,470,084	1.01
Sulawesi Utara	4.35	10,142,120	11.42	31,941,007	7.08
Sulawesi Tengah	6.02	16,487,860	10.21	40,691,302	4.19
Sulawesi Selatan	8.98	74,109,249	11.19	110,691,674	2.20
Sulawesi Tenggara	10.53	24,702,297	12.00	48,007,408	1.47
Gorontalo	5.15	5,561,873	10.73	16,542,813	5.59
Sulawesi Barat	6.31	7,639,881	11.38	23,435,177	5.07
Maluku	10.95	17,519,514	11.56	29,173,728	0.61
Maluku Utara	11.97	13,056,375	10.52	19,882,941	**(1.45)**
Papua Barat	11.16	9,007,543	11.97	18,889,758	0.81
Papua	5.19	15,436,634	7.73	35,132,023	2.54

Building on these results, the following additional steps were taken:

8. The DALYs for malaria were allocated to provinces based on the number of cases of malaria in each province, as shown in the *Statistical Yearbook of Indonesia 2014*.[20]
9. For each province, the DALYs were divided by person-months of exposure to calculate DALYs per person-month.
10. That calculated figure of DALYs per person-month of exposure was multiplied by projected person-months of exposure in 2050 to estimate DALYs from malaria in 2050.
11. As with DHF, the figure for projected DALYs in 2050 was multiplied by 2012 per capita income for each province to calculate forgone income due to malaria attributable to climate change in 2050.

The results of these calculations are presented in Table 5.

Data in the literature about the medical expenditures associated with malaria are less precise than those available for dengue fever/DHF. The only available estimates are from a 2009 UNICEF fact sheet, which said that the needed annual expenditures on malaria prevention and treatment were $400 million, while actual annual expenditures were $40 million (UNICEF, 2009). This study conservatively used the actual expenditure figure, divided by the total number of cases (from the *Statistical Yearbook of Indonesia 2014*) to get expenditure per case. That was converted to 2012 dollars and then to Indonesian rupiahs. That expenditure was allocated to provinces based on the number of cases in each province, again from the *Statistical Yearbook of Indonesia 2014*. This assumes that expenditures per case are consistent across provinces, which is probably not the case; however, there is no way to estimate the variation from province to province. The expenditures per province were then projected to 2050 based on the ratio of 2050 DALYs to 2013 DALYs. These calculations are also presented in Table 5. The resulting figures show the medical cost that Indonesia will incur if does not increase the expenditure per case above 2008 levels. As UNICEF considers those expenditures to represent only 10 percent of what is needed, the actual medical burden of climate change in 2050 associated with malaria may be much higher than the estimates here.

Table 5 shows the overall results of the analysis of costs imposed by malaria. The highest costs are incurred in Papua and Papua Barat. This is not surprising; those two provinces also have some of the highest rates of malaria in the country. Nusa Tenggara Timur also has very high rates of malaria; however, because provincial product per capita there is much lower than in Papua, the costs imposed end up being considerably lower.

Although the average suitability months for malaria are predicted to drop in four provinces, the number of cases and DALYs are not expected to drop. This is because of population growth, which is sufficient to greatly increase the actual number of cases even though the malaria season may be shorter in some places.

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[20] Badan Pusat Statistik (BPS) (2014), Table 4.2.6, p. 154.

Table 5. Costs imposed by climate change in 2050 due to impacts of malaria
(in millions of rupiahs)

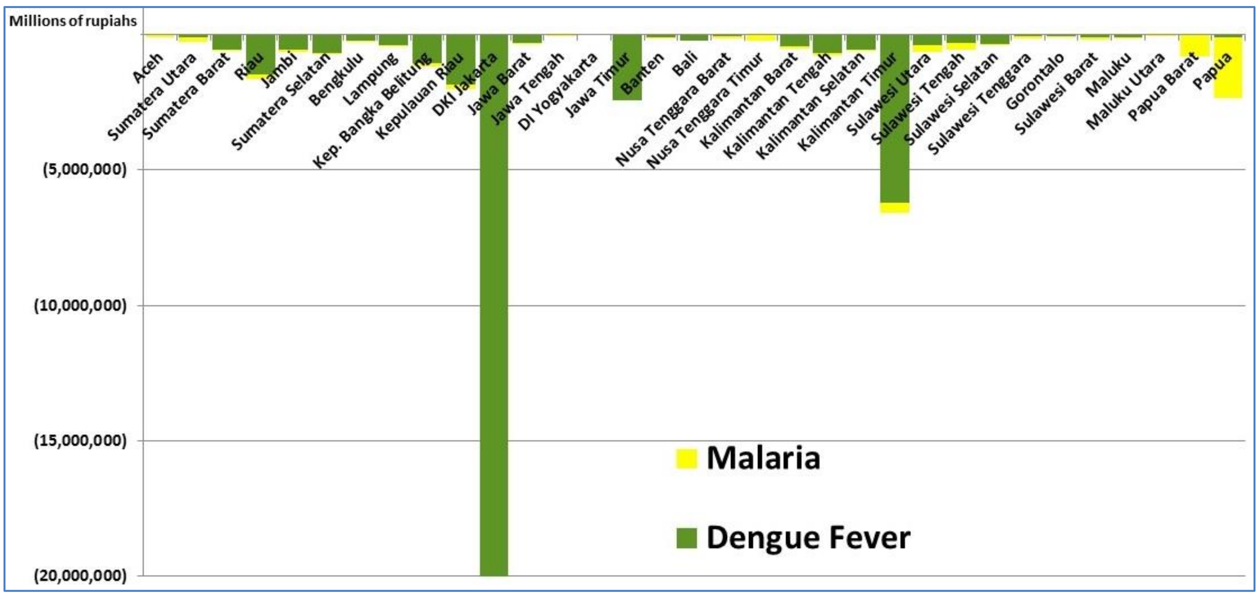
PROVINCE	FORGONE INCOME	MEDICAL EXPENDITURES	TOTAL
Aceh	(66,917)	(5,448)	(72,365)
Sumatera Utara	(149,034)	(9,472)	(158,506)
Sumatera Barat	(3,798)	(286)	(4,084)
Riau	(149,718)	(3,118)	(152,836)
Jambi	(61,879)	(3,432)	(65,311)
Sumatera Selatan	(23,104)	(1,392)	(24,496)
Bengkulu	(47,543)	(4,633)	(52,176)
Lampung	(13,757)	(1,138)	(14,894)
Kepulauan Bangka Belitung	(146,218)	(8,198)	(154,415)
Kepulauan Riau	(167,119)	(4,120)	(171,239)
DKI Jakarta	-	-	-
Jawa Barat	(36,276)	(2,839)	(39,115)
Jawa Tengah	(27,933)	(2,416)	(30,348)
DI Yogyakarta	-	-	-
Jawa Timur	-	-	-
Banten	(4,671)	(306)	(4,977)
Bali	-	-	-
Nusa Tenggara Barat	(66,124)	(8,804)	(74,928)
Nusa Tenggara Timur	(201,232)	(35,324)	(236,556)
Kalimantan Barat	(70,914)	(5,986)	(76,900)
Kalimantan Tengah	(87,128)	(5,469)	(92,597)
Kalimantan Selatan	(21,280)	(1,492)	(22,773)
Kalimantan Timur incl. Kalimantan Utara	(349,932)	(4,741)	(354,673)
Sulawesi Utara	(239,630)	(17,311)	(256,941)
Sulawesi Tengah	(238,123)	(18,526)	(256,648)
Sulawesi Selatan	(36,177)	(2,586)	(38,763)
Sulawesi Tenggara	(62,350)	(4,472)	(66,822)
Gorontola	(49,013)	(5,324)	(54,337)
Sulawesi Barat	(105,476)	(11,167)	(116,643)
Maluku	(35,700)	(4,580)	(40,280)
Maluku Utara	(22,972)	(2,563)	(25,536)
Papua Barat	(777,404)	(26,178)	(803,583)
Papua 2011	(2,152,303)	(112,232)	(2,264,535)
Total in Rps 10^6	**(5,413,726)**	**(313,553)**	**(5,727,279)**

Note: '-' indicates provinces that do not currently have malaria, according to Ministry of Health statistics.

3.4 COMPARISON OF HEALTH IMPACTS

Figure 8 shows clearly the relationship between costs associated with malaria and dengue fever across provinces. Overall, dengue fever accounts for most of the costs through health impacts of climate change, and those costs are far higher in Jakarta than in any other province. In Papua and Papua Barat, however, malaria dominates the health impacts of climate change. The incidence of malaria is very high in those provinces at present, so this is not surprising.

Figure 8. Losses in 2050 from health impacts by province
(in millions of rupiahs)



CHAPTER 4. COASTAL IMPACTS

The analysis of coastal impacts focuses on long-term, gradual sea level rise (SLR) and how it will affect coastal property and economic activity. More specifically, it includes estimates of forgone earnings from agriculture and aquaculture, and forgone annual value of industrial, office, and residential properties submerged. As discussed in the first chapter, it was not possible to estimate the losses due to extreme storms, nor to assess the macroeconomic or multiplier implications of lost roads, ports, or other key infrastructure. Both of these issues are very important, and will probably impose greater costs than gradual SLR. However, they should be the subject of separate studies.

4.1 GENERAL APPROACH

The analysis of the costs of gradual SLR was done in a series of steps:

1. Dr. Ibnu Sofian of BIG provided projections of the annual rate of SLR through 2040 for all of the waters around Indonesia. The variation in these figures from place to place was very small. Assuming that sea level will continue to rise at the same rate, these data were extrapolated to 2050, which gave a figure of 33 centimeters (cm) of SLR due to climate change. (Note that this only takes into account change in the ocean; it does not factor in changes in land levels, which can also play a role in coastal flooding. In fact, in some parts of Indonesia coastal land is subsiding, both from water extraction and from non-anthropogenic reasons such as earthquakes and other geological phenomena. Increases in water extraction could be a response to climate change, if decreases in rainfall lead to more use of groundwater for irrigation. Since data on subsidence are not available, this possibility could not be taken into account in the analysis. A researcher applying this study to a specific locality or province could possibly incorporate this.)
2. Using one arc-second (30-meter) resolution shuttle radar topography mission (SRTM) data[21] taken in 2000, the area that will be expected to flood at an average SLR of 0.33 meters was mapped. These are the best elevation data available for the entire country (it is possible that better data exist for individual cities). They do have some limitations, notably that in some cases what appears to be measuring the height of land could actually be measuring the tops of buildings or trees, giving readings that are too high. This possible error is unavoidable, unfortunately.
3. The flood line map was overlaid with provincial boundaries to estimate the amount of land in each province that will flood.

[21] These are measures of elevation at 30-meter intervals, and with 1-meter vertical resolution, collected by the US National Aeronautics and Space Administration (NASA) and the US National Geospatial-Intelligence Agency (NGA) for the entire world, and made available online to anyone wishing to use them. For more information and to download data, see https://lta.cr.usgs.gov/SRTM1Arc.

4. Those maps were also overlaid with the most recent land use/land cover (LU/LC) imagery available from the Indonesia spatial data portal.[22] Several of the LU/LC categories (shown in Table 6) were used to estimate the costs of SLR.

Table 6. Land use/land cover categories used

INDONESIAN:	ENGLISH:
Permukiman dan tempat kegiatan	Settlements and places
Sawah	Rice paddy
Tegalan/ladang	Moor/field (annual agriculture)
Air tambak	Brackish water pond[23]

6. For each province, the area in each LU/LC category was calculated, along with the area within the flood area in each LU/LC category. The latter was divided by the former to get the share of each LU/LC category of land that would flood in each province.[24]

4.2 COASTAL AGRICULTURE

To estimate the value of lost agricultural output, two steps were taken:[25]

1. To calculate the impact of SLR on output of soybeans, corn, and sugarcane, the share of land in the "moor/field" category that floods in each province was applied to the value of output of those crops in the same province. The result is the loss in income from those three crops from all flooded land.

2. To calculate the impact of SLR on output of rice, the share of land in the "paddy" category that floods in each province was applied to the value of rice (irrigated and rainfed) in the same province to calculate loss in rice income from all flooded land.

4.3 COASTAL AQUACULTURE

For aquaculture, several kinds of data were used. The Ministry of Marine Affairs and Fisheries (MMAF) provides data on the total value of aquaculture output by type of technology, including marine culture, brackish water ponds, freshwater ponds, cages, floating cage nets, and paddy

[22] http://portal.ina-sdi.or.id

[23] This translation of "air tambak" comes from MMAF (2013), Table 4.2, which translates "tambak" as "brackish water pond."

[24] These calculations are in the worksheets entitled "LULC prov-coast" and "shares flooded" of the study spreadsheet.

[25] These calculations are in the worksheet entitled "financial loss SLR" of the study spreadsheet.

fields.[26] The Indonesia statistical yearbooks provide data on aquaculture output in tons, by technology, for each province.[27] These two data sources were used to do the following: [28]

1. Based on the share of each province in the total aquaculture output using each technology, the value of 2013 production was assigned to provinces, by technology.

2. To calculate the impact of SLR on general coastal aquaculture, the share of land in the "brackish water pond" LU/LC category that floods in each province was applied to the total value of that output in the same province. In so doing, the assumption was that infrastructure investments made in construction of those ponds are lost due to SLR; what is calculated is the lost income stream from those investments.

3. To calculate the impact of SLR on paddy-based aquaculture, the share of land in the paddy LU/LC category that floods in each province was applied to the total value of paddy aquaculture in the same province.

These are the only losses that were estimated for aquaculture due to SLR. The assumption was that cages and nets floating in the sea and plants or animals cultivated in the sea would not be greatly affected by gradual SLR (though they might be harmed by extreme storms). Another assumption was that freshwater ponds would not be located directly on the coast and therefore would not be affected by gradual SLR. This left only the brackish water pond and paddy categories to include in the analysis.

4.4 COASTAL PROPERTY LOSSES

The calculation of the value of settled property lost due to SLR was much more complicated than the analysis of agriculture or aquaculture losses because of the challenges of determining what kinds of property might be flooded and what they will be worth. The LU/LC data show the area considered to be settled but do not indicate how that land might be used. The available data on property values were limited and essentially anecdotal. Moreover, there was not a practical way to statistically assess the area of coastal cities, which might be related to property values. For these reasons, the analysis of the value of property lost to SLR was necessarily even simpler than other analyses in this study.

Two kinds of data on property values served as the basis for further calculations:[29]

- For most rural dwellings lost to the sea, the compensation rate paid to households that lost

[26] MMAF (2013), Table 4.2, p. 35.

[27] BPS (2015), Table 5.6.5.

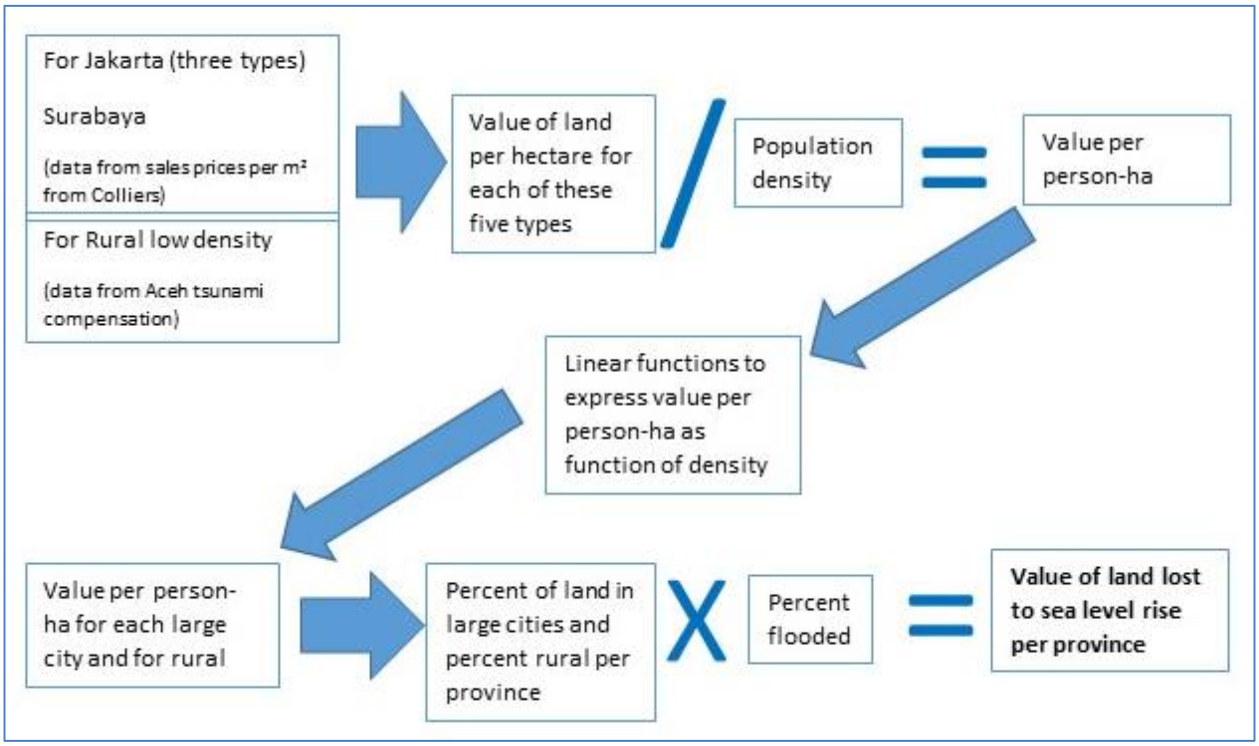
[28] These calculations are in the worksheet entitled "financial loss SLR" of the study spreadsheet.

[29] These data and the calculations to arrive at values per hectare are in the worksheet entitled "real estate prices" of the study spreadsheet.

their homes in the 2004 tsunami was used.[30] The assumption was that all homes located within the flooded area would be destroyed.

- Colliers International, a global real estate company, publishes quarterly reports on the state of Jakarta real estate markets and an annual report on the Surabaya market.[31] From these reports, data were obtained on sale and (in some cases) rental prices for residential, office, industrial, hotel, and retail properties in Jakarta and residential, office, and retail properties in Surabaya. The Colliers data certainly reflect the highest end of these two urban markets as their audience is international companies considering investments or relocating staff to the country. The Jakarta data differentiate between the central business district (CBD), other areas within the city boundaries, and specific communities outside the city itself such as Bogor, Bekasi, and Tangerang. The Surabaya data do not make such distinctions.

Figure 9. Process for determining value of residential land lost to flooding



The analysis made use of the data on residential, industrial, and office properties. Retail properties and hotels were not included. The Colliers data on retail properties are only for large modern shopping malls. To the extent that there is any retail activity right on the shoreline, it seemed likely to be small shops serving workers in the ports or industrial areas rather than upscale malls. While hotels in resort areas are located on the coast, the assumption was that these represented a small enough share of the actual coastline that they could be left out of the analysis.

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[30] Republic of Indonesia (2005), p. 8-2.

[31] Colliers International (2014, 2015 a-d).

To make use of these rather limited data, a relationship was established between the density of the communities for which data were available and the price per square meter. The density data were located on the Internet, either from Google maps or Wikipedia. The exact details of the procedure depended on the type of data available.

Urban residences: For residences, the Colliers report provides sale prices per square meter for Jakarta CBD, Jakarta non-prime, South Jakarta, and Surabaya. (Colliers also provides monthly rental data but only the sales values were used.) This needed to be converted to a value per hectare of land. To do this, several assumptions were made based on examining the websites of some of the properties about which the report provides information: that each building has 30 stories, and that 5 percent of the land area of the development is residences. (Much of the land in these high-end developments goes to gardens, swimming pools, sports facilities, parking, roads, et cetera.) From those two assumptions, the research team calculated that for each hectare of land, 15,000 square meters of residence could be sold (30 stories x 10,000 m^2/ha x 5 percent of land actually covered with residences = 15,000 m^2). From the Colliers data for Surabaya and three types of neighborhoods of Jakarta, four different values per hectare for urban residences were calculated.

Rural residences: For the lowest-density rural areas, the figure for tsunami compensation was used to estimate the value of a hectare of residential land. This was done using the average household size in Indonesia, 3.888 people,[32] and the population density for rural areas and small cities in Indonesia (calculation of this figure is discussed below), which is 1.093 people/hectare. The household size was divided by density to get the number of hectares occupied by one household: 3.543. The compensation price for one home, Rp 28,000,000, was then divided by hectares per household to get a figure of Rp 7,902,431 per residential hectare in the most rural parts of the country.

Computing value per person-hectare: For each of the five locations (three in Jakarta, one in Surabaya, and "lowest-density rural"), the real estate price per hectare was divided by population density (people per hectare). For Jakarta, it was not possible to distinguish density in the CBD, "Jakarta non-prime," and South Jakarta, so the average density (144 people per hectare) was used for the whole urban area. For each of the five areas, this provided a value per person living in a hectare of residential property in that place ("value per person-hectare). From these values were calculated two coefficients for relating value per person-hectare to density: one for places whose density ranged from the most rural to the Surabaya density value (119 people per hectare); and the other from the Surabaya density to the Jakarta CBD density. Two linear functions were used to express value per person-hectare based on density per hectare, as shown in Table 7.

[32] BPS (2014), p. 81.

Table 7. Calculations for determining value of residential land lost to flooding

Location	Value/ha in Rp	Density/ha	Value per person-ha in Rp	Coefficient = change in value/ha of lower-density category to this one / change in density	Offset = "value/person-ha" of lower-density category in Rp
Highest price - Jakarta CBD	666,805,935,000	144	4,617,820,876	94,278,634	2,250,787,006
Middle price - Surabaya	268,500,000,000	119	2,250,787,006	18,982,180	7,201,632
Lowest price - rural, use Aceh tsunami compensation	7,902,431	1	7,201,632		

Thus for a large city whose density is between 1 and 119, the value per hectare is calculated as the city's density multiplied by the coefficient for lower-density cities, Rp18,982,180 plus the offset, Rp 7,201,632. For a city whose density exceeds 119, the value per hectare is calculated as density times the higher coefficient, 94,278,634 plus the offset, Rp 2,250,787,006.

These rates were then used to calculate the value of a hectare of residential land in all cities in Indonesia with population greater than 50,000.[33] The list of cities was identified from Wikipedia based on data in the 2010 census, so it may not be entirely reliable; however, this was the only practical way to identify the largest cities in the country. For each city, the area was located either on Google maps or, when that was not available, Wikipedia, and the province in which it is located determined.

For each province, the surface area of the large cities and their populations were each summed. The area of large cities was divided by provincial area to get the share of land in large cities for each province. For each province, the population of large cities was divided by area of large cities, and remaining population by remaining area, to get the population density, respectively, of large cities and the small-city/rural portion of each province. The rates of change in value of residential land per hectare, applied to the calculated densities, were used to estimate an average value per hectare of large city and small-city/rural land in each province. Note that this was done based on base year 2012 population densities, not projections of the increase in urban population to 2050. All property loss values would have come out higher had projected population figures been used; however, since no projected future prices were used for the other calculations in this study, this was not done in this case either.[34]

Urban office and industrial: The calculations for office and industrial land were done in essentially the same way as the calculations for residential land, though in the absence of any

[33] The list of cities over 50,000 and the data about them are in the worksheet entitled "City list" in the study spreadsheet.

[34] These calculations are in the worksheet entitled "City data for valuation" in the study spreadsheet.

tsunami compensation rates for nonresidential properties, no "lowest-density" prices were available.[35] Instead of calculating two different rates of change in value, a single "value per person-hectare" was calculated for each of these categories, which was multiplied by the urban density for each province to get a value per hectare. In addition, a portion of the office and industrial properties are rented rather than sold. To factor in both kinds of property, the income streams from rental properties were converted to a capital value. This required making assumptions about the shares rented and sold; as with the other assumptions, these are only educated guesses.

ASSUMPTIONS FOR OFFICE PRICE CALCULATIONS

- **20% of office space is owned rather than rented**
- **30 years in operation for rental buildings**
- **8% discount rate**
- **10 floors in the average building**
- **40% of land area is built on**
- **40,000 square meters sold/rented per ha (calculated from previous two values)**

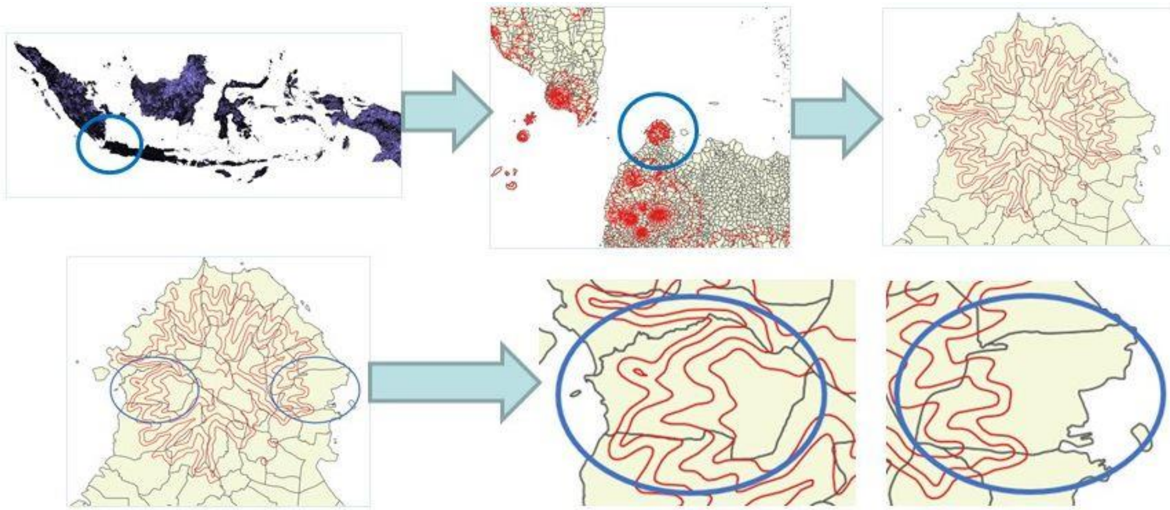
Office: For the office calculations, several key assumptions were made to convert rental prices to capital values and come up with a price per hectare (see box at right). The building lifespan and discount rate were used to convert the rental prices to capital values for office space. For Jakarta, this came to a 12–45 percent higher value than the equivalent prices for office space that is sold; for Surabaya, it was 28 percent lower. The Colliers reports suggested that purchasing office space is a relatively new and unfamiliar practice in Indonesia. Based on that, the assumption was that 20 percent of office space is purchased and the rest rented. Thus to get the average price of a hectare of office land, the purchase price was weighted by 0.2 and the capital value of rented space by 0.8. The assumptions about average building height and land coverage on office properties led to the calculation that 40,000 square meters of office space could be used on each hectare of land.

Industrial: For industrial land, the Colliers data included both prices to purchase land (without buildings) and prices to rent both built space and land. Using the same 8 percent discount rate and 30-year income stream, rental prices were converted to capital values. Since any industrial user needs both land and buildings, the land prices and the calculated capital values of the buildings were summed rather than using a weighted average as with office space. The calculations assumed that industrial structures are one story and cover 30 percent of the land area (assuming outdoor space is needed for transportation, trucks, storage, and loading, et cetera).

[35] The calculations of values per hectare for office and industrial land are in the worksheet entitled "real estate prices" in the study spreadsheet.

Figure 10. Analyzing sea level rise in a Geographic Information System (GIS)

This image shows the progression of spatial analysis in a geographic information system from country to province to local level. Contour lines along the coast can be used to determine what would be flooded with a certain rise in sea level. The village on the right has much more land closer to sea level than does the one on the left and therefore would lose more land to sea level rise.



To use the resulting property values per hectare to estimate losses from flooding, a few more assumptions were made:

- All flooded industrial and office land is in large cities; in the small-city/rural areas, all flooded land is residential. For rural areas this is most certainly true and for small cities, the industrial portion is likely to be very small scale and to be a mix that would be very difficult to determine, and would vary considerably along the spectrum of size from village to small city.
- The share of large-city land in each province is the same as the share of large-city land flooded. By making this assumption, that share could be multiplied by the hectares of settlement land flooded in each province to calculate how many hectares of large-city land are flooded.
- The large-city flooded land is 20 percent residential, 70 percent industrial, and 10 percent office. This breakdown was made based on an assumption that in big cities the coastline is likely to be primarily devoted to ports, transportation infrastructure, and related industrial and office activity. (It was assumed that port land and associated transportation infrastructure would be similar to industrial land for pricing purposes. This could, in fact, be inaccurate. Because it is the only land that can be used for shipping, its sale value might in fact be considerably higher than that of land used for industrial activity that does not need to be on the water.)

Based on these assumptions, the total value of the flooded land was calculated for each province in each of four categories: large-city residential, large-city industrial, large-city office, and small-city/rural residential. This is a capital value representing the total loss of urban property due to gradual SLR between 2013 and 2050. The 8 percent discount rate and 30-year lifespan assumptions were used to convert that to an equivalent income stream, so that these values would be comparable to the lost income from agriculture and aquaculture due to SLR.[36]

4.5 RESULTS

> **ABOUT PIXEL SIZE**
>
> **Each pixel in a raster image used for spatial analysis in a GIS covers a fixed area, whose size depends on how detailed the image is. Each pixel has a single value. The smaller the area covered by the pixel, the more precise is the value for that area. The pixels in the raster images for temperature and rainfall are half a degree (360 degrees in the circumference of the earth), which at the equator would be about 55 kilometers.**

Obviously these calculations are rough approximations based on limited data, many assumptions, and a methodology that, in the case of property values, may not produce anything that bears much relation to actual sale prices. No one should consider them plausible measures of the actual property losses resulting from SLR in any given location. As a basis for comparing impacts across provinces, and between agriculture, aquaculture, and property loss, however, they are worth considering. Figure 7 summarizes the results of these calculations; the underlying data are found in Table 8.[37]

The first point that jumps out is that the highest values are from property losses, not surprisingly those in urban areas; Rp 14,406,695 million out of a total of Rp 17,198,244 million, or 84 percent. Equally unsurprising is that property losses in Jakarta account for Rp 13,844,737 million; 96 percent of the urban property losses and 81 percent of all losses due to SLR. Jawa Barat, which is projected to be entirely urban by 2050, comes a very distant second in losses of property income, at Rp 375,123 million.

Perhaps more surprising is that office values exceed residential or industrial ones, even though it was assumed that they accounted for only 10 percent of the flooded area. This is due both to the base prices of offices and to the assumptions required to make the calculations. The actual sale prices of office space per square meter from the Colliers data are about 20 percent higher than the equivalent prices for residential property. Using the 8 percent discount rate and 30-year lifespan, the equivalent sale prices of office space actually rented come out 12–45 percent higher than the sale prices. In addition, the assumption that 40 percent of office land is built on compared with only 5 percent of residential land leads to more saleable (or rentable) office than residential space per hectare, even though it was assumed that office buildings average 10 stories and residential structures 30 stories.

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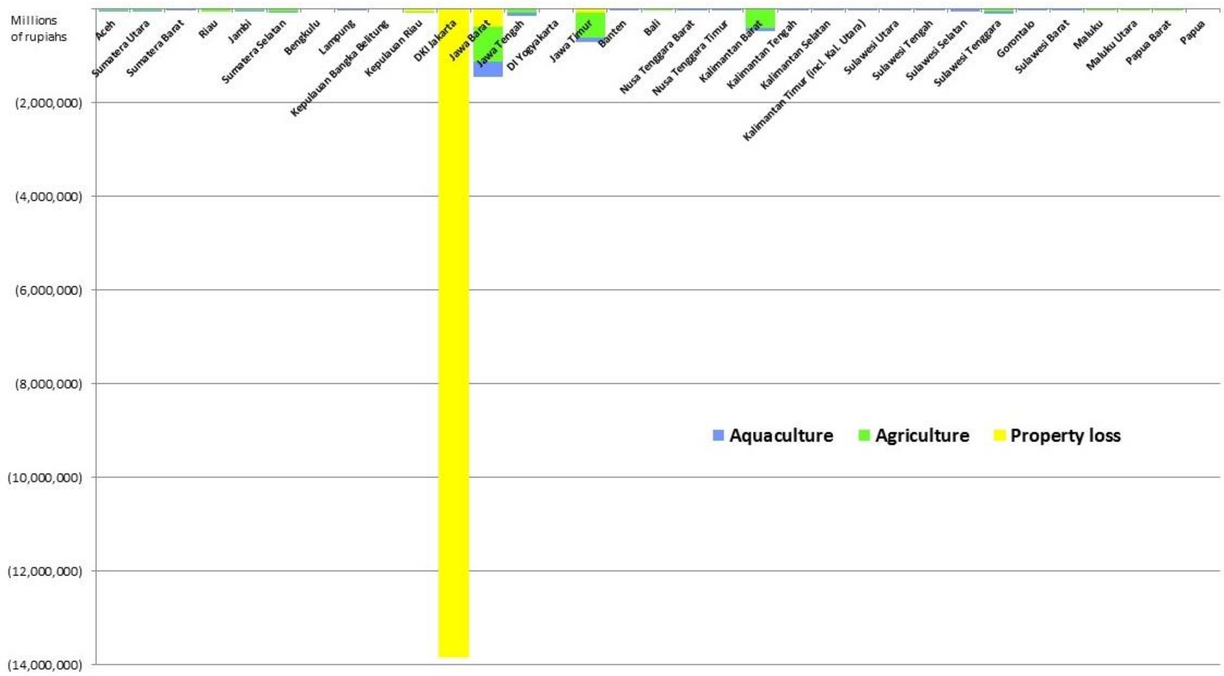
[36] These calculations are carried out in the worksheet entitled "City data for valuation" in the study spreadsheet.

[37] This table may be found in the worksheet entitled "financial loss SLR" in the study spreadsheet, in both thousands and millions of rupiahs.

Figure 11. Costs imposed in 2050 due to sea level rise by province and area of impact (in millions of rupiahs)



The value of lost industrial space is much lower than that of residential or office space, even though it was assumed that it accounted for 70 percent of flooded land. This is also a result of both the base prices and the assumptions. The per square meter sale prices of industrial land and rental prices of industrial buildings are far lower than the prices of residential or office space. In addition, it was assumed that industrial buildings are only one story in height, so much less usable space is available per hectare than for the other categories.

After property losses, the biggest losses from flooding come from decreased production of rice. This reflects the importance of rice in land use and the importance of paddy in the coastal areas flooded. For other cropped land ("Tegalan/ladang" in the LU/LC classification), the share of provincial land that floods is 0.049 percent, whereas for paddy it is 0.319 percent, more than six times as high. The only land categories that have greater representation in the flooded area are those by the sea, namely salt flats and brackish water ponds.

Table 8. Value of losses in 2050 due to sea level rise by province and area of impact (in millions of rupiah)

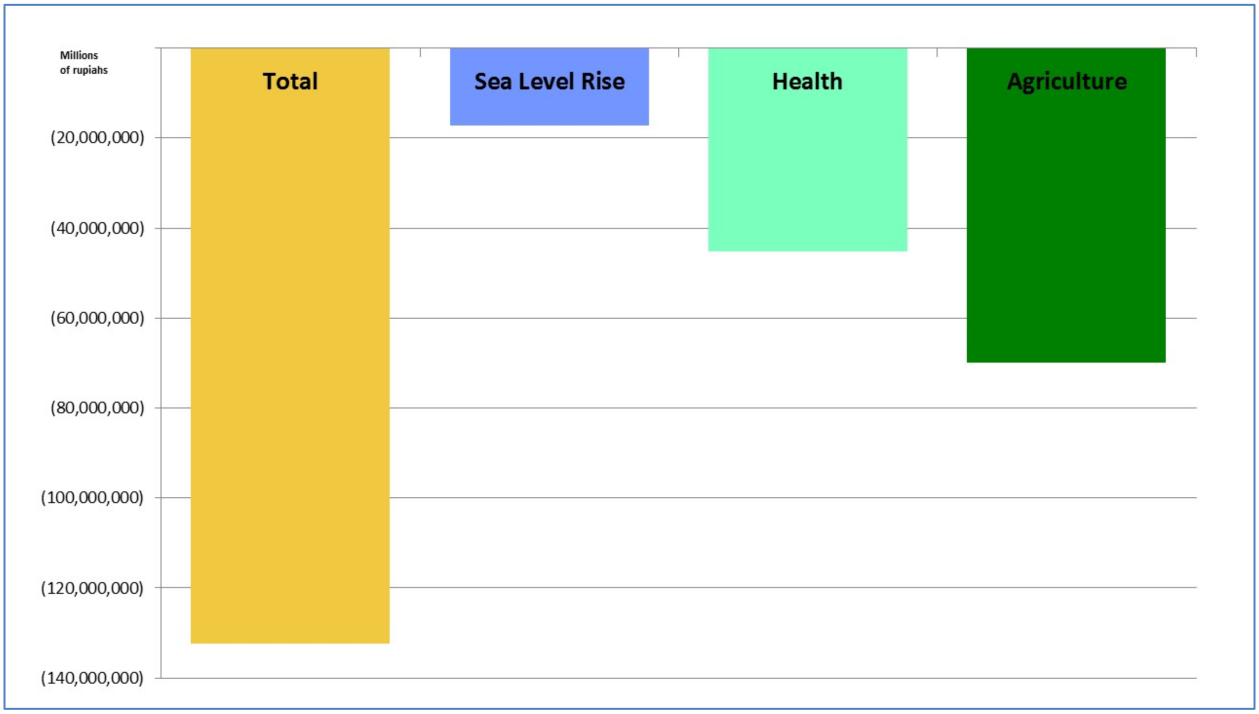
Province	Agriculture		Aquaculture		Settlements				Total
	Crops	Rice	Brackish ponds	Paddy	Urban residence	Urban industrial	Urban office	Rural homes	
Aceh	(74)	(29,278)	(13,156)	(15)	(274)	(169)	(489)	(3,848)	(47,302)
Sumatera Utara	(1,301)	(24,720)	(141)	(65)	(484)	(299)	(864)	(997)	(28,872)
Sumatera Barat	(253)	(5,874)	-	(16)	(252)	(156)	(450)	(310)	(7,313)
Riau	(118)	(26,899)	-	-	(2,909)	(1,796)	(5,190)	(12,777)	(49,689)
Jambi	(46)	(34,568)	-	(1)	(411)	(253)	(732)	(2,716)	(38,728)
Sumatera Selatan	(250)	(44,144)	(250)	(130)	(2,492)	(1,538)	(4,445)	(10,669)	(63,918)
Bengkulu	(20)	-	-	-	(24)	(15)	(42)	(30)	(131)
Lampung	(451)	(717)	(1,072)	(0)	(364)	(225)	(650)	(1,787)	(5,265)
Kep, Bangka	(1)	(45)	-	-	(85)	(53)	(152)	(184)	(520)
Kepulauan Riau	(105)	-	-	-	(13,891)	(8,574)	(24,780)	(7,127)	(54,478)
DKI Jakarta	(2)	-	-	-	(4,070,699)	(2,512,518)	(7,261,520)	-	[illegible]
Jawa Barat	(368)	(752,743)	(313,481)	(1,746)	(110,295)	(68,077)	(196,751)	-	(1,443,460)
Jawa Tengah	(9,771)	(60,866)	(63,258)	(24)	(3,043)	(1,878)	(5,429)	(8,839)	(153,108)
DI Yogyakarta	(3)	(224)	-	(0)	-	-	-	(7)	(234)
Jawa Timur	(147,217)	(395,432)	(82,550)	(277)	(19,030)	(11,746)	(33,947)	(21,139)	(711,339)
Banten	(49)	(1,038)	(4,601)	(0)	(2,538)	(1,567)	(4,528)	(301)	(14,623)
Bali	(45)	(686)	-	(0)	(1,372)	(847)	(2,448)	(61)	(5,459)
NT Barat	(4,779)	-	(55)	-	(793)	(489)	(1,414)	(2,585)	(10,114)
NT Timur	(159)	(5)	(9)	(0)	(145)	(90)	(259)	(494)	(1,161)
Kalimantan Barat	(5)	(411,478)	(55,628)	-	(78)	(48)	(140)	(547)	(467,924)
Kalimantan Tengah	-	-	(3,269)	-	(35)	(22)	(63)	(1,270)	(4,659)
Kalimantan Selatan	(35)	-	(41)	-	(334)	(206)	(596)	(3,078)	(4,291)
Kalimantan Timur	(1)	(7,124)	(30,700)	(0)	(840)	(518)	(1,498)	(1,444)	(42,127)
Sulawesi Utara	(219)	(33)	(80)	(1)	(553)	(341)	(986)	(586)	(2,799)
Sulawesi Tengah	(97)	(5,981)	(10,173)	(0)	(312)	(193)	(557)	(2,759)	(20,073)
Sulawesi Selatan	(723)	(1,474)	(51,700)	(1)	(718)	(443)	(1,281)	(691)	(57,032)
Sulawesi Tenggara	(293)	(37,615)	(53,711)	(1)	(2,669)	(1,647)	(4,760)	(3,089)	(103,783)
Gorontalo	(1,097)	(139)	(312)	(1)	(74)	(45)	(131)	(267)	(2,066)
Sulawesi Barat	(100)	(2,040)	(135)	-	-	-	-	(144)	(2,419)
Maluku	(59)	-	-	-	(625)	(386)	(1,115)	(2,657)	(4,842)
Maluku Utara	(386)	-	-	-	(300)	(185)	(535)	(1,317)	(2,724)
Papua Barat	(8)	-	-	-	(241)	(149)	(430)	(1,169)	(1,998)
Papua	(1)	(0)	-	-	(46)	(28)	(81)	(899)	(1,055)
Indonesia	**(168,036)**	**(1,843,123)**	**(684,322)**	**(2,278)**	**(4,235,929)**	**(2,614,501)**	**(7,556,265)**	**(93,789)**	**(17,198,244)**

CHAPTER 5. OVERALL RESULTS AND DISCUSSION

5.1 COMPARISON ACROSS AREAS OF IMPACT

The impacts of climate change vary substantially both across areas of impact and across provinces. Figure 12 gives the big picture. The total cost to the economy is about Rp 132 trillion. Agriculture accounts for the majority, at 53 percent, while health and SLR account for 34 percent and 13 percent, respectively.

Figure 12. Cost of climate change in 2050 by area of impact
(in millions of rupiahs)



The significant impact of agriculture – negative in most provinces but positive in some – will be important in developing approaches to adapt to climate change, from both an economic and a food security perspective. Where rainfall is expected to rise, farmers may wish to shift to corn, rainfed rice, or other rainfed crops whose yields will be higher than in the past. In areas with increased rainfall the need to make use of existing irrigation systems may decrease unless the increase in volume is also accompanied by an increase in irregularity.

The fact that this agricultural analysis (and indeed, all of the studies identified that consider links between agriculture and climate change in Indonesia, including the government's climate change roadmap) relies on the same 2008 study by Handoko & Syaukat means that more research on climate change and agriculture is essential. This issue is too important for policy decisions to be based on a single study whose coefficients are probably applicable only to a marginal change in weather conditions. Additional research into how climate patterns affect agricultural output, covering the whole country rather than just selected provinces, addressing a wider range of changes in temperature and rainfall, and considering more carefully which crops may do better or worse under the new conditions, are essential to design effective adaptation strategies.

The impacts of health problems are second to those of agriculture. The research on health and climate change focuses on how disease may increase with climate change but the analysis finds that in some specific cases, the incidence of disease drops rather than increases with climate change. This is quite clear in the case of dengue fever; where rainfall is expected to drop, the disease may become less prevalent than it is at present. These results suggest that more research on empirical links between rainfall, temperature, and the incidence of malaria across Indonesia, analogous to the Arcari et al. (2007) work on dengue fever, may be useful to better understand the implications of climate change for disease. This is not to suggest that climate change is less of a problem for health than is usually thought. Rather, it is to suggest that to plan for adaptation, it will be important to know more about the cases of lower costs as well as the higher costs, as this is important information for the allocation of resources to address the impacts of climate change.

As expected – and unavoidably – the impacts of SLR are only negative. Indeed, there would be no plausible explanation for these results to be positive. Also not surprisingly, the value of flooded urban land is much greater than that of flooded rural settlements, a natural result of the higher property values in urban areas. Flooded urban land is also much more costly than lost property in agriculture or aquaculture; again, not a surprising result given the property values and income streams from the different activities.

As already discussed, the biggest problem with coastal flooding relates to extreme storms rather than long-term SLR. Gradual SLR is predictable and easier to avoid, but extreme storms may impose much greater costs and destroy properties near the coast before the gradual change ever occurs. From an adaptation perspective, of course, the problem is that the timing, magnitude, and location of extreme events are difficult to predict, and the probability of one occurring in any specific place at any given time is assumed to be low.

If it is not possible to estimate the probability of an extreme storm in any given place, one way to analyze possible impacts is simply to determine what would flood, if there were a storm surge of a given height, without knowing how likely it actually is. If it can be determined what will flood, it is possible to estimate the losses, both direct and, if the models can be built, indirect through economic multiplier effects. To prioritize the choice of areas for investment in adaptation and to assess how much investment is appropriate, it would be valuable to know how likely it is that a storm surge of a given height would actually occur in different parts of the country; knowing what would be lost if it did occur but not how likely it is to occur is not an adequate basis for policy choices.

5.2 COMPARISON ACROSS PROVINCES

Figures 13 and 14 show the total and per capita impacts, respectively, of climate change by area of impact at the provincial level. The data underlying these figures are included in Table 9. The figures and associated data make it very clear which provinces are net winners and which are net losers. Jakarta is clearly expected to incur the greatest costs, in both total and per capita terms; the capital area accounts for more than 25 percent of the national harm from climate change. Jawa Barat, Jawa Tengah, and Jawa Timur provinces are next, accounting for 19 percent, 15 percent, and 9.5 percent of total costs, respectively. In these three provinces, most of the losses are in agriculture, particularly due to decreased yields from irrigated rice. Portions of Jawa Barat close to Jakarta will certainly lose property of significant value due to SLR. However, as the results cannot be disaggregated at a subprovincial level, it is not possible to identify this separately. Lampung and Gorontalo provinces are clearly the two strongest beneficiaries of climate change because of the importance of increases in rain to their agricultural output.

The differences between total impact and impact per capita in some provinces, notably Gorontalo, Sulawesi Utara, and Papua Barat, result from their relatively small projected populations in 2050. Though the overall impact on those two provinces is relatively modest, the impact per capita is very significant. From the perspective of potential burden or benefit to the province from climate change impact, this cost or benefit per capita is likely to be more important than total impact. Figure 15 shows the per cent gain and loss versus prevailing incomes. Clearly, the same size loss in rupiahs to a person in the poorest provinces is more devastating than the same rupiahs lost in a province with a high income such as Jakarta. Finally, Figure 16 shows the total impact per province versus the entire 2013 budget (revenue) of each provincial government. The average of these is about 2/3 which would be a significant sum.

The fact that agriculture dominates the impact of climate change in every province except Jakarta means that these impacts may be fairly widely distributed across the population, at least to the extent that agriculture in those provinces is characterized by small farmers rather than large agribusiness. Since the agricultural analysis does not take into account large-scale oil palm plantations, the agriculture output that dominates the impacts by climate change may indeed primarily affect smallholders.

The impacts on Jakarta are, of course, quite different from those on other provinces. Agriculture is obviously of little importance; indeed, it is not likely that there will be any agriculture within the city limits by 2050, though the analysis continues to show a modest amount. Dengue fever is expected to impose the greatest climate-related costs on Jakarta, in part because the disease flourishes in urban areas, and in part because per capita incomes in Jakarta are higher than in the rest of the country so forgone income due to disease is greater there. The analysis of the impacts of climate change on Jakarta must also take into account the impacts of extreme storms, considering not only the direct loss of property but also the repercussions of those losses for the country as a whole. Economic research has shown that some impacts, such as flooding of the international airport, would impose costs far beyond the investments required to prevent them. In many other areas, more detailed analysis is needed to identify priorities for investments to prevent harm from extreme storms. This should be a priority in Indonesian work to establish priorities for climate change adaptation.

Figure 13. Total monetary impact of climate change by province and area of impact
(in millions of rupiahs)

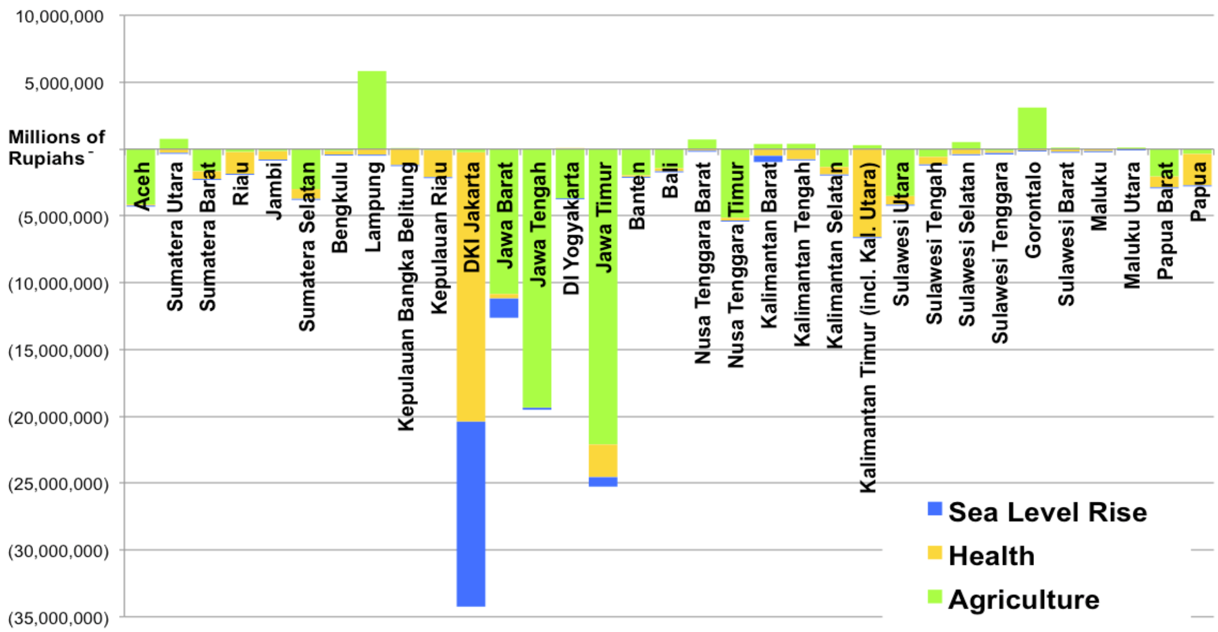


Figure 14. Per capita monetary impact of climate change by province and area of impact
(in rupiahs)

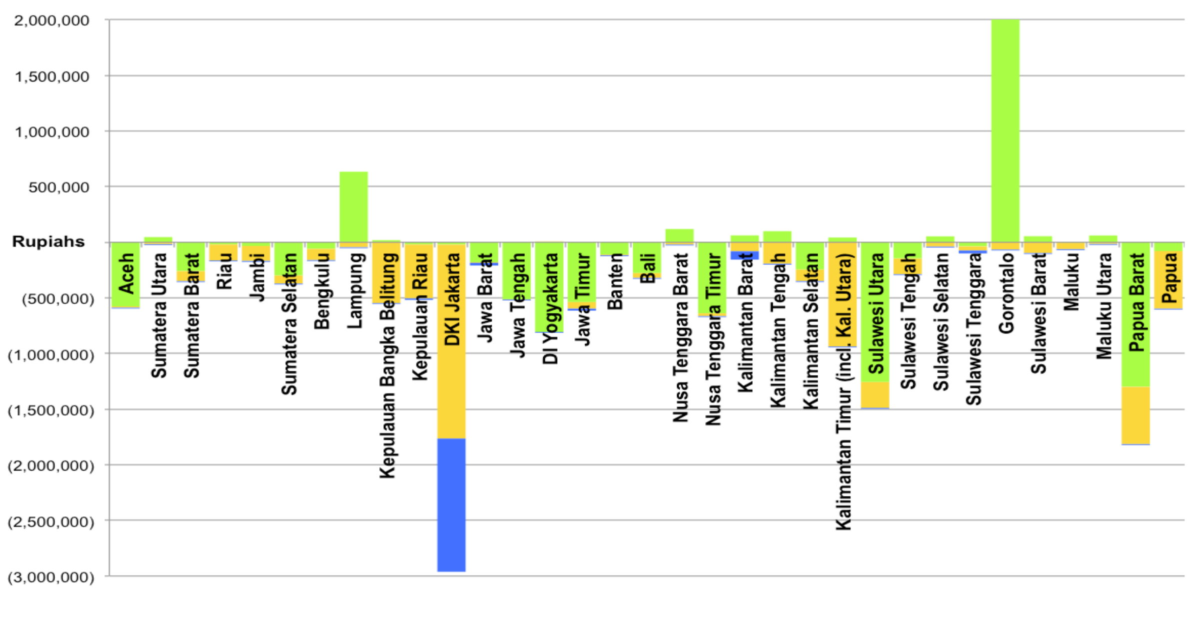


Figure 15. Percent gains and losses in income per capita by province (in percent)

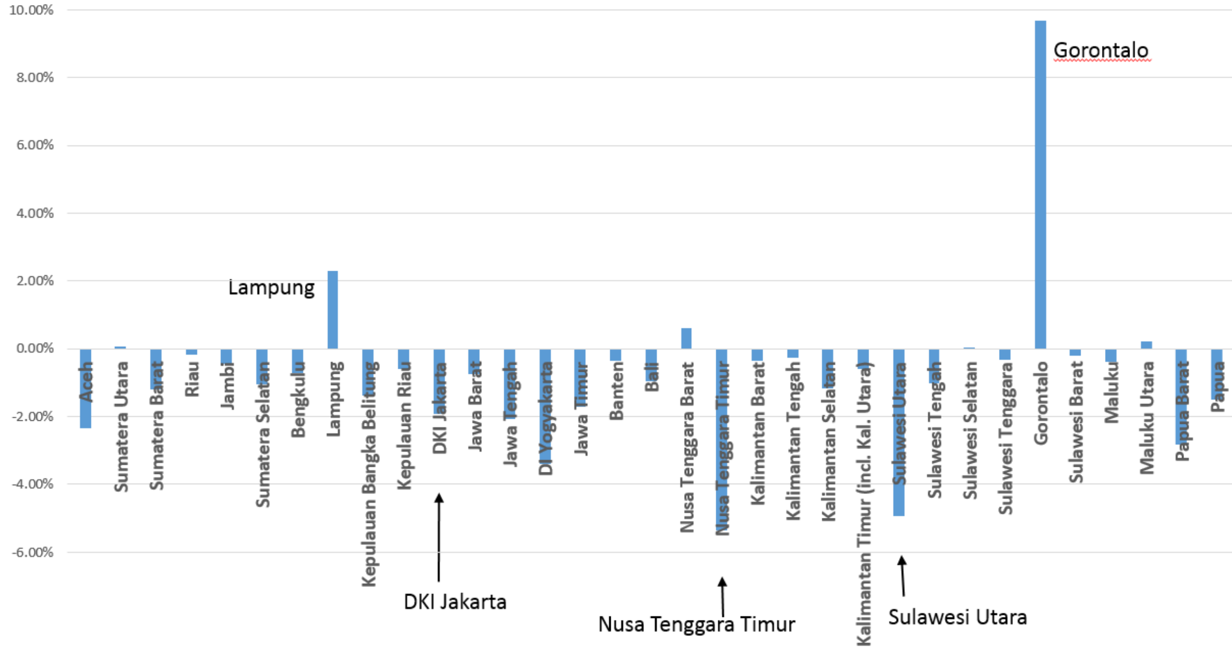


Figure 16. Impact of climate change compared to provincial budget revenues (in percent)

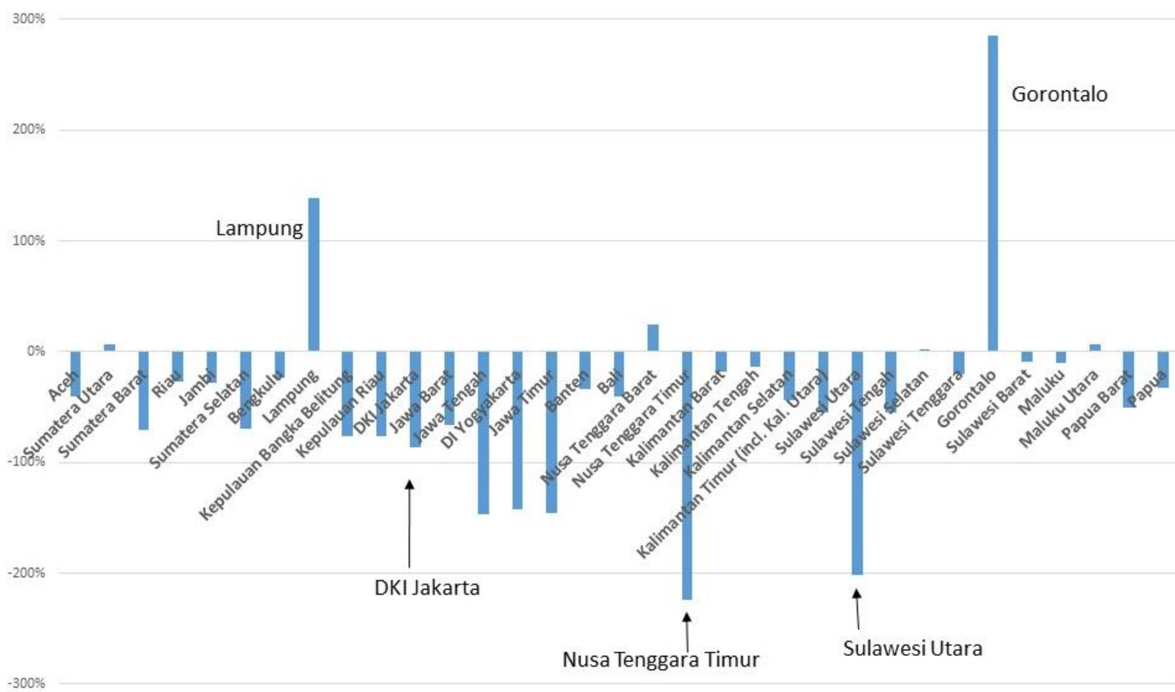


Table 9. Total and per capita monetary impacts of climate change in 2050 by province and area of impact

PROVINCE	TOTALS, IN MILLIONS OF RUPIAHS				PER CAPITA, IN RUPIAHS			
	AGRICULTURE	HEALTH	SEA LEVEL RISE	TOTAL IMPACTS	AGRICULTURE	HEALTH	SEA LEVEL RISE	TOTAL IMPACTS
Aceh	(4,146,927)	(83,323)	(47,302)	(4,277,552)	(576,386)	(11,581)	(6,575)	(594,542)
Sumatera Utara	768,555	(282,393)	(28,872)	457,291	46,706	(17,161)	(1,755)	27,790
Sumatera Barat	(1,654,408)	(579,456)	(7,313)	(2,241,177)	(259,411)	(90,859)	(1,147)	(351,416)
Riau	(223,589)	(1,625,502)	(49,689)	(1,898,780)	(19,863)	(144,401)	(4,414)	(168,678)
Jambi	(154,811)	(629,483)	(38,728)	(823,022)	(33,177)	(134,904)	(8,300)	(176,381)
Sumatera Selatan	(2,995,428)	(730,538)	(63,918)	(3,789,884)	(299,029)	(72,928)	(6,381)	(378,338)
Bengkulu	(149,367)	(260,458)	(131)	(409,956)	(58,687)	(102,335)	(51)	(161,073)
Lampung	5,843,894	(418,434)	(5,265)	5,420,194	634,340	(45,420)	(572)	588,349
Kepulauan Bangka Belitung	41,673	(1,201,633)	(520)	(1,160,480)	18,994	(547,677)	(237)	(528,921)
Kepulauan Riau	(82,798)	(2,019,223)	(54,478)	(2,156,499)	(19,895)	(485,183)	(13,090)	(518,168)
DKI Jakarta	(241,915)	(20,155,714)	(13,844,738)	(34,242,367)	(20,925)	(1,743,414)	(1,197,532)	(2,961,870)
Jawa Barat	(10,844,190)	(339,772)	(1,443,460)	(12,627,421)	(179,261)	(5,617)	(23,861)	(208,739)
Jawa Tengah	(19,340,164)	(17,932)	(153,108)	(19,511,204)	(513,999)	(477)	(4,069)	(518,544)
DI Yogyakarta	(3,685,685)	17,078	(234)	(3,668,841)	(806,565)	3,737	(51)	(802,879)
Jawa Timur	(22,106,786)	(2,444,143)	(711,339)	(25,262,268)	(537,514)	(59,428)	(17,296)	(614,238)
Banten	(1,961,306)	(111,586)	(14,623)	(2,087,515)	(110,417)	(6,282)	(823)	(117,522)
Bali	(1,435,244)	(228,619)	(5,459)	(1,669,322)	(276,985)	(44,121)	(1,053)	(322,159)
Nusa Tenggara Barat	720,110	(126,991)	(10,114)	583,006	118,759	(20,943)	(1,668)	96,148
Nusa Tenggara Timur	(5,138,916)	(211,575)	(1,161)	(5,351,652)	(638,386)	(26,283)	(144)	(664,813)
Kalimantan Barat	385,237	(505,244)	(467,924)	(587,932)	61,896	(81,178)	(75,181)	(94,463)
Kalimantan Tengah	397,654	(769,665)	(4,659)	(376,670)	99,690	(192,951)	(1,168)	(94,429)
Kalimantan Selatan	(1,338,320)	(565,526)	(4,291)	(1,908,137)	(245,911)	(103,913)	(788)	(350,613)
Kalimantan Timur (incl. Kal. Utara)	297,430	(6,586,399)	(42,127)	(6,331,096)	42,333	(937,446)	(5,996)	(901,109)
Sulawesi Utara	(3,512,945)	(650,167)	(2,799)	(4,165,911)	(1,256,385)	(232,528)	(1,001)	(1,489,914)
Sulawesi Tengah	(582,002)	(566,382)	(20,073)	(1,168,457)	(145,992)	(142,074)	(5,035)	(293,101)
Sulawesi Selatan	529,426	(389,726)	(57,032)	82,669	53,512	(39,392)	(5,764)	8,356
Sulawesi Tenggara	(148,653)	(148,383)	(103,783)	(400,819)	(37,157)	(37,090)	(25,942)	(100,189)
Gorontalo	3,112,082	(102,307)	(2,066)	3,007,709	2,019,447	(66,388)	(1,341)	1,951,719
Sulawesi Barat	112,634	(201,766)	(2,419)	(91,551)	54,699	(97,985)	(1,175)	(44,460)
Maluku	(10,902)	(147,431)	(4,842)	(163,175)	(4,320)	(58,415)	(1,918)	(64,653)
Maluku Utara	115,430	(30,135)	(2,724)	82,572	61,047	(15,937)	(1,441)	43,669
Papua Barat	(2,050,554)	(813,674)	(1,998)	(2,866,226)	(1,299,195)	(515,529)	(1,266)	(1,815,989)
Papua	(359,207)	(2,356,322)	(1,055)	(2,716,584)	(79,011)	(518,292)	(232)	(597,535)
Indonesia	**(69,839,993)**	**45,282,822**	**17,198,244**	**132,321,059**	**(215,545)**	**(139,755)**	**(53,078)**	**(408,378)**

5.3 RECOMMENDATIONS

Agriculture, health, and sea level rise are three areas of impact that represent major aspects of the Indonesian economy and society. The five crops studied account for a significant share of the value of food crops, while the two diseases analyzed are those expected to be most affected by climate change. The climate change scenario used is an average of all international climate models for middle-of-the-road assumptions about greenhouse gas emissions. Although this study presents only one projection of the impacts of climate change among many possibilities, and hence is neither comprehensive nor exact, it provides valid insight into the possible future and valuable direction for further analysis.

This study makes several key recommendations:

- In general, the GOI should discuss these results with provincial authorities to inform local planning and budgeting. Climate change will have implications for agriculture, health, infrastructure, and general development in both expenditures and revenues.

- When considering adaptation strategies for these sectors the benefits and costs of various actions should be considered in the context of the costs shown here.

- In each province, policy makers and agriculture interests should look for opportunities to benefit from climate change, encouraging growth of crops that will do well under the new conditions and investing in water control and irrigation infrastructure to take advantage of where rainfall may increase. This study alone may not be sufficient to say that policy makers should immediately encourage corn production in Lampung and Gorontalo provinces, but at both the national and provincial level, understanding where the opportunities will emerge is important, especially given that the climate will not change equally everywhere.

- The responsible authorities should plan now to avoid or alleviate the clear significant negative consequences for Jakarta associated with dengue fever. Similarly, in many provinces the conditions for malaria will worsen and authorities should be planning or initiating programs for this. More research should be carried out on links between disease and climate, including not only of the expected increased incidence but also of the possibility that some changes in climate may actually hinder the spread of certain diseases in some locations. More detailed research on malaria along the lines of the study used to analyze dengue fever would be particularly important.

- Actions against gradual SLR must be chosen carefully: The study shows negative effects of SLR nationwide, but the costs foreseen are almost all incurred in urban areas where property is much more valuable and adaptation will be most costly. Both policy makers and private investors working on shoreline development should be extremely interested in this. It is unlikely that large-scale protective infrastructure would be cost-effective anywhere except possibly in Jakarta or other very large and economically valuable urban areas. Such a cost-benefit analysis was done before the decision was made to build the National Capital Integrated Coastal Development (NCICD) sea wall for Jakarta that is now under construction.

- Extreme storms and weather pose a great economic threat: Analysis of the probability of extreme storms in different parts of the country would be very valuable in identifying the costs they will impose and setting priorities for investments in adaptation. To the extent that the fields of climatology and oceanography can shed light on this issue, investments in further research will be essential. Policy makers must order more detailed analysis of the impacts of extreme storms on large urban areas, particularly Jakarta. In particular, work that can consider the macroeconomic or multiplier implications of the loss of key urban infrastructure will be essential to set priorities for investments in adaptation or strategies to minimize the harm caused by such storms. The private sector must anticipate these problems as well; every company whose business relies on transportation through the harbor or airport should create plans for continuity of its operations in the face of such extreme storms.

- To identify optimal implementable policy responses much more information is needed on certain aspects. In particular, more work is crucial on links between climate change and agricultural yields given the huge monetary impacts involved. The wide range of impacts on agriculture found here are dependent on a single piece of research. It is essential for Indonesia to invest in more research on links between climate and agriculture, considering a wider range of crops and more areas of the country. Moreover, the research and this study point to the varying effects in different locations; a more comprehensive understanding of this geographic variation across this vast country would be valuable to design provincial or local adaptation responses.

- Work on the probability of extreme storms and the costs they would impose in different parts of the country is also very important, particularly the macroeconomic implications of flooding on nationally important transportation infrastructure in Jakarta. More generally, flooding and drought have direct costs and multiplier effects throughout the economy and these should be studied.

- Indonesia cannot wait until 2050 to act: This study projects the situation in 2050 in specific areas of impact under specific parameters. As climate change is gradual, it may be assumed that the conditions described for 2050 will evolve between now and then, and that Indonesia will increasingly and inexorably experience the costs and benefits each year. This means that policy makers should not wait until the future to implement changes that either lessen or take advantage of the impacts.

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