

Climate Change in Indonesia: Implications for Humans and Nature



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Climate Change in Indonesia

Implications for Humans and Nature

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Summary

Observed Climate Change (Hulme and Sheard, 1999; Boer and Faqih, 2004)

- Mean annual temperature has increased by about 0.3°C in Indonesia
- Overall annual precipitation has decreased by 2 to 3% in Indonesia
- Precipitation patterns have changed; there has been a decline in annual rainfall in the southern regions of Indonesia and an increase in precipitation in the northern regions
- The seasonality of precipitation (wet and dry seasons) has changed; the wet season rainfall in the southern region of Indonesia has increased while the dry season rainfall in the northern region has decreased

Projected Climate Change (Hulme and Sheard, 1999; Boer and Faqih, 2004; Naylor et al., 2007)

- Warming from 0.2 to 0.3°C per decade in Indonesia
- Increase in annual precipitation across the majority of the Indonesian islands, except in southern Indonesia where it is projected to decline by up to 15 percent
- Change in the seasonality of precipitation; parts of Sumatra and Borneo may become 10 to 30% wetter by the 2080's during December-February; Jakarta is projected to become 5 to 15% drier during June-August
- 30-day delay in the annual monsoon, 10% increase in rainfall later in the crop year (April-June), and up to 75% decrease in rainfall later in the dry season (July-September)

Impacts:

Water Availability

- Decreased rainfall during critical times of the year may translate into high drought risk, uncertain water availability, and consequently, uncertain ability to produce agricultural goods, economic instability, and drastically more undernourished people, hindering progress against poverty and food insecurity (Wang et al., 2006)
- Increased rainfall during already wet times of the year may lead to high flood risk, such as, the Jakarta flood on 2 February 2007 that inundated 70,000 houses, displaced 420,440 people and killed 69 people with losses of Rp 4.1 trillion (US\$ 450 million) (WHO, 2007)
- Stronger, more frequent El Niño events will exacerbate drying and/or flooding trends and could lead to decreased food production and increased hunger
- Delayed wet season (monsoon) and a temperature increase beyond 2.5°C is projected to substantially drop rice yields and incur a loss in farm-level net revenue of 9 to 25% (Lal, 2007)

Sea-level rise

- Currently increasing at 1-3 mm/year in coastal areas of Asia and is projected to accelerate to a rate of about 5 mm per year over the next century (Cruz et al., 2007)
- Increase from 13 million to 94 million people flooded annually in South Asia (under very conservative sea-level rise scenarios - 40cm by 2100) (Wassmann et al., 2004)
- 1 million at risk from flooding and sea-water intrusion due to sea-level rise and declining dry-season precipitation, negatively impacting the aquaculture industry (e.g.,

fish and prawn industries) and infrastructure along the coasts of South and South-East Asia, (Cruz et al., 2007)

Biodiversity and Ecosystem Services

- Up to 50% of Asia's total biodiversity is at risk (Cruz et al., 2007)
- 88% loss of coral reefs in Asia in the next 30 years because of warming sea-surface temperatures, sea level rise, and other added stresses (Wilkinson, 2004)
- Significant declines in fish larvae abundance and large-scale changes in fish habitat, such as skipjack tuna, are projected in the equatorial Pacific (Cruz et al., 2007; Loukos et al., 2003)
- Massive coral bleaching leading to widespread loss of coral reefs and biodiversity, including the fish that many Indonesians rely on for food and livelihoods
- Sea-level rise, increased extreme weather events, warming temperatures, and changes in ocean circulation and salinity patterns impacting Indonesia's marine turtle populations (WWF, 2007a)
- More frequent forest fires having significant impacts on wildlife habitat and biodiversity and translating into serious economic and domestic and trans-boundary pollution consequences - the economic costs of the droughts and fires in 1997-1998 were about US\$ 9 billion (Applegate et al., 2002)
- Sea-level rise, reduced freshwater flows, and salt-water intrusion, in addition to the existing stresses primarily due to human activities threaten Indonesia's coastal mangroves (Tran et al., 2005)
- Changes in species distribution, reproduction timings, and phenology of plants (Cruz et al., 2005)

Human Health

- More frequent and severe heat waves, floods, extreme weather events, and prolonged droughts leading to increased injury, illness, and death
- Increased vector-borne infections (e.g., malaria and dengue), an expansion of water-borne diseases, such as diarrhea, an increase in infectious diseases, poor nutrition due to food production disruption, ill-health due to social dislocation and migration, and increased respiratory effects from worsening air pollution and burning
- Increased diarrhoeal disease and endemic morbidity and mortality (Checkley et al., 2000)
- Rise in severe respiratory problems following an increase in the frequency and spread of wildfires that release toxic gases such as carbon monoxide, ozone, nitrogen dioxide and hydrocarbons
- A rise in the number of dengue fever cases during the rainy season (PEACE, 2007)
- More phytoplankton blooms, providing habitats for survival and spread of infectious bacterial diseases, such as, cholera (Pascual et al., 2002)
- Increased water-borne diseases such as cholera and diarrhoeal diseases (e.g., Giardia, Salmonella, and Cryptosporidium) (McMichael et al., 2003)

Vulnerability and Adaptation

- Water availability and food production are highly sensitive and vulnerable sectors to changes in temperature and precipitation include (Cruz et al., 2007)
- Prolonged droughts, increased flooding, and more frequent and severe storms may lead to major agricultural losses and a substantial drop in food productivity
- Increased frequency and severity of El Niño events and fires will impact food production and will the ability of natural systems to provide ecosystem services
- Warming ocean temperatures, sea-level rise, and increased storms will impact coastal systems by increasing coral bleaching events, changes in fish availability, inundation of coast lines and mangroves, and exacerbating risks to human health affecting millions of people
- The following can enhance social capital and reduce the vulnerability to climate



change:

- Increase education and technical skills
- Increase income levels
- Improve public food distribution
- Improve disaster preparedness and management and health care systems
- More integrated agro-ecosystems
- Increased water storage, water efficiency and re-prioritizing current water use
- Investment in drought-tolerant and salt-tolerant crops
- Crop diversification
- Better early El Niño warning systems
- Sustainable management of coastal zones
- Conservation of mangroves
- Reducing deforestation and protection of forests

Preface

Indonesia is the fourth most populous nation and a significant emitter of greenhouse gases due to deforestation and land-use change (WRI, 2005). Indonesia consists of nearly two million square km of land, most of which is covered by forests. However, deforestation and land-use change is estimated at 2 million hectares (ha) per year and accounts for 85% of the Indonesia's annual greenhouse gas emissions (WRI, 2002). Indonesia's forested land also supports extremely high levels of biodiversity, which in turn, support a diverse array of livelihoods and ecosystem services. The combination of high population density and high levels of biodiversity together with a staggering 80,000 km of coastline and 17,508 islands, makes Indonesia one of the most vulnerable countries to the impacts of climate change.

Spanning both sides of the equator, Indonesia has a tropical climate, with two distinct seasons; monsoon wet and dry. The rainy season is usually from November to April, with some regional variations. Jakarta, the national capitol, has the heaviest rainfall from January to February. Average annual rainfall varies greatly with the lowlands receiving about 1.7 to 3.1 cm and the mountainous regions getting up to 6.1 cm. Average annual temperature is less variable and ranges from 23–32 °C (University of Indonesia, 2007).

Because of Indonesia's geography, topography, and climate, Indonesia hosts a wide array of diverse ecosystems from sea and coastal systems to peat swamp forests to montane forests. Subsequently, Indonesia has extremely high levels of biodiversity; possessing about 10 percent of the world's flowering plant species, 12 percent of the world's mammals, 16 percent of the world's reptile and amphibian species, 17 percent of the world's birds, and at least 25 percent of all the world's fish species. In fact, the islands of Borneo and Sumatra are home to the last remaining Sumatran tigers, orangutans, pygmy elephants and Sumatran rhinos and are a key source of freshwater to Borneo and Sumatra's 56 million people. Indonesian's seas cover more than 33,000 million hectares (ha), contain some 450 species of coral, and support one of the world's largest varieties of reef fish, as well

as commercial and community fisheries.

Indonesia's economy is heavily dependent on these natural ecosystems and their resources but there are threats to their sustainability. Current threats include Indonesia's increasing population and rapid industrialization, such as large-scale deforestation and wildfires, land conversion and habitat destruction, over-exploitation of marine resources, and a multitude of environmental problems associated with rapid urbanization and economic development and now climate change. Climate change threatens not only to exacerbate the aforementioned issues, but also create new ones, some of which are already taking place.

Observed climate change

While the overall observed surface air temperature in Asia has increased by approximately 1-3°C over the last century, the Intergovernmental Panel on Climate Change (IPCC) suggests that reliable historic temperature data in Indonesia is not available (Cruz et al., 2007). However, Hulme and Sheard (1999), find that Indonesia has become warmer since 1900 and that the annual mean temperature has increased by about 0.3°C (Figure 1). Annual precipitation overall has decreased by two to three percent across all of Indonesia over the last century (Figure 1). However, there is significant spatial variability; there has been a decline in annual rainfall in the southern regions of Indonesia (e.g., Java, Lampung, South Sumatra, South Sulawesi, and Nusa Tenggara) and an increase in precipitation in the northern regions of Indonesia (e.g., most of Kalimantan, North Sulawesi) (Boer and Faqih, 2004). There has also been a shift in the seasonality of precipitation (wet and dry seasons); in the southern region of Indonesia the wet season rainfall has increased while the dry season rainfall has decreased, whereas the opposite pattern was observed in the northern region of Indonesia (Boer and Faqih, 2004). It should be noted that precipitation in Indonesia (and many parts of the world) is strongly influenced by El Niño/Southern Oscillation (ENSO) events and that some researchers suggest that there will be more frequent and perhaps intense ENSO events in the future because of the warming global climate (Tsonis et al., 2005).

Because Indonesia typically experiences droughts during El Niño events (the warm phase of ENSO) and excessive rain during La Niña events (cool phase of ENSO), this global pattern will have regional impacts.

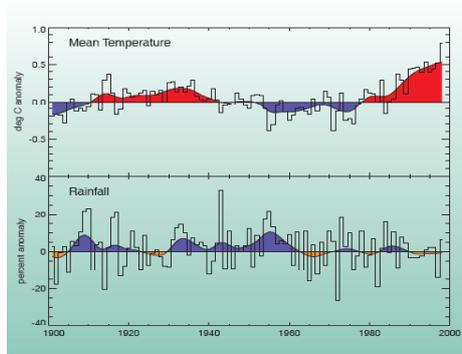


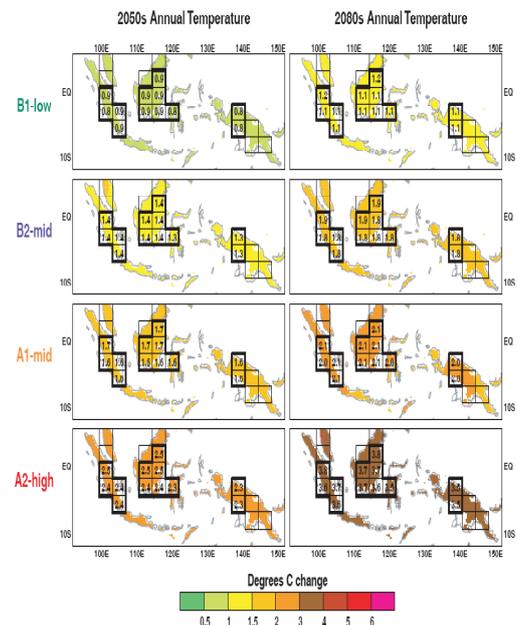
Figure 1. Changes in annual mean temperature, 1901-1998 (top), and annual rainfall, 1901-1998 (bottom), across Indonesia. Adapted from Hulme and Sheard (1999), Figure 1.

Projected Climate Change

Temperature and precipitation are both projected to increase in the future over all of Southeast Asia, including Indonesia. Under IPCC scenarios, it is projected that temperature may warm anywhere from 0.72 to 3.92°C and precipitation may decrease by two percent or increase by up to twelve percent the end of the century (Cruz et al., 2007). Downscaled modeling specific for Indonesia projects that the rate of warming will rise relatively uniformly across all of Indonesia from about 0.1 to 0.3°C per decade for the next 100 years (Figure 2A) (Hulme and Sheard, 1999). A more recent study suggests that the rate of warming for Indonesia will be slightly greater from 0.2 to 0.3°C per decade (Boer and Faqih, 2004). Modeled precipitation changes are not as uniform; it is projected that annual rainfall will increase across the majority of the Indonesian islands, with the possible exception of southern Indonesia (including Java), where it is projected to decline by up to 15 percent (Figure 2B) (Hulme and Sheard, 1999). However, there is considerable variance in rainfall for different climate models, regions of Indonesia, and times of the years. For example, during the December-February season, parts of

Sumatra and Borneo become 10 to 30 percent wetter by the 2080's. In contrast, rainfall changes during the June-August season are generally negative; Jakarta for example, is projected to become 5 to 15 percent drier depending on the emissions scenario (Hulme and Sheard, 1999). Changes in the timing and seasonality of rainfall is also projected to change; a recent analysis suggests that there is an increased likelihood that the annual monsoon could be delayed by 30 days because of changes in regional climate and there may be a 10% increase in rainfall later in the crop year (April-June), but a substantial decrease (up to 75%) in rainfall later in the dry season (July-September) (Naylor et al., 2007). Consequently, regions of Indonesia with decreasing rainfall might be exposed to high drought risk, while those with increasing rainfall might be exposed to high flood risk and the frequency of extreme events might increase (Boer and Faqih, 2004).

(a)



(b)

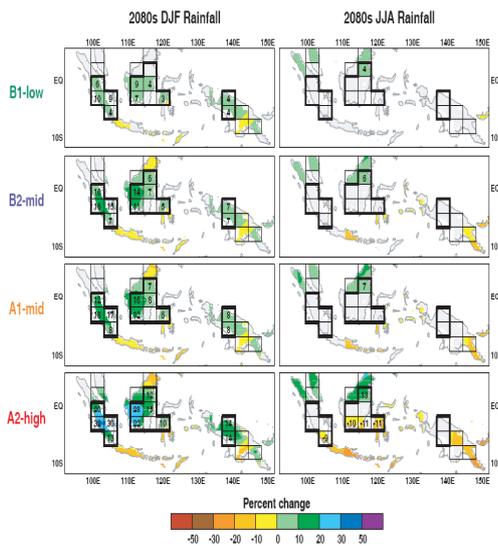


Figure 2. Change in mean annual temperature (deg Celsius from the average 1961-90 climate) for the 30-year periods centered on the 2050s and 2080s for four IPCC emissions scenarios. The printed numbers show the estimated change for each model land gridbox over Indonesia. Changes are only shown where they are large in relation to simulated natural temperature variability on 30-year time-scales. Adapted from Hulme and Sheard, 1999.

Impacts

Impacts of observed changes in climate are already evident in Indonesia and will likely worsen due to further human-induced climate change. Rising concentrations of greenhouse gases will continue to raise the surface and ocean temperatures, change precipitation patterns, increase sea levels, and cause various other impacts from more frequent forest fires to increased health risks. Climate change will also continue to affect “natural” climate variability, such as El Niño, and may lead to more frequent and more intense weather events. Highlighted below are some of these projected climate impacts in Indonesia.

I. Changes in Water and Food Availability

Precipitation in parts of Indonesia has decreased and is projected to continue to decrease during critical times of the year (i.e., during the dry season) and can lead to prolonged droughts. In other areas of Indonesia, it is projected that rainfall will increase and may occur in fewer, more intense events which could lead to flooding. Events such as this can be disastrous, for example, the Jakarta flood on 2 February 2007 affected 80 districts in Jakarta, causing traffic chaos and paralyzing the city. More than 70,000 houses were inundated with water levels ranging from 10cm to 5m and 69 people were killed and an estimated 420,440 people were displaced. The Indonesian government estimates that losses amount to Rp 4.1 trillion (US\$ 450 million) (WHO, 2007). These types of trends (drying in parts and flooding in some areas), combined with an overall shift of the seasonality and timing of rainfall will lead to unpredictable and uncertain water availability and consequently, uncertain ability to produce agricultural goods and economic instability. Climate change-induced food production losses could drastically increase the number of undernourished people and hinder progress against poverty and food insecurity (Wang et al., 2006).

Indonesia is strongly influenced by ENSO cycles (e.g., El Niño typically results in widespread droughts and La Niña results in flooding in Indonesia), which could exacerbate drying and/or flooding trends.

The El Niño-induced droughts of 1997-1998 caused massive crop failures, water shortages, and forest fires in parts of Indonesia and if climate model projections of stronger, more frequent El Niño events materialize (Tsonis et al., 2005), Indonesia may experience even more adverse impacts, including less food production and increased hunger. For example, a recent study that looked at

A temperature increase beyond 2.5°C and the resulting drop in rice yield would incur a loss in farm-level net revenue of 9 to 25% (Lal, 2007).

II. Sea-level Rise

Global sea-level rise is currently increasing at about 2 mm per year (1-3 mm/year in coastal areas of Asia) and is

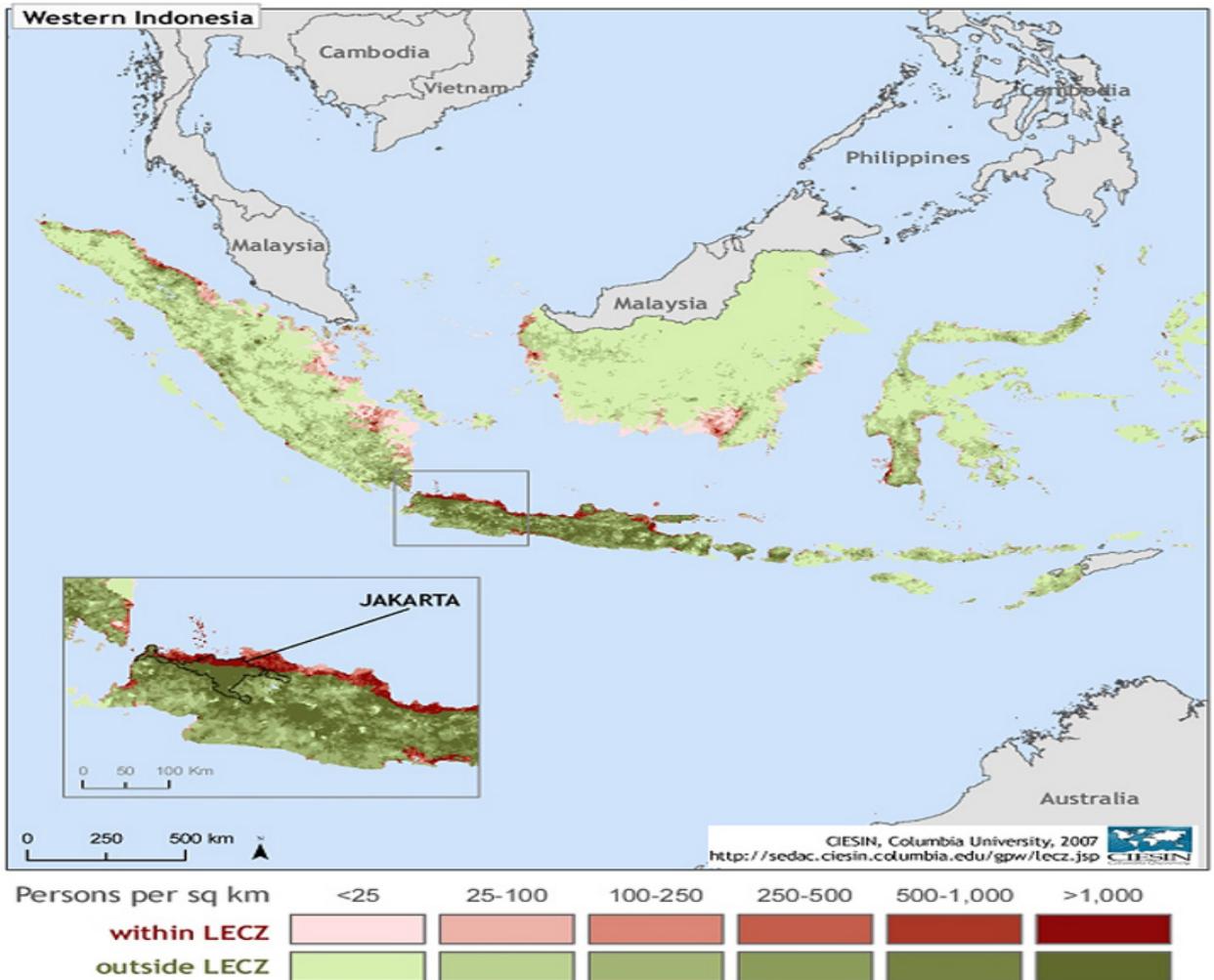


Figure 3. Population density within and outside of a 10 meter low elevation coastal zone, 2000. Adapted from CIESIN, Columbia University, 2007, Available online <http://sedac.ciesin.columbia.edu/gpw/lecz.jsp>.

assessing the risks of climate change on Indonesia rice production suggests that under future climate projections, there is a significant 30-day delay in the onset of monsoon season and a substantial decrease in precipitation later in the dry season (Naylor et al., 2007), which when combined with temperature increases of up to 4°C (for every 1°C increase in minimum temperature, rice yields decrease by 10%; Peng et al., 2004), will lead to massive drops in rice production.

projected to accelerate to a rate of about 5 mm per year over the next century (Cruz et al., 2007). A change of this magnitude will undoubtedly result in significant losses of Indonesia's 80,000 km of coastline and thousands of islands and the associated marine resources (e.g., coral reefs, fisheries, mangroves, etc.) Under very conservative sea-level rise scenarios (40cm by 2100), the annual number of people flooded in coastal populations will increase from 13 million to 94

million in South Asia (Wassmann et al., 2004). Additionally, a million or so people along the coasts of South and South-East Asia will

all Indonesians live in coastal areas and low-lying coastal cities like Jakarta and Surabaya. Sea-level rise when combined

climate change and orangutans

Chairul Saleh, WWF-Indonesia

Orangutans require vast amounts of habitat to live and breed; their home range can cover areas up to 9000 Ha. In Gunung Leuser National Park, South Aceh, an adult male has a home range about 2500 Ha (Singleton dan van Schaik, 2001). Orangutans are critically dependent on their forested habitat, especially the trees and lianas (vines), which produce fruits throughout the year (Meijaard et al., 2001). For orangutans, good habitat is defined as a large, intact forest with trees that produce nutrient-rich (30–50% nutrients) fruits. The number of trees that produce fruit vary with the season (wet versus dry season), for example, in Indonesian peat swamp forests, there are at least 40 species of trees that produce fruit during the wet season and at least 60 species that produce fruit during the dry season.



Warming temperatures and changes in precipitation and seasonality will have negative impacts on orangutans by affecting the phenology of fruit trees. Climate modeling done for the Central Kalimantan region projects that precipitation will increase by 70% by year 2025 (Suhud and Saleh, 2007). Changes in the onset and duration of seasons will also likely affect the availability of orangutan food resources. For example, a longer dry season will reduce the abundance of fruits and will negatively impact orangutan populations because females are more likely to conceive during periods when food resources are not limited. The El Niño event of 1997-98, which manifested in hot, dry weather and drought in Indonesia, had a massive impact on the phenology of trees in the Kayan Mentarang National Park, East Kalimantan (Wulffraat, Tatenkeng, and Salo, 2006). More specifically, during the El Niño event, fruit was very abundant and reached a peak in January-March 1998, but then fruit productivity plummeted and remained low during 1999 and 2000, with massive impacts to many animals in the park.

Climate change-induced fire will also negatively impact orangutan populations by fragmenting their habitat and reducing the number of fruit bearing trees, which can take many years to mature and fruit (Hulme and Sheard, 1999). For example, following the El Niño event of 1997-98, widespread drought (compounded by logging), led to massive wildfires and resulted in the burning of millions of hectares, including orangutan habitat. An estimated 1,000 out of 40,000 total orangutans (2.5%) died from these severe fires in 1997. Using this data, it is predicted that severe El Niño events, such as the 1997-98 event, would kill an average 3.5% of orangutans per episode, while less severe El Niño events would kill about 1% (Singleton et al., 2004).

There are about 5400 orangutans in the Sabangau National Park in Central Kalimantan (Ancrenas, 2007), and while this is one of the most viable orangutan populations in Central Kalimantan (Singleton et al., 2004), they are also one of the most threatened by climate change. Fire is a major threat to the peat swamp forests of Sabangau and has recently been exacerbated by El Niño-caused drought and excessive human-induced drainage. During 1997, 12% of the core forest cover in the Sebangau-Katingan catchment area was burned (Morrogh-Bernard et al., 2003) and in the last ten years periods (1997-2006), based on the hot spot data, Central Kalimantan province is top on the list as the areas with the highest fire intensity and largest fire size in all of Indonesia (Suhud and Saleh, 2007).

Photo © WWF-Canon / Alain Compost

likely be at risk from flooding and sea-water intrusion due to sea-level rise and declining dry-season precipitation, which will seriously affect the aquaculture industry (e.g., fish and prawn industries) and infrastructure in the region (Cruz et al., 2007). Even moderate sea-level rise will result in significant physical and socio-economic impacts because much of Indonesia's population, industries infrastructure, and most fertile agricultural lands are concentrated in low-lying coastal areas (Figure 3). Approximately 60% of

with the present subsidence or sinking that is being observed in Jakarta Bay will result in massive impacts on infrastructure and businesses. Groundwater near the coasts is also at risk due to saltwater intrusion, a result of higher sea levels, over-extraction of the resource (resulting in lower groundwater levels), and recharge with more saline surface waters. Further climate warming may also lead to more intense tropical cyclones (Emanuel, 2005), putting more people at risk and increasing damage losses.

III. Warming Sea-surface Temperatures

The loss of coral reefs in Asia may be as high as 88% in the next 30 years because of warming sea-surface temperatures, sea level rise, and other added stresses (Wilkinson, 2004). Evidence of this occurring in the future is represented by the 1997/98 El Niño event, in which over 34% of Asia's coral reefs were reported to have been lost primarily due to coral bleaching in response to high sea-surface temperatures. This particularly strong El Niño event may represent the future as sea-surface temperatures continue to warm, major bleaching events become more common, and the ability of corals to calcify is reduced due to increased acidification. Unfortunately, many coral reefs in the region are already in poor condition and the destructive effects of climate change compound these existing stresses.

Warming sea-surface temperatures are also causing changes in oceanic circulation patterns and salinity and are likely leading to a reduction of primary production in tropical oceans with cascading effects. And because the Asia-Pacific region is the world's largest producer of fish (e.g., one-fourth of the world's tuna catch is from East and South-East Asia), the region has a lot to lose. Projected climate models indicate that there could be large-scale changes in fish habitat, such as skipjack tuna, in the equatorial Pacific because of regional warming (Loukos et al., 2003). Additionally, if El Niño events become more frequent as predicted in a warmer world (Tsonis et al. 2005), there could be significant declines in fish larvae abundance in the coastal waters of South and South-East Asia (Cruz et al., 2007). Freshwater fish may also be affected by climate change because of changes in the timing and amount of precipitation could affect migration, spawning, dispersal, and growth (FAO, 2003, Ficke et al., 2007). Continued climate change and the resulting changes in fish habitat will impact the food supply for fish and ultimately the abundance of fish populations in Asia (Cruz et al., 2007). Because of these impacts, Indonesia may find it increasingly difficult to meet future food demand and may experience economic losses.

III. Biodiversity and Ecosystem Services

Asia's biodiversity, and hence the ecosystem services that they provide, are at risk due to climate change. The IPCC states that up to 50% of Asia's total biodiversity is at risk, specifically due to climate change (Cruz et al., 2007). Climate change poses an additional risk to coral reefs, especially those whose habitats are already threatened. Coral reefs located in areas with higher human population densities, such as in western Indonesia, are negatively affected at a greater rate when compared to coral reefs located in areas with low human population densities. Massive coral bleaching and warming sea-surface temperatures can lead to widespread loss of coral reefs, and substantial loss of biodiversity, including the fish that many Indonesians rely on for food and livelihoods. Sea-level rise, increased extreme weather events, warming temperatures, and changes in ocean circulation and salinity patterns may impact Indonesia's marine turtle populations (WWF, 2007a).

Indonesia contains some of the world's most endangered species (e.g., Proboscis Monkey (*Nasalis larvatus*), Javan Rhinoceros (*Rhinoceros sondaicus*), Sumatran Rhinoceros (*Dicerorhinus sumatrensis*), Komodo dragon (*Varanus komodoensis*), and the Sumatran and Bornean Orangutan (*Pongo abelii* and *P. pygmaeus*, respectively), and therefore Indonesia's biodiversity is especially threatened by the effects of climate change. For example, the island of Borneo is home to a number of biologically important wildlife species including orangutans (see box below).

Over the last 20 years, temperature rise, precipitation changes, and land-uses change, have lead to an increase in the intensity of forest fires and area burned in South-East Asia (Cruz et al., 2007). In Indonesia, the 1997-98 El Niño caused 9.7 million ha of forest to burn and had serious economic and domestic and trans-boundary pollution consequences. It is estimated that the economic costs of the droughts and fires in 1997-1998 were about US\$ 9 billion (Applegate et al., 2002). During the same El Niño event in Indonesian, over 2 million ha of peat swamp forests burned (Page et al., 2002). In the past 10 years

about 3 million ha of peat swamp forests in South-East have been burnt, while draining of peat swamp forests has affected an additional 6 million ha (Cruz et al., 2007). Peat swamp forests can hold about 30 times as much carbon compared to the above ground carbon storage in tropical rainforests. However, disturbances, such as, fires and land-use change can release stored carbon into the atmosphere, thereby causing a positive feedback of increased warming and additional fires. Increased frequency and intensity of fires will have both negative and positive impacts on wildlife habitat quality and biodiversity by modifying forest structure and composition. Structural and compositional changes will provide opportunities for some species to invade while reducing the competitiveness and habitat for other species.

Indonesia's coastal mangroves are also threatened by sea-level rise, reduced freshwater flows, and salt-water intrusion, in addition to the existing stresses primarily due to human activities (e.g., cutting and clearing of mangrove forests for agriculture). According to a recent study, a substantial portion of South and South-East Asian mangroves have already been lost during the past 50 years because of human activities (Zafar, 2005) and projections of sea-level rise illustrate that the future of the region's mangroves is questionable (Tran et al., 2005).

Other climate change impacts to Indonesian biodiversity include the effect that changing precipitation patterns and altered seasonality may have on water availability (i.e., prolonged droughts and more intense flooding), which could affect amphibians, reptiles, birds, and large animals, such as the Javan and Sumatran rhinoceros, Asian elephant (*Elephas maximus*), Sumatran flying squirrel (*Hylopetes winstoni*), Bawean deer (*Axis kuhlii*), Javan warty pig (*Sus verrucosus*), and other various monkeys and small mammals. Changes in species distribution, reproduction timings, and phenology of plants will also impact Indonesia's biodiversity.

IV. Human Health

Human health in Indonesia will be adversely affected by climate change and its associated effects both directly (e.g.,

deaths due to heat waves, floods, and storms) and indirectly (e.g., increases in infections and diseases and less available food). Direct effects, such as higher temperatures, changes in precipitation and sea-level rise can cause more frequent and severe heat waves, floods, extreme weather events, and prolonged droughts and lead to increased injury, illness, and death. Indirect effects, which are more difficult to attribute to climate change, may include more widespread vector-borne infections (e.g., malaria and dengue), an expansion of water-borne diseases, such as diarrhea, an increase in infectious diseases, poor nutrition due to food production disruption, ill-health due to social dislocation and migration, and increased respiratory effects from worsening air pollution and burning. Rising temperatures can compound the effects of poverty and poor hygiene on bacterial proliferation, leading to diarrhoeal disease and endemic morbidity and mortality (Checkley et al., 2000). Numerous studies have documented the link between climate-related factors such as, severe floods, ENSO-induced droughts, warm sea-surface temperatures (among other non-climatic factors) with diarrhoeal diseases and outbreaks of other infectious diseases, such as, cholera, hepatitis, malaria, and dengue fever (Durkin et al., 1993; Akhtar and McMichael, 1996; Bouma and van der Kaay, 1996; Colwell, 1996; Bangs and Subianto, 1999; Lobitz et al., 2000; Pascual et al., 2000; Bouma and Pascual, 2001; Glantz, 2001; Pascual et al., 2002; Rodo et al., 2002). It is therefore predicted that because more floods and droughts are expected in South-East Asia, that there will be increases in endemic morbidity and mortality due to diarrhoeal diseases (Cruz et al., 2007). Additionally, due to Indonesia's expanding urban population in cities like Jakarta and the limited public health capacity, increases in extreme events (i.e., heat waves and flooding) will undoubtedly impact Indonesia's poor population.

A rise in severe respiratory problems following an increase in the frequency and spread of wildfires that release toxic gases such as carbon monoxide, ozone, nitrogen dioxide and hydrocarbons will likely get worse in Indonesia. Specifically, air quality in newly industrialized areas, such as Jakarta,

has deteriorated significantly and will likely contribute to widespread heat stress and smog induced cardiovascular and respiratory illnesses (Patz et al., 2000). For example, during the 1997-98 El Niño event malaria spread to higher elevations in Indonesia (i.e., the highlands of Irian Jaya) (Epstein et al., 1998). And a recent rise in the number of dengue fever cases during the rainy season in Indonesia may be caused by warming temperatures and changes in precipitation patterns (PEACE, 2007).

Other health issues that may be influenced by climate change include some infectious diseases, such as, cholera. Warming tropical sea-surface temperatures near Indonesia may support higher phytoplankton blooms which could provide excellent habitats for survival and spread of infectious bacterial diseases, such as, cholera (Pascual et al., 2002). Changes in precipitation, increased flooding, and sea-level rise could also degrade freshwater quality and potentially contaminate drinking water. Water-borne diseases such as cholera and a suite of diarrhoeal diseases (e.g., *Giardia*, *Salmonella*, and *Cryptosporidium*) may be more common in the region (McMichael et al., 2003).

Vulnerability and Adaptation

Indonesia is highly vulnerable to climate change and must take mitigation action now in order to prevent massive impacts. While efforts to limit the rate and extent of climate change to prevent dangerous climate change (i.e., a temperature increase of 2°C above pre-industrial levels [WWF, 2007b]) continue to be urgently needed, so too are effective ways to build resilience or enhance our ability to adapt to climate change, particularly in the world's most fragile ecosystems and vulnerable human communities. As a recent review on assessing the economic costs of the impacts of climate change and the costs and benefits of action versus inaction pointedly makes, "the benefits of strong, early action on climate change outweigh the costs" (Stern, 2006). Further, the balance between mitigation of greenhouse gases, the costs, and the climate risks of delay should involve an iterative risk management process that considers adaptation, actual

and avoided climate change damages, co-benefits, sustainability, equity, and attitudes to risk (IPCC, 2007). Sectors that are highly vulnerable and sensitive to changes in temperature and precipitation include water availability and food production, according to the IPCC (Cruz et al., 2007). Rising temperature, changes in precipitation (i.e., prolonged droughts and increased flooding), and more frequent and severe storms may lead to major agricultural losses and a substantial drop in productivity. Increased frequency and severity of El Niño events will lead to more frequent and longer droughts, which increase the likelihood of fires. This increased risk of fires may significantly affect Indonesia's ability to produce food, and will affect the ability of natural systems to provide ecosystem services. Warming ocean temperatures, sea-level rise, and increased storms will undoubtedly affect coastal systems by increasing coral bleaching events, changes in fish availability, inundation of coast lines and mangroves, and potential risks to human health. These effects could impact millions of people that rely on coral reefs and coasts for protection, subsistence, livelihoods, transportation, and ecosystem services.

In order to cope with the impacts that are already inevitable, adaptation should be employed as soon as possible and the IPCC has suggested the following to enhance social capital and reduce the vulnerability to climate change: increase education and technical skills, increase income levels, improve public food distribution, and improve disaster preparedness and management and health care systems through sustainable and equitable development (Cruz et al., 2007). For Indonesia, adaptation measures that address sea-level rise, increased extreme weather, and threats to ecosystems and biodiversity should be a high priority. More specifically, more sustainable management options, such as more integrated agro-ecosystems, could likely improve land conditions and reduce pressures from climate change impacts (Cruz et al., 2007). Increased water storage and an investment in both drought-tolerant and salt-tolerant crops, crop diversification, and better early El Niño warning systems could also help Indonesians adapt to climate change (Naylor et al., 2007). In parts of Indonesia where water resources

are already under stress from growing water demands and inefficiencies in water use, managers may consider increased water efficiency and perhaps re-prioritizing current water use (Manton et al., 2001). The long-term effects of sea-level rise demands that Indonesia considers the effects of 1,000-year storm-surges and, in response, provide substantial protection of current socio-economic activities and populations (Cruz et al., 2007). Sustainable management of coastal zones through Integrated Coastal Zone Management (ICZM) could also provide effective coastal protection and maximize the benefits provided by coastal zones (World Bank, 2002). Conservation of mangroves can also help protect against storm surges, coastal erosion and strong wave actions as demonstrated by the Indian Ocean tsunami of 26 December 2004 and 2005 hurricane season in the Gulf of Mexico (UNEP-WCMC, 2006). Improvement in the protection from deforestation, fires, insects and diseases could significantly reduce the vulnerability to climate change of Indonesia's forests. Adaptation and mitigation of greenhouse gases can also be closely linked, for example, forest-related mitigation activities can significantly reduce carbon emissions and increase carbon sinks at relatively low costs and can be designed to create synergies with adaptation and sustainable development

While there are multiple issues that may hinder adaptation in Indonesia, such as poverty, insufficient information and knowledge on climate impacts and limited information on the costs and benefits of adaptation, WWF-Indonesia has already begun implementing some adaptation strategies and will be scaling up their efforts in the next few years. Below are a number of current adaptation activities that WWF-Indonesia is working on:

- Contributing to the development of a national adaptation strategy;
- Established a network of coral reef monitoring and warning system referred to as "Friends of the Reef", which is strengthening the livelihoods of coastal communities in Bali Barat National Park;
- Assessing climate change effects on orangutans and their habitat;
- Mainstreaming adaptation strategies

into small island sustainable development in Lombok, Nusa Tenggara;

- Integrating adaptation into community-based disaster risk management in Indonesia;
- Promoting sustainable forest and peat swamp forest management and adaptation-mitigation in Riau, West and Central Kalimantan
- Conducting a thorough climate change impacts and vulnerability assessment for key watersheds in West Java and West Kalimantan;

Conclusion

The world is now facing the greatest environmental challenge humanity has ever known, and the next few years is our last best chance to keep the extent of climate change and our vulnerability to its effects within manageable bounds. We are likely committed to a 1.6°C increase in global average temperature above pre-industrial levels and if we allow the increase to reach 2°C, we likely face irreversible effects with decreasingly effective and increasingly expensive adaptation options. Munich Re, one of the world's largest reinsurers, predicts that the annual cost of climate change-related claims could reach US\$300 billion annually by 2050 (Cruz et al., 2007).

The challenge for Indonesia is to create appropriate and effective adaptation strategies to address climate change and its impacts by building resilience and resistance. Action needs to take place at all levels; from international, to national, to local and community-based efforts. Because climate change will compound environmental and socio-economic problems, it is critical that all sustainable development policies and initiatives include climate change adaptation and resilience building. Climate change is here and the world is changing and society has a responsibility to act now.

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