

Floods After Fires:

The Modeled Impacts of the 2026 Super El Niño and the Probable Super La Nina That Follows on the Indonesian Economy

Climate Change Series #2

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The system dynamics model on which this paper is based, ENSONINAI26, is available on the Landscape website. It extends ENSOID26, the model behind *Fire on the Horizon* (June 2026), with a La Nina phase, links between the two phases, an adaptation layer, and a dated quarterly layer.

Abstract

Fire on the Horizon, published in June 2026, modeled the economic effects of an El Niño that was still forming. The El Niño has since become one of the strongest on record, and the fire season it drives is now under way. This paper updates that account with the events of February to mid-October 2026, checks the June prognosis against them, and extends the analysis to the La Nina that frequently follows a strong El Niño. It uses ENSONINAID26, which adds a wet chain of extreme rain, cyclones, floods, and landslides to the dry chain of drought, fire, and haze, and links the two phases through nine cross-phase channels. Run from weak to record intensity, the model puts the net damage of an El Niño year followed by a La Nina year at 3.5 percent of gross domestic product (GDP) under a strong cycle, 4.6 percent under a super cycle, and 7.1 percent under a record cycle, or \$47 billion to \$97 billion (Rp759 trillion to Rp1,558 trillion). Growth falls by 1.1 to 2.1 percentage points over the two years, the deficit widens by 1.1 to 1.6 percentage points of GDP, 2.8 to 5.2 million livelihoods come under stress, and 3.2 to 7.7 million people fall below the poverty line at the peak. Damage in the dry year raises damage in the wet year, and this compound effect adds about a tenth to the cost of the cycle. The first wave has arrived as modeled. Official data show 202,011 hectares (ha) burned by July, more than in the same months of 2019 and 2023, alongside hydropower shortfalls and stalled river freight. Satellites recorded more fire detections in August 2026 than in August 2015. Prices and growth have moved less than the June prognosis expected, because rice stocks are high and the harvest effect lags into 2027. The 2026 event is therefore more severe than past events in its ocean forcing, below 2015 in burned area so far, and potentially the most costly cycle on record if a strong La Nina follows. An integrated adaptation portfolio would avoid close to half of the net damage at a benefit–cost ratio of 1.7 to 2.5. Early warning and peatland rewetting return the most per rupiah. The figures are scenario outputs, not forecasts.

Keywords: El Niño; La Nina; ENSO; Indonesia; system dynamics; forest fires; floods; food prices; adaptation; climate stress test.

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1 Introduction and Context

He was found at seven in the morning on the last Sunday of August, lying in a dry ditch at the edge of a village oil-palm plot in Ketapang, West Kalimantan, where the forest had turned to smoke. The villagers gave him the name of their hamlet, Sempurna, which means perfect. He was a grown male Bornean orangutan, and he could no longer stand. Each breath came short and shallow, as if the air itself had grown too thin to hold him. Rescuers from the West Kalimantan conservation agency and International Animal Rescue Indonesia gave him oxygen and fluids and carried him to their rehabilitation center. At twenty past three that afternoon his heart stopped. The necropsy found his lungs heavy and partly collapsed, and the veterinarians named the smoke as the likely cause.¹

Sempurna did not die alone. In the peat of Padang Sugihan in South Sumatra, three pangolins were found burned to death in a reserve that also shelters wild elephants.² In Central Kalimantan, twenty-one orangutans in the Nyaru Menteng center fell ill with respiratory infections, and a mother named Raya was carried out of burned peat together with her infant. In West Kalimantan, eighteen orangutans have been pulled from the fire's path, one of them with both feet badly burned.³

The fire took people too. Ahmadin, a volunteer firefighter in Kotawaringin Barat, breathed smoke for a week and died in a hospital in Pangkalan Bun on the same day as Sempurna. Ahmad Rizani, who led the village fire team of Sabaru in Palangka Raya, fell on the fire line and did not rise.⁴ By early September the Ministry of Health counted four dead, 324 in hospital, more than 113,000 cases of acute respiratory infection, a quarter of them in children under five, and 12.5 million people living under the haze.⁵ Children in Palangka Raya learned at home behind shut windows, and in Pontianak the planes stayed on the ground while the runway vanished into a gray noon.⁶

¹ Kementerian Kehutanan (Ministry of Forestry), 2026, "BKSDA Kalbar tangani orangutan Sempurna yang diduga terdampak asap karhutla," *Siaran Pers*, (September 3, 2026). <https://www.kehutan.go.id/pers/bksda-kalbar-tangani-orangutan-sempurna-yang-diduga-terdampak-asap-karhutla> (accessed on September 17, 2026); Uli, M., 2026, "One orangutan dies, more rescued as wildfire rages," *The Jakarta Post*, (September 5, 2026); Fadilah, R., 2026, "Kisah Sempurna dan ancaman karhutla bagi orangutan Kalimantan," *Antara*, (September 8, 2026). Some outlets spell the name Sempurna and the village Laman Satong; the ministry uses Sempurna and Kuala Satong.

² Yuliani, 2026, "Karhutla SM Padang Sugihan, tiga trenggiling ditemukan mati terpanggang," *IDN Times Sumsel*, (September 15, 2026).

³ Wicaksana, D.R., 2026, "Asap kebakaran hutan Kalimantan buat 21 orangutan jatuh sakit," *Liputan6*, (September 5, 2026); "Induk dan anak orangutan terjebak karhutla, begini nasibnya," *Prokalteng*, (September 3, 2026); "Karhutla ancam habitat orangutan Kalimantan, 18 individu diselamatkan di Kalbar," *CNA.id*, (September 14, 2026).

⁴ "Relawan karhutla di Kalteng meninggal, sempat dirawat sesak napas," *CNN Indonesia*, (August 31, 2026); *RCTI+*, (September 4, 2026), on Ahmad Rizani; BNPB condolences as reported by *detikKalimantan*, (September 4, 2026).

⁵ Prasetyo, M.R.B.E., 2026, "Kemenkes catat 113 ribu kasus ISPA akibat karhutla di tujuh provinsi," *Antara*, (September 10, 2026); Dewi, S., 2026, "Kemenkes ungkap dampak karhutla, 4 orang meninggal, 324 dirawat di RS," *IDN Times*, (September 11, 2026).

⁶ "PJJ Palangka Raya diperpanjang hingga 16 September, kualitas udara masih berbahaya," *Prokalteng*, (September 14, 2026); Jeckmus, 2026, "30 penerbangan di Bandara Supadio dibatalkan," *Borneo Tribun*, (September 12, 2026).

2 The Super El Niño That Has Been

2.1 Fire on the Horizon

Landscape Advisory published *Fire on the Horizon* in June 2026.⁷ That paper was written before the El Niño gained its present strength. At the time, the Climate Prediction Center (CPC) of the United States National Oceanic and Atmospheric Administration (NOAA) had only just declared El Niño conditions, and forecasters still debated whether the event would reach the strong or the very strong class. The event has since shown itself. The central and eastern Pacific have warmed to levels last seen in the strongest events on record, the dry season has covered four-fifths of the country, and the fires have spread across Kalimantan, Sumatra, Papua, and Nusa Tenggara. This paper, *Floods After Fires*, has three aims. It updates the account of the 2026 fires as they happen. It tests the June prognosis against the real events of February to mid-October. It models the La Nina that often follows a strong El Niño, and the floods, landslides, and price shocks that a La Nina brings. The analysis uses a new model, ENSONINAI26. It keeps the El Niño structure of the earlier model, ENSOID26, adds a wet chain, a set of cross-phase links, and an adaptation layer, and places the results on the calendar.

2.2 The Fires that Have Been

The El Niño grew faster and larger than the June paper assumed. In February the tropical Pacific was still in a weak La Nina, and the CPC gave only a 50 to 60 percent chance of an El Niño later in the year.⁸ It issued its first El Niño Watch on March 12 and declared El Niño conditions on June 11.⁹ The Oceanic Niño Index (ONI), the three-month mean of the sea-surface temperature anomaly in the central equatorial Pacific, rose from -0.21°C in January to March to 0.95°C in April to June, 1.80°C in June to August, and 2.16°C in July to September.¹⁰ The weekly traditional Niño-3.4 anomaly reached 3.3°C in the week of October 7, the highest reading of the year so far.¹¹ In September the Niño-3 region of the eastern Pacific ran 4.0°C above normal on the index of the Japan Meteorological Agency (JMA), above the previous record of 3.6°C set in December 1997.¹² The Australian Bureau of Meteorology (BoM) reported a weekly relative Niño-3.4 value of 2.81°C for the week to October 11, the highest in its weekly record and above the 2.78°C of November 2015.¹³ Indonesia's Meteorology, Climatology, and Geophysics Agency (Badan Meteorologi, Klimatologi, dan Geofisika, BMKG) classes the event as very strong, with an index of 2.70 for July to September, and reports a positive Indian

⁷ Sari, A.P., 2026, *Fire on the Horizon: The Modeled Impacts of the 2026 Super El Niño on the Indonesian Economy*, Climate Change Series #1, Landscape Advisory, Jakarta, (June 2026).

⁸ CPC (Climate Prediction Center, NOAA), 2026, "ENSO diagnostic discussion," (February 12, 2026). https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_feb2026/ensodisc.shtml (accessed on October 13, 2026).

⁹ CPC (Climate Prediction Center, NOAA), 2026, "ENSO diagnostic discussion," (March 12, 2026), https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_mar2026/ensodisc.shtml; CPC, 2026, "ENSO diagnostic discussion," (June 11, 2026), https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_disc_jun2026/ensodisc.shtml (both accessed on October 13, 2026).

¹⁰ NOAA (National Oceanic and Atmospheric Administration), 2026, "Cold and warm episodes by season," ONI data file, Climate Prediction Center. <https://www.cpc.ncep.noaa.gov/data/indices/oni.ascii.txt> (accessed on October 13, 2026). On the relative index (RONI) that the CPC now uses, the value for July to September is 1.69°C .

¹¹ CPC, 2026, "Weekly Niño-3.4 index (OISST, 1991–2020 base)." <https://www.cpc.ncep.noaa.gov/data/indices/wksst9120.for> (accessed on October 13, 2026). The relative index for the same week is about 2.3°C .

¹² JMA (Japan Meteorological Agency), 2026, "El Niño outlook (October 2026 to April 2027)," Tokyo Climate Center, (October 9, 2026). <https://ds.data.jma.go.jp/tcc/tcc/products/elnino/outlook.html> (accessed on October 13, 2026).

¹³ BoM (Bureau of Meteorology, Australia), 2026, "ENSO and IOD monitoring," data to October 11, 2026. <https://www.bom.gov.au/climate/enso/> (accessed on October 13, 2026).

Ocean Dipole of 0.72 in September.¹⁴ The agencies use different indices, and the BMKG index runs higher than the CPC index for the same months.

Figure 2.1 sets the path of the ONI in 2026 against four earlier strong El Niños. The 2026 index started the year below zero, as in 1997 and 2023, and has risen faster than any of them since April. By July to September it stood at 2.16°C, above the 1.79°C of 1997 and the 1.73°C of 2015 at the same point of the year. The dashed line follows the central case of this paper, with a peak of +3.1°C in October to December 2026, above the 2.59°C record of 2015–16, and a La Nina of –1.5°C a year later. Section 2.3 sets out the forecasts behind this path, and Section 4.2 the model that uses it.

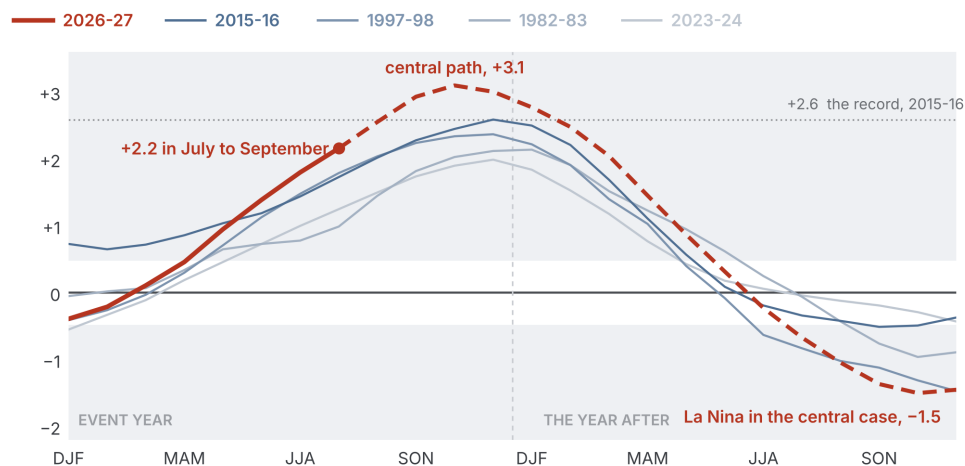


Figure 2.1. The intensity of the 2026 El Niño. The Oceanic Niño Index in 2026 and in four earlier El Niño events, from December to February of the event year to November to January of the year after, in degrees Celsius. The 2026 line is observed to July to September and follows the central case of ENSONINAI26 after that, with an El Niño peak of +3.1°C in October to December 2026 and a La Nina of –1.5°C a year later. Shaded areas mark El Niño conditions above +0.5°C and La Nina conditions below –0.5°C. Sources: NOAA Climate Prediction Center, ONI (accessed on October 14, 2026); Landscape Advisory.

The dry season came early and lasted. In March BMKG expected the dry season to arrive earlier than normal in 46.5 percent of the country's seasonal zones and to peak in August in 61.4 percent of them.¹⁵ West Kalimantan declared a fire emergency alert (siaga darurat) on February 2, and Jambi, South Sumatra, Riau, South Kalimantan, and Central Kalimantan followed as the season advanced.¹⁶ By early August 73.8 percent of the country's area was in the dry season. By early September the share reached 80.7 percent, and 1,637 observation points had gone more than 60 days without rain.¹⁷ At

¹⁴ "El Nino sangat kuat, BMKG keluaran peringatan-prediksi terbaru," *CNBC Indonesia*, (October 6, 2026), citing BMKG. <https://www.cnbcindonesia.com/news/20261006101827-4-773666/el-nino-sangat-kuat-bmkg-keluar-peringatan-prediksi-terbaru> (accessed on October 13, 2026).

¹⁵ BMKG (Badan Meteorologi, Klimatologi, dan Geofisika), 2026, "Musim kemarau 2026 datang lebih awal, puncak terjadi Agustus mendatang," *Siaran Pers*, (March 4, 2026). <https://www.bmkg.go.id/siaran-pers/bmkg-musim-kemarau-2026-datang-lebih-awal-puncak-terjadi-agustus-mendatang> (accessed on October 13, 2026).

¹⁶ BNPB (Badan Nasional Penanggulangan Bencana), 2026, "Perkembangan situasi dan penanganan karhutla di sejumlah wilayah Indonesia 5 September 2026," (September 5, 2026). <https://www.bnpb.go.id/berita/perkembangan-situasi-dan-penanganan-karhutla-di-sejumlah-wilayah-indonesia-5-september-2026> (accessed on October 13, 2026).

¹⁷ Mufarida, B., 2026, "BMKG: 73,8% wilayah Indonesia memasuki kemarau hingga awal Agustus 2026," *Okezone*, (August 9, 2026), <https://news.okezone.com/read/2026/08/09/337/3235084/bmkg-73-8-wilayah-indonesia-memasuki-kemarau-hingga-awal-agustus-2026>; Ananda, A., 2026, "Kemenhutimbau masyarakat waspada karhutla hingga awal November 2026," *Antara*, (September 16, 2026), <https://www.antaranews.com/berita/5743513/kemenhut-imbau-masyarakat-waspada-karhutla-hingga-awal-november-2026> (both accessed on October 13, 2026).

the end of September only about 5.7 percent of the country had entered the rainy season.¹⁸

The fires followed the drought. Figure 2.2 shows the daily count of hotspots, the satellite pixels that register as hotter than their surroundings, from two sources. The first is SiPongi, the fire monitoring system of the Ministry of Forestry. It draws on the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors of the Terra and Aqua satellites and the Visible Infrared Imaging Radiometer Suite (VIIRS) sensors of the Suomi National Polar-orbiting Partnership (Suomi NPP) and NOAA-20 satellites, and grades each detection as high, medium, or low confidence.¹⁹ The second is the VIIRS 375 meter product of the National Aeronautics and Space Administration (NASA) from the Suomi NPP satellite alone, distributed through NASA's Fire Information for Resource Management System (FIRMS).²⁰ The two sources trace the same curve. The daily count in SiPongi rarely exceeded 1,000 through June. It climbed through July, passed 10,000 a day in mid-August, and has stayed between about 8,000 and 26,000 a day since. SiPongi recorded 320,393 hotspots in August, 477,931 in September, and 234,547 in the first twelve days of October, so the October pace is faster than that of September. The busiest day of the year so far was October 6, with 26,059 detections. Kalimantan carried 51 percent of all detections from January 1 to October 12, Papua 16 percent, and Sumatra 15 percent.

¹⁸ *CNBC Indonesia*, (October 6, 2026), *op. cit.*

¹⁹ Kementerian Kehutanan (Ministry of Forestry), 2026, SiPongi+, "Sebaran titik panas," daily counts by confidence level, satellite, and province for January 1 to October 12, 2026, retrieved from the SiPongi data service. <https://sipongi.gakkum.kehutanan.go.id/sebaran-titik-panas> (accessed on October 13, 2026). Counts are by calendar day. Attribution SIPONGI KEMENHUT.

²⁰ NASA (National Aeronautics and Space Administration), 2026, "Active fire alerts (VIIRS)," Suomi NPP VIIRS 375 m product (VNP14IMG1), daily counts for Indonesia by confidence level, accessed from Global Nature Watch on October 13, 2026. <https://www.globalnaturewatch.org>; Schroeder, W., P. Oliva, L. Giglio, and I.A. Csiszar, 2014, "The new VIIRS 375 m active fire detection data product: Algorithm description and initial assessment," *Remote Sensing of Environment*, 143, pp. 85–96. Data courtesy of NASA's Fire Information for Resource Management System (FIRMS). Ten days are missing from the 2026 series in this distribution (April 28 and 29, June 1, July 11 to 16, and August 3), so the 2026 totals are slightly low.

Daily hotspots in Indonesia, January 1 to October 12, 2026

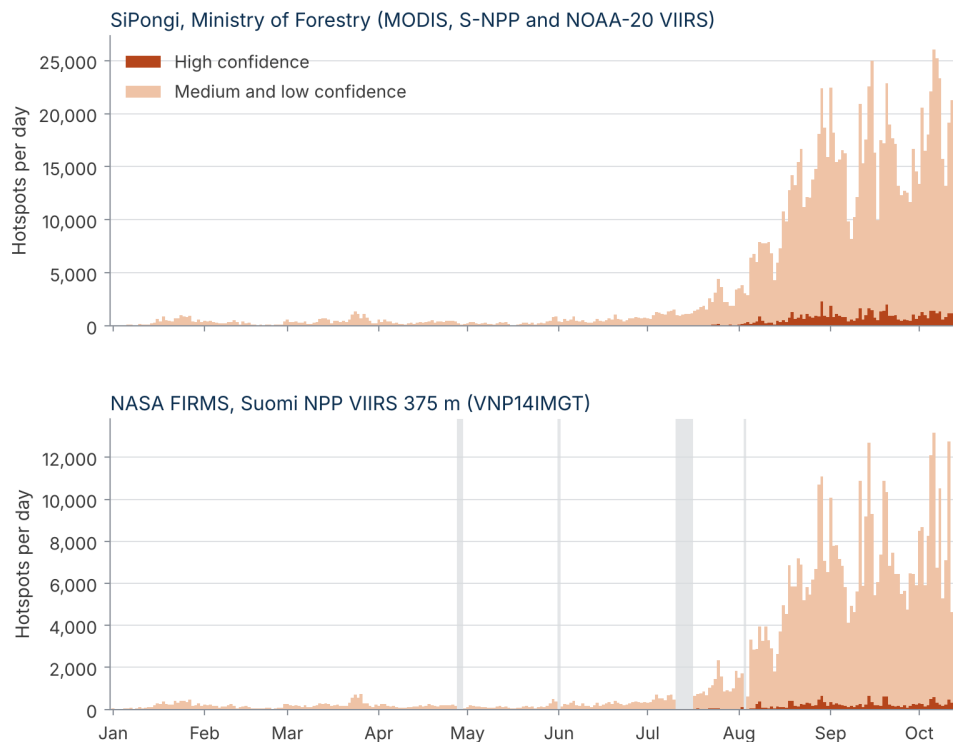


Figure 2.2. Daily hotspots in Indonesia, January 1 to October 12, 2026. The upper panel is SiPongi, which combines MODIS and two VIIRS sensors. The lower panel is the NASA VIIRS product from Suomi NPP alone. Dark bars are high-confidence detections and light bars are medium- and low-confidence detections. Gray bands mark days missing from the NASA series. Sources: SIPONGI KEMENHUT; NASA FIRMS via Global Nature Watch.

The confidence grade changes the count by an order of magnitude. Of the 1,160,393 SiPongi detections from January 1 to October 12, 65,920, or 5.7 percent, carry high confidence. The high-confidence count peaked at 2,327 on August 29 and reached 28,697 for September. This is the grade that the Ministry of Forestry cites in its daily releases. A high-confidence filter suits the question of where fires are certain. It also removes most of the low-intensity smoldering of peat, which releases most of the carbon, so it understates the fire for emissions and health.²¹

The Suomi NPP record allows a fair comparison with past El Niño years, because the same sensor has flown since 2012. Figure 2.3 sets 2026 against 2015, 2019, and 2023. August 2026 recorded 145,280 detections, more than the 120,007 of August 2015. September 2026 recorded 214,709, more than the 195,615 of September 2019 and about three quarters of the 292,742 of September 2015. From January to September 2026 the sensor recorded 415,055 detections. That is 1.4 times the count for the same months of 2019, 2.7 times that of 2023, and 84 percent of that of 2015. The count to October 12 already exceeds the full-year totals of 2019 and 2023. At its pace in early October, the month would reach about 268,000 detections, below the 318,336 of October 2015. Among these four years, 2026 is second only to 2015, and its August was more intense than that of 2015.

²¹ Landscape Advisory, 2026, "A tale of two burning maps," *Occasional Fact Sheet*, (August 22, 2026). <https://landscape.id/docs/ofs-aug-22-2026.pdf> (accessed on October 13, 2026).

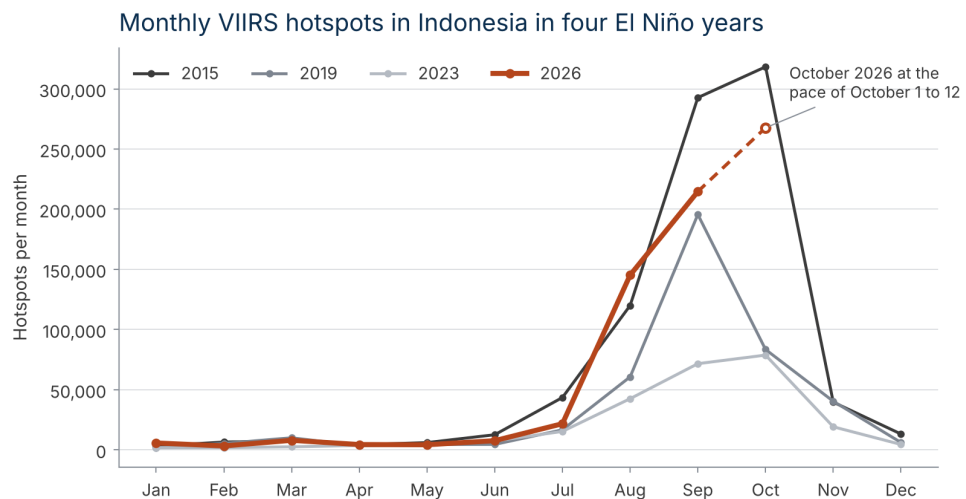


Figure 2.3. Monthly hotspots in Indonesia from the Suomi NPP VIIRS sensor in four El Niño years, all confidence levels. The open circle shows October 2026 at the daily pace of October 1 to 12. Source: NASA FIRMS via Global Nature Watch.

The official burned area, discussed in Section 4.1, points to different places from the hotspots. Kalimantan holds 28 percent of the burned area to July but half of the hotspots. Bali, Nusa Tenggara, and Maluku hold 52,347 hectares (ha), or 26 percent of the burned area, but only 9 percent of the hotspots. Grass and savanna burn wide and fast and leave a short thermal signature, while peat smolders for days and is detected again and again over a small area.²² Riau burned 15,478 ha in the first half of the year, its worst first half since 2019 and seventeen times the 2025 figure, and 92 percent of it was on peat.²³ The Global Fire Emissions Database put Indonesian fire emissions at 76 million tonnes of carbon by September 7, against 333 million tonnes for all of 2015, and its lead scientist described 2026 as “more or less on track” to reach the 2015 level.²⁴

Landscape Advisory's Occasional Fact Sheets followed the peak of the season in Kalimantan.²⁵ In the week of August 13 to 20 the VIIRS fire footprint in Kalimantan covered 426,727 ha, about 0.8 percent of the island in eight days. The footprint is an upper bound on burned area, because a 375 meter pixel can be flagged by a fire that covers only part of it. Peat carried 81,759 ha of the footprint and burned at 2.3 times the rate of mineral soil. Half of the footprint lay inside a logging, pulpwood, or oil palm concession, and oil palm alone held 21.7 percent of the footprint on 18 percent of the island's land. The week released an estimated 16 to 33 million tonnes of carbon dioxide equivalent, about three quarters of it from peat. By August 21 and 22 the center of the fire had moved 51 kilometers to the south-southwest, from West to Central Kalimantan, and the estimated share of the fire on peat had risen from 19 to 35 percent.

²² Landscape Advisory, 2026, “The 2026 season so far,” *Occasional Fact Sheet*, (August 26, 2026). <https://landscape.id/docs/ofs-aug-26-2026.pdf> (accessed on October 13, 2026). Island shares of the burned area are from the SiPongi register for January to July 2026.

²³ *Ibid.*, citing the Ministry of Forestry, BRIN, and the Ministry of Environment, (July 17, 2026).

²⁴ Keating, C., 2026, “El Niño: Indonesia fire emissions in 2026 ‘on track’ to match record for this century,” *Carbon Brief*, (September 11, 2026). <https://www.carbonbrief.org/el-nino-indonesia-fire-emissions-in-2026-on-track-to-match-record-for-this-century> (accessed on October 13, 2026).

²⁵ Landscape Advisory, 2026, “Kalimantan burning: The 2026 fire season, week of August 13 to 20,” *Occasional Fact Sheet*, (August 21, 2026). <https://landscape.id/docs/ofs-aug-20-2026.pdf> (accessed on October 13, 2026); Landscape Advisory, 2026, “A tale of two burning maps,” *op. cit.* The footprint counts each 375 m VIIRS cell once and is an upper bound on burned area.

The fire also reached the conservation estate.²⁶ Between August 13 and September 5, NASA satellites recorded 31,161 high-confidence hotspots in Indonesia, and 2,067 of them, or 7 percent, fell inside protected areas. Ten sites carried 70.4 percent of all detections inside the estate. Sungai Barito in Central Kalimantan had the highest density, at 6,201 detections per 1,000 square kilometers. Category Ia of the International Union for Conservation of Nature (IUCN), the strictest class of protection, held 7,729 detections across 145 sites, so legal status offered little protection on the ground. Sites with records of the Bornean orangutan held 8,602 detections, with Sebangau alone at 2,939. Sites with records of the southern cassowary held 6,564, with Wasur at 4,195.

The smoke crossed borders. The ASEAN Specialised Meteorological Centre (ASMC), which serves the Association of Southeast Asian Nations (ASEAN), raised its haze alert for the southern ASEAN region to Level 3, its highest, on August 26. Malaysia declared a haze emergency in Serian, Sarawak, on September 4 and 5, after the air pollution index passed 500. On October 9 it closed schools in Kuala Lumpur, Putrajaya, Johor, Malacca, Negeri Sembilan, Selangor, and parts of Pahang, affecting about two million students, and Singapore's 24-hour Pollutant Standards Index (PSI) reached the unhealthy range.²⁷ The government had deployed 64 aircraft and 54,394 personnel by September 20, and enforcement widened to corporations after August (Section 5.1).²⁸ Section 4.1 records what these months have done to output, prices, health, and the public budget.

2.3 The Outlook for the Coming Seasons

The El Niño has not yet peaked. On October 8 the CPC said that the event would continue to strengthen through the end of the year and that a strong to very strong El Niño was likely through January to March 2027, with a probability above 83 percent. It put the chance that the October to December value of its relative index would reach 2.5°C or more, above every El Niño since 1950, at 83 percent.²⁹ Its median forecast for that index peaks at 2.74°C in October to December, against a peak of 2.3°C in 2015–16, and falls to 0.83°C by March to May 2027. Neutral conditions of the El Niño–Southern Oscillation (ENSO) become the most likely state in April to June 2027. The International Research Institute for Climate and Society (IRI) reported in September that all 22 models in its plume showed a very strong event through the northern winter, and that most showed the traditional Niño-3.4 index at or above 3.0°C.³⁰ The World

²⁶ Landscape Advisory, 2026, "Fire in the protected areas," *Occasional Fact Sheet*, (September 9, 2026). <https://landscape.id/docs/ofs-sep-09-2026.pdf> (accessed on October 13, 2026). Hotspots from the NASA FIRMS MODIS and VIIRS near-real-time products. Protected areas from the World Database on Protected Areas (WDPA), UNEP-WCMC and IUCN.

²⁷ ASMC (ASEAN Specialised Meteorological Centre), 2026, "Activation of Alert Level 3 for the southern ASEAN region," (August 26, 2026), <https://asmc.asean.org/asmc-alerts/>; Gimino, G., and S. Ling, 2026, "Haze emergency declared in Serian," *The Star*, (September 5, 2026), <https://www.thestar.com.my/news/nation/2026/09/05/haze-emergency-declared-in-serian>; "Malaysia shuts schools as haze from Indonesian fires chokes Southeast Asia," *Al Jazeera*, (October 9, 2026), <https://www.aljazeera.com/news/2026/10/9/malaysia-shuts-schools-as-haze-from-indonesian-fires-chokes-southeast-asia>; NEA (National Environment Agency, Singapore), 2026, "Haze situation update (10 October 2026)," <https://www.nea.gov.sg/media/news/advisories/index/haze-situation-update-10-october-2026> (all accessed on October 13, 2026).

²⁸ Cabinet Secretariat, 2026, "Gov't mobilizes 64 aircraft, 54,394 personnel to handle forest, land fires," (September 20, 2026). <https://setkab.go.id/en/govt-mobilizes-64-aircraft-54394-personnel-to-handle-forest-land-fires/> (accessed on October 13, 2026).

²⁹ CPC (Climate Prediction Center, NOAA), 2026, "ENSO diagnostic discussion," (October 8, 2026), https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.shtml; CPC, 2026, "Official CPC ENSO probabilities," https://cpc.ncep.noaa.gov/products/analysis_monitoring/enso/roni/probabilities/; CPC, 2026, "RONI outlook," https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso/roni/outlook/ (all accessed on October 13, 2026). The CPC states strength on its relative index (RONI), which runs below the traditional index.

³⁰ IRI (International Research Institute for Climate and Society), 2026, "ENSO forecast," (September 21, 2026). <https://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/> (accessed on October 13, 2026).

Meteorological Organization (WMO) expects the Niño-3.4 anomaly to average about 3.7°C in October to December, with a peak around December.³¹ The JMA considers it virtually certain that the strongest El Niño conditions will continue through the northern winter, and expects the event to peak at a record level.³² The BoM expects the warmth to peak in November or December and to persist into March to May 2027.³³ The Copernicus Climate Change Service (C3S) of the European Union finds consensus among its forecast systems on a steep decline after a peak at the end of the year, with conditions still above the El Niño threshold in the spring of 2027.³⁴ NASA's Sentinel-6 Michael Freilich satellite showed warm water piling up along the equator as early as June, in a pattern that NASA scientists compared with 1997.³⁵

The Indian Ocean adds to the drought. A positive Indian Ocean Dipole, which cools the waters west of Sumatra and Java and reduces rain over western Indonesia, developed in September. The BoM recorded a weekly index of 0.88°C for the week to October 11, and the agencies expect the dipole to peak in October and fade to neutral by January 2027.³⁶ BMKG expects the 2026–27 rainy season to start later than normal over 61.08 percent of the country's area and to be shorter than normal over 51.90 percent. Onset falls in November over 24.66 percent of the area and in December over 17.31 percent, and the rains peak between December and February.³⁷ For the fire provinces, BMKG expected rain in Riau from September, in Jambi and South Sumatra in October, and persistent rain in southern West and Central Kalimantan only from the second half of October. In early October the head of the National Disaster Management Agency (Badan Nasional Penanggulangan Bencana, BNPB), citing BMKG, put the start of rain between the third week of October and the third week of November. The Minister of Forestry said that rain would reach South Kalimantan only in mid-November.³⁸ The ASMC expects below-normal rainfall over much of the Maritime Continent in October to December, and drier than usual conditions over the southern ASEAN region from October 12 to 25. It expects the haze to remain escalated until inter-monsoon showers at the end of October begin to relieve it.³⁹ The fire season is therefore likely to run into November, later than in a normal year.

The risk continues after the first rains. El Niño is expected to remain strong through January to March 2027, and a short rainy season leaves peat less time to rewet. Riau

³¹ WMO (World Meteorological Organization), 2026, *Global Seasonal Climate Update for October–November–December 2026*, (October 8, 2026). <https://wmo.int/resources/publication-series/global-seasonal-climate-updates/gscu-ond2026> (accessed on October 13, 2026).

³² JMA, 2026, *op. cit.*

³³ BoM, 2026, *op. cit.*

³⁴ C3S (Copernicus Climate Change Service), 2026, "Seasonal forecasts," forecast issued October 10, 2026. <https://climate.copernicus.eu/seasonal-forecasts> (accessed on October 13, 2026).

³⁵ NASA Earth Observatory, 2026, "El Niño is underway," (June 18, 2026).

<https://science.nasa.gov/earth/earth-observatory/el-nino-is-underway/> (accessed on October 13, 2026).

³⁶ BoM, 2026, *op. cit.*; WMO, 2026, *Global Seasonal Climate Update for October–November–December 2026*, *op. cit.*; ASMC, 2026, "El Niño and the Indian Ocean Dipole," (September 21, 2026).

<https://asmc.asean.org/asmc-el-nino/> (accessed on October 13, 2026).

³⁷ Wibawana, W.A., 2026, "Prakiraan awal dan puncak musim hujan 2026/2027 di Indonesia," *detikNews*, (September 23, 2026), citing BMKG. <https://news.detik.com/berita/d-8675280/prakiraan-awal-dan-puncak-musim-hujan-2026-2027-di-indonesia> (accessed on October 13, 2026). Shares are of land area.

³⁸ Prasetyo, M.R.B.E., 2026, "BMKG prakirakan hujan berangsur turun di daerah rawan karhutla," *Antara*, (September 22, 2026), <https://www.antaranews.com/berita/5752437/bmkg-prakirakan-hujan-berangsur-turun-di-daerah-rawan-karhutla>; BNPB, 2026, "Kabut asap selimuti Bandara Palembang, pesawat OMC terbang dari Bandara Pangkal Pinang," (October 11, 2026), <https://www.bnpb.go.id/berita/kabut-asap-selimuti-bandara-palembang-pesawat-omc-terbang-dari-bandara-pangkal-pinang>; Kementerian Kehutanan, 2026, "Menhut Raja Juli Antoni: ada 4 syarat tuntaskan karhutla," *Siaran Pers*, (October 12, 2026), <https://www.kehutan.go.id/news/menhut-raja-juli-antoni-ada-4-syarat-tuntaskan-karhutla> (all accessed on October 13, 2026).

³⁹ ASMC (ASEAN Specialised Meteorological Centre), 2026, "Seasonal outlook for October to December 2026," (October 5, 2026), <https://asmc.asean.org/asmc-seasonal-outlook/>; ASMC, 2026, "Subseasonal weather outlook (12 to 25 October 2026)," (October 7, 2026), <https://asmc.asean.org/subseasonal-weather-outlook-12-25-october-2026/> (both accessed on October 13, 2026).

and parts of Sumatra have a second, shorter dry season in February and March, and in 2027 it will fall inside a still-strong El Niño. No agency has yet issued a fire outlook for that window.

The harvest effect will arrive with a delay. Statistics Indonesia (Badan Pusat Statistik, BPS) projects rice output for September to November 2026 at 7.06 million tonnes (Mt), 11.95 percent below the same months of 2025, and an agricultural economist at IPB University expects rice prices to keep rising through March 2027, until the delayed harvest arrives in the second quarter.⁴⁰ The United States Department of Agriculture (USDA) lowered its forecast of Indonesian palm oil output for 2026–27 by 2.2 Mt to 45 Mt because of dry weather, and expects global palm oil stocks to fall to their lowest level since 2017–18.⁴¹ The October forecasts of the World Bank and the International Monetary Fund (IMF) do not cite El Niño as a reason for their headline numbers for Indonesia. The World Bank expects growth of 5.2 percent in 2026 and 2027, and names a very strong El Niño, with a probability above 90 percent, as a regional downside risk.⁴² The IMF expects growth of 5.1 percent in both years and inflation of 3.3 percent in 2026 and 2.8 percent in 2027, and lists El Niño-driven extreme weather among the global risks.⁴³

The El Niño is also lifting global temperature. C3S reported that September 2026 was 1.63°C warmer than the pre-industrial average and that the monthly Niño-3.4 sea-surface temperature reached an all-time high of 29.70°C. Berkeley Earth puts the chance that 2026 becomes the warmest year on record at about 93 percent, and expects a further warming influence in 2027.⁴⁴

La Nina is the cold phase of the same oscillation. Trade winds strengthen, warm water piles up in the western Pacific, and rain falls heavily over the Indonesian archipelago. La Nina often follows a strong El Niño. The two phases are asymmetric. El Niños tend to decay by the following northern summer, and many La Ninas then persist through the next year and strengthen again the winter after.⁴⁵ The pattern is common but not universal. Of the ten El Niños since 1950 that reached an index of 1.5°C, five were followed by a La Nina within about three years, including those of 1973–76, 1998–2001, and 2010–12. The 2015–16 event was followed only by weak La Nina conditions.⁴⁶ Climate change is likely to make the pairing stronger. Model studies project that extreme

⁴⁰ "Dampak El Nino makin memburuk, produksi beras RI 2026 masih stabil," *CNBC Indonesia*, (October 4, 2026), citing BPS, <https://www.cnbcindonesia.com/news/20261003222413-4-773087/dampak-el-nino-makin-memburuk-produksi-beras-ri-2026-masih-stabil>; Reuters, 2026, "Indonesia rice prices poised to remain near record as El Niño threatens 2027 harvest," *AsiaOne*, (October 2, 2026), <https://www.asiaone.com/asia/indonesia-rice-prices-poised-remain-near-record-el-nino-threatens-2027-harvest> (both accessed on October 13, 2026).

⁴¹ USDA (United States Department of Agriculture), 2026, *World Agricultural Supply and Demand Estimates*, WASDE-676, (October 9, 2026). <https://www.usda.gov/oce/commodity/wasde/wasde1026.pdf> (accessed on October 13, 2026).

⁴² World Bank, 2026, *East Asia and Pacific Economic Update, October 2026*, World Bank, Washington, DC. <https://www.worldbank.org/en/publication/east-asia-and-pacific-economic-update> (accessed on October 13, 2026).

⁴³ Andrianto, R., 2026, "IMF ramal ekonomi RI tumbuh 5,1% di 2026, inflasi bisa naik ke 3,3%," *CNBC Indonesia*, (October 13, 2026), reporting the IMF *World Economic Outlook*, October 2026. <https://www.cnbcindonesia.com/news/20261013095833-4-775624/imf-ramal-ekonomi-ri-tumbuh-51-di-2026-inflasi-bisa-naik-ke-33> (accessed on October 13, 2026).

⁴⁴ C3S (Copernicus Climate Change Service), 2026, "Second-warmest September, global temperatures stay above 1.5°C," (October 9, 2026), <https://climate.copernicus.eu/copernicus-second-warmest-september-global-temperatures-stay-above-15degc>; Berkeley Earth, 2026, "August 2026 temperature update," (September 24, 2026), <https://berkeleyearth.org/august-2026-temperature-update/> (both accessed on October 13, 2026).

⁴⁵ Okumura, Y.M., and C. Deser, 2010, "Asymmetry in the duration of El Niño and La Niña," *Journal of Climate*, 23 (21), pp. 5826–5843.

⁴⁶ Author's count from the NOAA ONI v6 table, counting a La Nina episode (five or more seasons at or below –0.5°C) that begins within twelve seasons of the end of the El Niño. On the relative index the count is six of nine. The result depends on the index version and is best read as about half to two-thirds.

La Nina events will nearly double in frequency, from one in 23 years to one in 13, with about three-quarters of the increase occurring in years that follow an extreme El Niño.⁴⁷ Consecutive, multi-year La Ninas are also projected to become more frequent.⁴⁸ No agency yet forecasts a La Nina for late 2027, because the official outlooks end by mid-2027. The CPC's October outlook gives La Nina a probability of 1 percent for April to June 2027 and 13 percent for May to July 2027,⁴⁹ and the WMO does not anticipate a return to La Nina before February 2027.⁵⁰ A strong El Niño drains heat from the upper equatorial Pacific as it decays, and the deficit can be large enough to sustain a La Nina for two years.⁵¹ The La Nina phase in this paper is therefore a stress test for the wet season of late 2027 and 2028, and should be read as a conditional scenario.

Each phase strikes the economy in two waves. In the dry phase, the first wave falls on everything that depends on rain or burns in drought. Rice and other food crops lose yield, oil palm and other estate crops suffer water stress with a lag, fish catches shift, peat and forest burn, reservoirs fall, and rivers become too shallow for barges. In the wet phase, the first wave falls on the same land from the other side. Floods and landslides destroy houses, roads, bridges, and standing crops, heavy rain rots chili and shallots in the field, open-pit mines flood and stop hauling coal, fishing boats stay in port, and harvest roads on plantations turn to mud. In both phases the second wave then travels through food prices, household incomes, public health, tourism, trade, production costs, and the public budget. The historical record shows both waves at work. The 1997–98 El Niño burned between 9.7 and 11.7 million ha and cost Indonesia and its neighbors several billion dollars, and the 2015 fires cost \$16.1 billion (Rp221 trillion), or 1.9 percent of GDP.⁵² The wet La Nina year of 2010 pushed inflation to 6.96 percent, led by rice, chili, and shallots, and kept the coal miner Adaro Energy at 94 percent of its production target.⁵³ The floods and landslides that followed Cyclone Senyar in Aceh, North Sumatra, and West Sumatra in late November 2025 killed about 1,200 people and are still being rebuilt at a planned cost of about Rp100 trillion.⁵⁴

3 The Propagation of the Impacts Throughout the Economy

3.1 Indonesia's Current Economic Challenges

The economy has held up better than its markets. Growth reached 5.61 percent year on year (y/y) in the first quarter (Q1) of 2026 and 5.29 percent in the second quarter (Q2),

⁴⁷ Cai, W., G. Wang, A. Santoso, M.J. McPhaden, L. Wu, F.-F. Jin, A. Timmermann, M. Collins, G. Vecchi, M. Lengaigne, M.H. England, D. Dommenget, K. Takahashi, and E. Guilyardi, 2015, "Increased frequency of extreme La Niña events under greenhouse warming," *Nature Climate Change*, 5, pp. 132–137. <https://doi.org/10.1038/nclimate2492>.

⁴⁸ Geng, T., F. Jia, W. Cai, L. Wu, B. Gan, Z. Jing, S. Li, and M.J. McPhaden, 2023, "Increased occurrences of consecutive La Niña events under global warming," *Nature*, 619, pp. 774–781. <https://doi.org/10.1038/s41586-023-06236-9>.

⁴⁹ CPC, 2026, "Official CPC ENSO probabilities," *op. cit.*

⁵⁰ CPC (Climate Prediction Center, NOAA), 2026, "ENSO diagnostic discussion," (September 10, 2026); CPC, 2026, "ENSO: recent evolution, current status and predictions," (September 14, 2026); IRI, 2026, "ENSO quick look," (August 19, 2026); WMO, 2026, *El Niño/La Niña Update* (August 2026), (September 3, 2026).

⁵¹ Iwakiri, T., and M. Watanabe, 2021, "Mechanisms linking multi-year La Niña with preceding strong El Niño," *Scientific Reports*, 11, 17465.

⁵² Tacconi, L., 2003, *Fires in Indonesia: Causes, Costs and Policy Implications*, CIFOR Occasional Paper No. 38, Center for International Forestry Research, Bogor; World Bank, 2016, *The Cost of Fire: An Economic Analysis of Indonesia's 2015 Fire Crisis*, Indonesia Sustainable Landscapes Knowledge Note 1, World Bank, Jakarta.

⁵³ "Inflasi 2010 capai 6,96 persen," *Antara*, (January 3, 2011), citing BPS; Adaro Energy, 2011, *Fourth Quarter 2010 Quarterly Activities Report*, Adaro Energy, Jakarta, (January 31, 2011).

⁵⁴ BNPB data as reported by *Katadata Databoks*, (January 14 and January 20, 2026); "DPR, pemerintah sepakati rekonstruksi Sumatra Rp100 T," *Economix*, (May 26, 2026).

for 5.45 percent in the first half (H1).⁵⁵ Government consumption carried much of the gain, rising 15.97 percent in Q2, while household consumption grew 5.06 percent and agriculture slowed to 3.80 percent from 4.97 percent in Q1.⁵⁶ Forecasts for the full year range widely. In their October forecasts the World Bank expects 5.2 percent and the IMF 5.1 percent,⁵⁷ Bank Indonesia (BI) expects 4.9 to 5.7 percent, and the government's financial stability committee projects 5.6 to 6.0 percent.⁵⁸

The financial markets remain fragile. The rupiah passed Rp18,000 per dollar for the first time on June 4 and reached a record low of Rp18,201 on June 8. It was back near Rp18,000 in late September.⁵⁹ BI raised its policy rate three times in four weeks, by 50 basis points in May, by 25 basis points at an emergency meeting on June 9, and by 25 basis points on June 18, to 5.75 percent, and held it there in July, August, and September.⁶⁰ Foreign reserves stood at \$146.3 billion at the end of September, enough for 5.3 months of imports.⁶¹ The trade surplus has thinned. July recorded only \$0.12 billion as imports grew 27 percent, and the surplus for January to July was \$3.70 billion.⁶²

Prices are still inside the target band. Headline inflation was 3.19 percent in August and 3.28 percent in September, against BI's target of 2.5 percent plus or minus one point. Core inflation was 2.84 percent and volatile food inflation 5.03 percent in September, with chili, chicken, rice, and eggs among the contributors.⁶³ The poverty rate fell to 8.07 percent, or 22.93 million people, in March 2026, and open unemployment was 4.68 percent in February.⁶⁴ Both readings predate the height of the dry season. The erosion of the middle class described in the June paper continues, and many households sit just above the poverty line, so a food-price shock would act on the most exposed margin.⁶⁵

⁵⁵ BPS (Badan Pusat Statistik), 2026, "Ekonomi Indonesia triwulan II-2026 tumbuh 5,29 persen (y-on-y)," *Berita Resmi Statistik*, (August 5, 2026). <https://www.bps.go.id> (accessed on September 17, 2026).

⁵⁶ Sigit, B., 2026, "Ekonomi Indonesia tumbuh 5,29 persen," *Fortune IDN*, (August 6, 2026).

⁵⁷ World Bank, 2026, *East Asia and Pacific Economic Update, October 2026*, *op. cit.*; Andrianto, R., 2026, *op. cit.*

⁵⁸ World Bank, 2026, *Indonesia Economic Prospects, June 2026*, World Bank, Jakarta; "IMF soal ekonomi Indonesia 2026 stabil di 5 persen," *CNN Indonesia*, (July 10, 2026); Christian, I., 2026, "Bank Indonesia prediksi ekonomi Indonesia 2026 tumbuh 4,9–5,7 persen," *Liputan6*, (August 19, 2026); "Ekonomi RI diproyeksi tumbuh 5,6–6 persen pada 2026," *tvOne News*, (August 3, 2026).

⁵⁹ Herman, 2026, "Makin melemah, rupiah kembali ke level Rp18.000 per dolar AS," *Beritasatu*, (September 29, 2026). <https://www.beritasatu.com/ekonomi/3030080/makin-melemah-rupiah-kembali-ke-level-rp-18000-per-dolar-as> (accessed on October 13, 2026).

⁶⁰ Khaerunnisa, R., 2026, "BI-Rate kembali bertahan di level 5,75 persen pada RDG September," *Antara*, (September 23, 2026). <https://www.antaraneews.com/berita/5754408/bi-rate-kembali-bertahan-di-level-575-persen-pada-rdg-september> (accessed on October 13, 2026).

⁶¹ Alatas, M.B.I., 2026, "Cadangan devisa RI per September 2026 sebesar 146,3 miliar dolar AS," *Antara*, (October 7, 2026). <https://www.antaraneews.com/berita/5774780/cadangan-devisa-ri-per-september-2026-sebesar-1463-miliar-dolar-as> (accessed on October 13, 2026).

⁶² Fauzan, A.M., 2026, "BPS: neraca dagang RI hingga Juli 2026 surplus 3,70 miliar dolar AS," *Antara*, (September 1, 2026).

⁶³ Melani, A., 2026, "BI sebut inflasi September 2026 masih terjaga," *Liputan6*, (October 2, 2026), <https://www.liputan6.com/bisnis/read/8304419/bi-sebut-inflasi-september-2026-masih-terjaga>; Juwita, R.D., 2026, "Inflation ticks up, putting pressure on BI," *The Jakarta Post*, (October 1, 2026), <http://www.thejakartapost.com/business/2026/10/01/inflation-ticks-up-putting-pressure-on-bi> (both accessed on October 13, 2026).

⁶⁴ BPS, 2026, "Persentase penduduk miskin Maret 2026 turun menjadi 8,07 persen," *Berita Resmi Statistik*, (August 5, 2026); BPS, 2026, "Tingkat pengangguran terbuka (TPT) sebesar 4,68 persen," *Berita Resmi Statistik*, (May 5, 2026).

⁶⁵ World Bank, 2026, *Indonesia Economic Prospects, June 2026*, *op. cit.*; Nugroho, A., 2026, "UGM economist warns of growing vulnerability as Indonesia's middle class declines," Universitas Gadjah Mada, (February 27, 2026).

The fiscal position has less room than it did in June. The deficit reached Rp240.1 trillion, or 0.93 percent of GDP, by the end of August.⁶⁶ The Ministry of Finance projects a full-year deficit of Rp734.3 trillion, or 2.85 percent of GDP, against a budgeted 2.68 percent, close to the legal ceiling of 3 percent.⁶⁷ The draft 2027 budget, presented on August 14, assumes 6.0 percent growth, 2.5 percent inflation, and an exchange rate of Rp17,500, with a deficit of 2.40 percent of GDP.⁶⁸ These assumptions leave little space for an El Niño that lasts into 2027 or a La Nina that follows it. The priority programs described in the June paper, including the free nutritious meals program, still claim a large share of spending.⁶⁹ The government has also committed about Rp100 trillion over 2026 to 2028 to rebuild Aceh, North Sumatra, and West Sumatra after the Senyar floods.⁷⁰ For the El Niño response, the Ministry of Finance raised the disaster budget to Rp1.1 trillion from Rp494 billion, and points to an on-call fund of Rp256 billion, a ready-to-use emergency fund of Rp5 trillion, and a disaster insurance pooling fund of Rp14 trillion. The National Disaster Management Agency (Badan Nasional Penanggulangan Bencana, BNPB) reported only about Rp950 billion of its ready-to-use funds left in early September and asked for Rp5.7 trillion more.⁷¹

3.2 The Impacts of the Super El Niño and La Nina on Key Economic Sectors

The two phases of the oscillation reach the economy through the same sectors from opposite directions. Table 3.1 lists the sectors that each phase strikes first, and the physical channel in each case. The dry phase works through drought, heat, and fire. The wet phase works through extreme rain, tropical cyclones, floods, and landslides, and its reach is widened by upstream deforestation, which raises runoff and landslide risk.

⁶⁶ "APBN defisit Rp240,1 T per Agustus 2026," *CNN Indonesia*, (September 18, 2026).

<https://www.cnnindonesia.com/ekonomi/20260918121732-532-1405383/apbn-defisit-rp2401-t-per-agustus-2026> (accessed on October 13, 2026).

⁶⁷ Siifia, I., 2026, "Purbaya proyeksi defisit APBN 2026 melebar jadi 2,85 persen dari PDB," *Antara*, (July 7, 2026).

⁶⁸ "RAPBN 2027 tembus Rp4.097 triliun, defisit dijaga 2,40 persen PDB," *Investor Trust*, (August 14, 2026); Khaerunnisa, R., 2026, "Daftar lengkap asumsi makro dan target pembangunan RAPBN 2027," *Antara Jambi*, (August 14, 2026).

⁶⁹ "Indonesia cuts MBG budget by Rp67 trillion in 2026 APBN," *Antara News*, (May 19, 2026).

⁷⁰ *Economix*, (May 26, 2026), *op. cit.*; Bappenas (Ministry of National Development Planning), 2026, *Rencana induk percepatan rehabilitasi dan rekonstruksi pascabencana alam di wilayah Provinsi Aceh, Provinsi Sumatera Utara, dan Provinsi Sumatera Barat*, Bappenas, Jakarta.

⁷¹ Saputra, B., 2026, "Suahasil sebut sudah siapkan anggaran antisipasi El Nino dalam APBN," *Antara*, (September 16, 2026); Almira, Y.A., 2026, "Purbaya sebut BNPB punya dana siap pakai sebesar Rp950 miliar," *Fortune IDN*, (September 9, 2026).

Sector	El Niño channel (dry)	La Nina channel (wet)	Principal direct effect
Food crops and horticulture	Late and weak monsoon, delayed planting, drought	Waterlogging, flooding of paddy, rot of chili and shallots	Lower yields and harvest failure. The 1997–98 drought cut the 1998 paddy harvest by 3.6 percent, and the 2023 drought cut rice output by 1.4 percent. In the wet year of 2010, yields in some flooded West Java fields fell by more than half.
Estate crops (palm oil, rubber, coffee, cocoa)	Water stress with a lag of 6 to 24 months, fire in plantations	Poor pollination, flooded blocks, impassable harvest roads	Lower fresh-fruit-bunch output. The industry expects the 2026 drought to cost up to 3 million tons (Mt), with the larger effect in 2027.
Fisheries and aquaculture	Warmer seas and shifting upwelling	Storms, high waves, and floods in coastal ponds	Lower and displaced catches, lost fishing days, and pond losses in a sector of 2.6 percent of GDP.
Forestry and peatland	Drought-primed fire and peat combustion	Landslides on degraded slopes, burned peat that floods	Burned forest and crops, carbon release, and haze. The 2015 fires burned 2.6 million ha.
Water and hydropower	Low reservoirs and rivers	Silted and overtopped reservoirs, damaged intakes	Lower hydropower and irrigation supply in dry years. The model assumes no gain in wet years.
River and road transport	Rivers too shallow for barges	Flooded and broken roads, bridges, and ports	Stranded coal and palm-oil barges in dry years, and cut road links and higher freight costs in wet years.
Mining	Water shortage for processing, low river haulage	Flooded pits, slower overburden removal, halted hauling	Lost coal output. Adaro reached 94 percent of its 2010 target in record rain.
Housing and public assets	Fire damage to property	Floods and landslides destroying houses, roads, and bridges	Asset losses and reconstruction needs. The Senyar floods damaged 175,050 houses and 776 bridges.

Table 3.1. The first wave in both phases: sectors directly exposed to El Niño's drought and fire and to La Nina's rain and floods.

The timing of the first wave differs by sector and by phase. Food crops respond within a season. Estate crops respond with a lag of six months to two years, so a drought in 2026 lowers palm-oil output in 2027, which is also the most likely year of the wet phase. Fire is fast and concentrated in the peak dry months of August to October. Floods and landslides are fast and concentrated in the peak wet months of December to March.⁷² Rice is the link that matters most for households. The literature has long shown that sea-surface temperature in August explains about half the year-to-year variance in Indonesian paddy output, and that each degree of anomaly shifts output by about 1.3 to 1.4 Mt.⁷³ Water again ties the sectors together. In a dry year the same shortage lowers paddy yields, hydropower, and river freight. In a wet year the same excess floods paddies, mines, and roads.

⁷² Aldrian, E., and R.D. Susanto, 2003, "Identification of three dominant rainfall regions within Indonesia and their relationship to sea surface temperature," *International Journal of Climatology*, 23 (12), pp. 1435–1452; Lee, E., 2023, "El Niño expected to have minimal impact on palm oil production," *The Edge Malaysia*, (December 28, 2023), on the lag between drought and fruit production.

⁷³ Naylor, R.L., W.P. Falcon, N. Wada, and D. Rochberg, 2002, "Using El Niño–Southern Oscillation climate data to improve food policy planning in Indonesia," *Bulletin of Indonesian Economic Studies*, 38 (1), pp. 75–91; Falcon, W.P., R.L. Naylor, W.L. Smith, M.B. Burke, and E.B. McCullough, 2004, "Using climate models to improve Indonesian food security," *Bulletin of Indonesian Economic Studies*, 40 (3), pp. 355–377.

Channel	Transmission in the dry phase	Transmission in the wet phase	Principal indirect effect
Consumer prices	Rice and staple shortfalls pass through to prices	Perishables such as chili and shallots spike, and broken logistics raise costs	Higher headline inflation. Imports buffer staples well but perishables poorly, so the wet phase is harder to offset.
Household income and demand	Food and fuel costs cut real income, and rural incomes fall	Food prices, lost assets, and lost workdays cut real income	Softer consumption, and near-poor households slipping below the poverty line.
Public health	Haze from peat and forest fires	Water-borne and vector-borne disease after floods, and injuries	Respiratory illness and premature deaths in the dry phase, and disease outbreaks in the wet phase. Haze damage raises flood-season vulnerability.
Tourism	Haze, air-quality alerts, and flight cancellations	Flooded destinations and damaged transport	Fewer visitors and lower hotel revenue in affected regions.
Trade and exports	Low rivers delay coal and palm oil, and fire damages plantations	Flooded mines and ports cut coal and commodity exports	Lower export earnings, and pressure on the current account and the rupiah.
Production cost	Costlier power as hydropower falls, costlier freight	Costlier freight and inputs as roads and mines flood	Higher costs for manufacturing and services.
Public finances	Relief, subsidies, rice purchases, and lost revenue	Relief, reconstruction, lost mining royalties, and lost revenue	A wider deficit and less room for the other phase and for priority spending.
Reconstruction	Minor in the dry phase	Public rebuilding of houses, roads, and bridges	A fiscal cost that also adds demand and offsets part of the growth loss.

Table 3.2. The second wave in both phases: indirect channels through which the losses of El Niño and La Nina propagate.

The price level remains the master channel of the second wave. Food, beverages, and tobacco make up about a quarter of the consumer basket, and the volatile-food and administered-price components together make up close to two-fifths of it.⁷⁴ The two phases differ in how easily policy can offset a price shock. In a dry year the main shortfall is in rice, which can be stored and imported, so a well-stocked buffer can absorb much of it. In a wet year much of the shortfall is in perishables such as chili, shallots, and vegetables, which cannot be stored for long or shipped cheaply, so the same buffer works at about half strength. The 2010 experience shows the result. Rice, chili, and shallots together added close to two points to inflation that year, and the government imported 2.75 Mt of rice in 2011, the largest amount between 2000 and 2019.⁷⁵

Fire and flood also work through health, tourism, and trade. The haze of the dry phase settles into the lungs of millions of people, closes schools and airports, and crosses into Malaysia and Singapore. In early September 2026 Malaysia declared an air-quality emergency in Serian, Sarawak, where the air pollution index reached 521, and Singapore's 24-hour index reached the unhealthy range.⁷⁶ The floods of the wet phase damage water supply and sanitation and spread disease. The Senyar floods displaced about a million people at their peak.⁷⁷ Trade suffers in both phases. Low rivers in a dry

⁷⁴ Bank Indonesia, n.d., *Inflation*. <https://www.bi.go.id/en/fungsi-utama/moneter/inflasi/> (accessed on September 17, 2026).

⁷⁵ *Antara*, (January 3, 2011), *op. cit.*; Putri, A.M.H., 2022, "Jokowi impor beras, ini data lengkap era presiden sebelumnya," *CNBC Indonesia*, (December 18, 2022), citing BPS.

⁷⁶ Blackburn, G., 2026, "Malaysia declares air quality emergency as haze linked to Indonesia fires reaches critical," *Euronews*, (September 4, 2026); NEA (National Environment Agency, Singapore), 2026, "Haze situation update," (September 15, 2026).

⁷⁷ BNPB data as reported by *Katadata Databoks*, (December 2, 2025).

year and flooded pits in a wet year both cut coal shipments, while fire and waterlogging both cut palm-oil exports. Each loss of export earnings adds to the pressure on the rupiah.

All channels converge on the public accounts. In the dry phase the government buys and distributes rice, pays relief, and fights fires, while revenue from a slower rural economy softens. In the wet phase it pays relief again and then pays to rebuild, while mining royalties fall. When a La Nina follows an El Niño, the second bill arrives before the first has been absorbed. This is why the order of the two phases matters. Damage in the dry year weakens the capacity to respond in the wet year, and the physical scars of the dry year raise the damage of the wet year.

Indicator	Transmission to the indicator	Principal macroeconomic effect
Economic growth	Lost value added in exposed sectors, inter-industry spillovers, weaker demand, lower tourism and exports, and asset losses, partly offset by relief and reconstruction	A net subtraction from output. Cross-country evidence shows that El Niño lowers Indonesian activity, and that its effect persists for years.
Inflation	Staple shortfalls in the dry phase, perishable shortfalls in the wet phase, and higher production costs	Higher headline inflation. Dry-year inflation carries over into the wet year, so the wet year starts from a higher base.
Government budget	Relief, subsidies, rice purchases, and reconstruction, set against lower tax and royalty revenue	A wider deficit across two years, close to the 3 percent ceiling when the baseline is already high.
Employment	Crop failure, lost fishing days, flooded mines, and weaker demand	More underemployment and informal work, and slow recovery of jobs lost in the dry year.
Rupiah and external balance	Lower commodity exports and higher food imports	A weaker current account and pressure on the exchange rate.
Poverty and welfare	Food prices, lost income, and lost assets for near-poor households	More people below the poverty line. Households that sold assets in the dry year fall more easily in the wet year.

Table 3.3. The macroeconomic reckoning: how the losses of both phases register in the headline indicators.

Growth is the broadest measure. The IMF finds that an El Niño shock lowers Indonesian growth by 0.9 percentage points within two quarters and raises inflation.⁷⁸ Later work finds that the effect persists. Callahan and Mankin estimate global income losses of \$4.1 trillion for the 1982–83 El Niño and \$5.7 trillion for the 1997–98 event over five years, and find that Indonesia's output was still more than 10 percent below its counterfactual path years later.⁷⁹ The economic literature on La Nina in Indonesia is much thinner. What exists is event evidence, such as the 2010 inflation episode, the 2010 coal shortfall, and disaster loss records.⁸⁰ The model in this paper fills that gap with a structure that treats the two phases in the same way and calibrates the wet phase to these events.

Inflation, the budget, jobs, and poverty then follow. The IMF study finds that commodity prices rise after an El Niño, and Indonesia imports much of that rise because it buys rice, wheat, and fuel abroad.⁸¹ The fiscal cost is double-sided, with more spending and less revenue. Employment absorbs the shock through the quality of work, because agriculture still employs close to a third of the workforce and few workers have

⁷⁸ Cashin, P., K. Mohaddes, and M. Raissi, 2017, "Fair weather or foul? The macroeconomic effects of El Niño," *Journal of International Economics*, 106, pp. 37–54.

⁷⁹ Callahan, C.W., and J.S. Mankin, 2023, "Persistent effect of El Niño on global economic growth," *Science*, 380 (6649), pp. 1064–1069.

⁸⁰ Ministry of Finance (Badan Kebijakan Fiskal), 2023, press release on the fiscal cost of disasters, about Rp22.8 trillion a year, (July 10, 2023). <https://fiskal.kemenkeu.go.id/publikasi/siaran-pers-detil/507> (accessed on September 17, 2026); World Bank and GFDRR (Global Facility for Disaster Reduction and Recovery), 2011, *Indonesia: Advancing a National Disaster Risk Financing Strategy*, World Bank, Washington, DC.

⁸¹ Cashin, P., K. Mohaddes, and M. Raissi, 2017, *op. cit.*

unemployment insurance.⁸² Poverty is where the shock comes to rest. Food makes up about three-quarters of the poverty line, so higher food prices move people below it directly.⁸³ In 1998 the poverty rate rose to about 24 percent. Most of that rise came from the financial crisis, but the drought and the price of rice added to it.⁸⁴

Taken together, the two phases form one cycle. The dry year strikes the rain-bound sectors, burns the peat, and draws down stocks, budgets, and household savings. The wet year then strikes the same sectors, the same households, and the same budget, and finds each of them weaker. The model in the next section traces this cycle and measures how much the first phase adds to the damage of the second.

4 Simulating the Impacts

4.1 The State of the Indicators by Mid-October 2026

Fire on the Horizon was written in June, from the leading edge of the event. This paper is written from inside its peak. The fire season normally culminates in September and October, and in 2026 it has run through both. BMKG expects the rainy season to start late over 61 percent of the country's land area, and heavier rain over the fire provinces of Kalimantan only from mid-October. By late September only 5.7 percent of the season zones had entered the rainy season, and the BMKG outlook of October 8 still forecast low rain over central and southern Kalimantan.⁸⁵ The three tables below record where each register stands in mid-October 2026, and the fourth compares these readings with what the June paper expected.

4.1.1 The First Wave in the Data

The fire channel has moved the most. The official burned area, mapped from Landsat imagery and checked in the field, reached 202,011 ha for January to July 2026. July alone added 94,545 ha, almost three times the June figure.⁸⁶ This is more than the 137,007 ha of January to July 2019 and the 92,924 ha of January to July 2023, and well below the roughly 600,000 ha of the same months of 2015. The Minister of Forestry drew the same comparison in August.⁸⁷ These are partial-year figures. In 2019 and 2023, between 77 and 80 percent of the year's burning came after August, so the full-year comparison is still open. The official figures for August and September had not been published by mid-October, and both months burned heavily. On August 29 the satellites recorded 20,378 hotspots of all confidence levels, 8,488 of them in Central Kalimantan and 6,526 in West Kalimantan.⁸⁸ SiPongi recorded the highest daily count of the season

⁸² World Bank, n.d., "Employment in agriculture (percent of total employment) (modeled ILO estimate), Indonesia." <https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=ID> (accessed on September 17, 2026).

⁸³ BPS, 2026, "Indonesia poverty profile in September 2025," *Official Statistics News*, No. 19/02/Th. XXIX, (February 5, 2026).

⁸⁴ Hill, H., 2021, "What's happened to poverty and inequality in Indonesia over half a century?," *Asian Development Review*, 38 (1), pp. 68–97; Soekirman, S., 2001, "Food and nutrition security and the economic crisis in Indonesia," *Asia Pacific Journal of Clinical Nutrition*, 10 (1), pp. 57–61.

⁸⁵ Wibawana, W.A., 2026, *op. cit.*; Prasetyo, M.R.B.E., 2026, "BMKG prakirakan hujan berangsur turun di daerah rawan karhutla," *op. cit.*; *CNBC Indonesia*, (October 6, 2026), *op. cit.*; BMKG, 2026, weekly rainfall outlook for October 9 to 15, 2026, (October 8, 2026). <https://www.bmkg.go.id/cuaca/potensi-hujan-sepekan> (accessed on October 13, 2026). The 61 percent share refers to land area.

⁸⁶ Kementerian Kehutanan, 2026, SiPongi, "Indikasi luas kebakaran hutan dan lahan (ha)," data for January to July 2026. <https://sipongi.gakkum.kehutan.go.id/indikasi-luas-kebakaran> (accessed on September 17, 2026). Figures are cumulative, overwritten in place, and revised upward as verification proceeds.

⁸⁷ Statement by Minister of Forestry Raja Juli Antoni, (August 18, 2026), as reported in the Indonesian press.

⁸⁸ Kementerian Kehutanan, 2026, "Data terbaru Kemenhut, hotspot di Kalsel, Sumsel, Riau, dan Jambi turun," *Siaran Pers*, (August 30, 2026). High-confidence counts are much smaller. The ministry reported 946 on August 30.

so far on October 6, at 26,059 hotspots of all confidence levels.⁸⁹ Between August 13 and September 5, hotspots touched 185 of Indonesia's 881 protected areas, with Sebangau, Wasur, and Padang Sugihan among the most affected.⁹⁰ West and Central Kalimantan have declared emergencies and extended them into October, Banjar Regency in South Kalimantan declared one on October 9, and the government has named six priority provinces, Riau, Jambi, South Sumatra, and West, Central, and South Kalimantan.⁹¹

The water channels have also moved, and locally they have moved further than the model assumed. In South Sulawesi, output from the Poso, Bakar, and Malea hydropower plants fell from about 850 megawatts (MW) to about 250 MW, and the state electricity company Perusahaan Listrik Negara (PLN) prepared up to 627 MW of replacement generation.⁹² By late September PLN put the loss of hydropower capacity in southern Sulawesi at about 650 MW.⁹³ Falling water in Lake Toba threatens the hydropower plants that serve the smelter of Indonesia Asahan Aluminium (Inalum).⁹⁴ In mid-September its Siguragura and Tangga plants could deliver only 430 MW of their 603 MW.⁹⁵ On the Mahakam, the coal miner Indo Tambangraya Megah (ITMG) reports freight costs up 30 to 40 percent and volumes from its upstream mines down by the same share. Shallow water has stopped barges on the Barito, where more than half of the coal supply from Central Kalimantan was disrupted in the third quarter, and the Deputy Energy Minister reported that barges could not move in East Kalimantan and that fuel was being trucked across Kalimantan.⁹⁶ The food-crop channel has started to move. BPS estimates that rice output in August 2026 was 3.15 Mt, 2.90 percent below August 2025, and projects output for September to November at 7.06 Mt, 11.95 percent below the same months of 2025.⁹⁷ The main risk lies in the next wet-season crop, whose planting depends on rains that are now expected late.

⁸⁹ Kementerian Kehutanan, 2026, SiPongi+, "Sebaran titik panas," *op. cit.* The counts cover all NASA satellites and all confidence levels. Since early October the ministry's press releases report high-confidence counts only.

⁹⁰ Landscape Advisory analysis of NASA FIRMS hotspots over the World Database on Protected Areas, 13 August to 5 September 2026 (unpublished working file).

⁹¹ Helmi, I., 2026, "Kalimantan Barat perpanjang status tanggap darurat asap karhutla hingga 20 September 2026," *Kompas TV*, (September 10, 2026); "Kalteng resmi tetapkan status tanggap darurat karhutla," *Kalteng Maju*, (September 1, 2026), citing Antara; Oxtora, R., and S. Lucinda, 2026, "BPBD Kalbar perpanjang tanggap darurat karhutla hingga 18 Oktober 2026," *Antara*, (October 6, 2026), <https://www.antaranews.com/berita/5773080/bpbd-kalbar-perpanjang-tanggap-darurat-karhutla-hingga-18-oktober-2026>; Rizal, Y., 2026, "Pemkab Banjar tetapkan status tanggap darurat karhutla," *Antara Kalsel*, (October 9, 2026), <https://kalsel.antaranews.com/berita/538408/pemkab-banjar-tetapkan-status-tanggap-darurat-karhutla> (both accessed on October 13, 2026).

⁹² Savitri, P.I., 2026, "Bahil siapkan pembangkit pengganti PLTA Sulsel yang terdampak El Nino," *Antara*, (September 16, 2026); Syaharani, M., 2026, "Pasokan listrik tertekan, daya mampu PLTA Sulawesi bagian selatan anjlok 600 MW," *Katadata*, (September 15, 2026), <https://katadata.co.id/berita/energi/6aa8d15145207/pasokan-listrik-tertekan-daya-mampu-plta-sulawesi-bagian-selatan-anjlok-600-mw> (accessed on October 13, 2026). The 627 MW figure is PLN's.

⁹³ Djailani, M.F., and Y.A.A. Hutahut, 2026, "El Nino gerus PLTA, PLN kehilangan 650 MW di Sulawesi," *Suara*, (September 22, 2026), <https://www.suara.com/bisnis/2026/09/22/170000/el-nino-gerus-plta-pln-kehilangan-650-mw-di-sulawesi> (accessed on October 13, 2026).

⁹⁴ Rhamadanty, S.M., 2026, "Debit air Danau Toba susut, Inalum andalkan listrik PLTA Asahan 3," *Bloomberg Technoz*, (September 12, 2026), <https://www.bloombergtechnoz.com/detail-news/121325/debit-air-danau-toba-susut-inalum-andalkan-listrik-plta-asahan-3> (accessed on October 13, 2026).

⁹⁵ "Air Danau Toba susut, Inalum waswas," *Sumatera24Jam*, (September 16, 2026), reporting a hearing of DPR Commission XII. <https://www.sumatera24jam.com/2026/09/air-danau-toba-susut-inalum-waswas.html> (accessed on October 13, 2026).

⁹⁶ Purnama, I.D., 2026, "Sungai Mahakam surut, biaya angkut batu bara meroket hingga 40 persen," *Okezone*, (September 9, 2026); Purnama, A.Y.R., 2026, "Sungai Barito diramal pulih November, DMO batu bara tak terdampak," *Bloomberg Technoz*, (September 3, 2026); Savitri, P.I., 2026, "Wamen ESDM sebut angkutan batu bara terhambat sungai surut di Kaltim," *Antara*, (September 2, 2026); IMA (Indonesian Mining Association), 2026, news item on Barito coal shipments, (September 25, 2026), <https://ima-api.org/sungai-barito-surut-lebih-dari-50-pasokan-batu-bara-kalteng-terganggu/> (accessed on October 13, 2026).

⁹⁷ *CNBC Indonesia*, (October 4, 2026), *op. cit.*, citing the BPS release of October 1, 2026.

Indicator (first wave)	Where it stands (mid-October 2026)	Direction
Food crops (rice)	August rice output –2.90 percent y/y. September to November projected at 7.06 Mt, –11.95 percent y/y. Late rains threaten wet-season planting.	Turning down, risk moving to the 2027 harvest
Estate crops (palm oil)	The Indonesian Palm Oil Association (Gabungan Pengusaha Kelapa Sawit Indonesia, GAPKI) projects crude palm oil output to fall by about 2 Mt in 2027, to 51.73 Mt, after warning in August of a loss of up to 3 Mt. October reference price for crude palm oil \$1,042.15 per ton, up from \$1,007.51 in September. USDA cut its 2026–27 output forecast by 2.2 Mt to 45 Mt.	Lagged loss building
Fisheries	Fresh fish among the contributors to July and August inflation.	Early price signal
Forestry and peatland (fire and haze)	202,011 ha burned in January to July (2019 137,007; 2023 92,924; 2015 about 600,000). 20,378 hotspots on August 29. 1.16 million SiPongi hotspots to October 12. Emergencies in West and Central Kalimantan, extended into October. 185 protected areas touched.	Rising, at or near peak
Water and hydropower	South Sulawesi hydropower down from about 850 MW to 250 MW. About 650 MW of hydropower capacity lost in southern Sulawesi. Lake Toba low, with the Asahan plants at 430 of 603 MW. Local water crises in Java and in Samarinda.	Stressed, locally severe
River transport	Barges stopped on the Barito. Mahakam coal freight costs and volumes both 30 to 40 percent worse. Fuel trucked across Kalimantan.	Disrupted, recovery expected in November
Wet-phase sectors	Not yet active. El Niño expected to last into March to May 2027.	Latent, conditional on a La Nina

Table 4.1. The first wave at mid-October 2026: where the direct, physical channels stand.

4.1.2 The Second Wave in the Data

The price channel has moved less than the June paper expected. Headline inflation was 3.28 percent in September, only about 0.4 points above the 2.9 percent baseline in the model, and volatile food inflation rose to 5.03 percent.⁹⁸ Rice stocks explain much of the difference. The rice stocks of the State Logistics Agency (Badan Urusan Logistik, Bulog) stood at about 4.5 Mt in early October, down from a peak of almost 5.4 Mt in August,⁹⁹ and the Agriculture Minister has said that no rice for consumption will be imported in 2026.¹⁰⁰ The government has added 1 Mt of price-stabilization rice through December and 1 Mt of food aid for October to December, at 10 kilograms a month for 33.2 million families.¹⁰¹ Rice prices are still rising, and the average retail price reached Rp15,769 per kilogram in September, 3.73 percent above a year earlier.¹⁰²

The health channel has moved sharply. The Ministry of Health recorded 113,336 cases of acute respiratory infection linked to the fires in 63 districts of seven provinces by September 9, up from 50,891 on September 1, and 26,545 of them were children

⁹⁸ Melani, A., 2026, *op. cit.*

⁹⁹ Sidik, H., 2026, "Bulog sebut cadangan beras pemerintah capai 4,5 juta ton," *Antara*, (October 1, 2026), <https://www.antaranews.com/berita/5766631/bulog-sebut-cadangan-beras-pemerintah-capai-45-juta-ton>; Savitri, P.I., 2026, "Bulog catat puncak stok beras 5,4 juta ton pada 2026," *Antara*, (October 8, 2026), <https://www.antaranews.com/berita/5777001/bulog-catat-puncak-stok-beras-54-juta-ton-pada-2026> (both accessed on October 13, 2026).

¹⁰⁰ Yudha, T., 2026, "Stok melimpah, Amran pastikan tidak ada impor beras konsumsi," *Okezone*, (June 20, 2026). <https://economy.okezone.com/read/2026/06/20/320/3225597/stok-melimpah-amran-pastikan-tidak-ada-impor-beras-konsumsi> (accessed on October 13, 2026); Riswan, K.K., 2026, "Indonesia says no rice imports planned for 2026 amid El Niño threat," *Antara News*, (August 10, 2026).

¹⁰¹ Government announcement of September 10, 2026, as reported in the Indonesian press.

¹⁰² Rahman H., A., 2026, "BPS: harga beras naik September 2026, eceran tembus Rp15.769 per kg," *Liputan6*, (October 1, 2026). <https://www.liputan6.com/bisnis/read/8303768/bps-harga-beras-naik-september-2026-eceran-tembus-rp-15769-per-kg> (accessed on October 13, 2026).

under five.¹⁰³ By September 21 the ministry had recorded 174,694 cases, 40,363 of them in children under five.¹⁰⁴ By October 12 the count had reached 277,075 cases in six provinces, 62,400 of them in children under five.¹⁰⁵ West Kalimantan alone had reported 62,278 cases by September.¹⁰⁶ Air quality reached hazardous levels in many places. The air pollutant standard index (Indeks Standar Pencemar Udara, ISPU) for coarse particulate matter (PM10) reached 1,111 in Kotawaringin Timur on the morning of September 10, and the index reached 328 in Pontianak on August 27. On October 13 the index for fine particulate matter (PM2.5) reached 4,055 in Palangka Raya.¹⁰⁷ Landscape Advisory's own health cost model, which values premature deaths from fire smoke in Sumatra and Kalimantan, puts the full-season cost near Rp170 trillion, with a wide interval of Rp70 trillion to Rp410 trillion.¹⁰⁸ The same model attributes about 15,700 premature deaths and some 199,000 years of life lost to the smoke of the season.¹⁰⁹ The Center of Economic and Law Studies (CELIOS) estimates the cost of the fires, based on the area burned by July, at Rp39 trillion to Rp123 trillion.¹¹⁰ Tourism has held up at the national level, with about 1.6 million foreign arrivals in August, 6.27 percent more than a year earlier, but flights have been cancelled in Pontianak and Palangka Raya.¹¹¹ Between August 11 and October 9 the Ministry of Transportation recorded 1,673 flights affected by smoke, 907 of them cancelled or postponed.¹¹² The haze also crossed borders. Singapore's 24-hour Pollutant Standards Index reached 192 on October 9, its highest of 2026, and schools closed across much of peninsular Malaysia.¹¹³

¹⁰³ Prasetyo, M.R.B.E., 2026, "Kemenkes catat 113 ribu kasus ISPA akibat karhutla di tujuh provinsi," *op. cit.*

¹⁰⁴ Purnamasari, D.M., 2026, "Kemenkes temukan 174.694 kasus ISPA akibat karhutla," *IDN Times*, (September 23, 2026), <https://www.idntimes.com/news/indonesia/kemenkes-temukan-174-694-kasus-ispa-akibat-karhutla-00-9c71q-q4w13> (accessed on October 13, 2026).

¹⁰⁵ Hikmatiar, T.R., 2026, "277.075 kasus ISPA terdeteksi di 6 wilayah terdampak karhutla, 62.400 kasus dialami usia 0–5 tahun," *JawaPos*, (October 14, 2026).

<https://www.jawapos.com/nasional/2610130387/277075-kasus-ispa-terdeteksi-di-6-wilayah-terdampak-karhutla-62400-kasus-dialami-usia-0-5-tahun> (accessed on October 13, 2026). The count covers South Kalimantan, South Sumatra, West Kalimantan, Riau, Central Kalimantan, and East Kalimantan.

¹⁰⁶ "Kasus ISPA di Kalbar tembus 62.278," *Ruai TV*, (September 2026).

¹⁰⁷ Ayuningtyas, A.D., 2026, "Wilayah Kalimantan masih dikepung polusi udara berbahaya pagi ini, cek daftarnya," *Katadata*, (September 10, 2026), <https://katadata.co.id/berita/nasional/6aa20097c881c/wilayah-kalimantan-masih-dikepung-polusi-udara-berbahaya-pagi-ini-cek-daftarnya>; Prayoga, N., 2026, "Kabut asap karhutla di Pontianak berstatus bahaya," *iNews*, (August 29, 2026); Wirawan, N.A., 2026, "Rekor ISPU Palangka Raya tembus 4.055, paling berbahaya se-Indonesia," *detikKalimantan*, (October 13, 2026), <https://www.detik.com/kalimantan/berita/d-8705036/rekor-ispu-palangka-raya-tembus-4-055-paling-berbahaya-se-indonesia> (both accessed on October 13, 2026).

¹⁰⁸ Landscape Advisory, 2026, karhutla health cost model, unpublished working model (August 27, 2026). The estimate rests mostly on a value of statistical life and should be read as a welfare valuation. A cost-of-illness subtotal that excludes mortality is about Rp3.4 trillion.

¹⁰⁹ Landscape Advisory, 2026, "What the smoke costs," *Occasional Fact Sheet*, (August 27, 2026).

<https://landscape.id/docs/ofs-aug-27-2026.pdf> (accessed on October 13, 2026). The domain is Sumatra and Kalimantan, and the central case assumes 720,000 ha burned over the season.

¹¹⁰ Laia, K., 2026, "Kerugian akibat karhutla 2026 bisa tembus Rp123 T," *Betahita*, (September 4, 2026), reporting CELIOS.

¹¹¹ Saputra, S.D., 2026, "Kunjungan wisman ke Indonesia naik 6,27 persen jadi 1,6 juta pada Agustus 2026," *Investortrust*, (October 1, 2026), <https://investortrust.id/nasional/118028/kunjungan-wisman-ke-indonesia-naik-6-27-jadi-1-6-juta-pada-agustus-2026> (accessed on October 13, 2026); Jeckmus, 2026, *op. cit.*

¹¹² Putra, I.R., 2026, "Imbas asap karhutla, 907 penerbangan batal, 10 maskapai terdampak," *Liputan6*, (October 13, 2026), <https://www.liputan6.com/bisnis/read/8311929/imbasa-asap-karhutla-907-penerbangan-batal-10-maskapai-terdampak>; "Kemenhub catat 1.673 penerbangan terdampak karhutla," *GoRiau*, (October 12, 2026), <https://www.gorau.com/berita/baca/kemenhub-catat-1673-penerbangan-terdampak-karhutla-rute-malaysiasingapura-turut-dibatalkan.html> (both accessed on October 13, 2026). The count covers August 11 to October 9.

¹¹³ Alfianto, R., 2026, "Gara-gara karhutla Indonesia, Singapura catat kualitas udara terburuk di 2026," *JawaPos*, (October 13, 2026), <https://www.jawapos.com/internasional/2610130159/gara-gara-karhutla-indonesia-singapura-catat-kualitas-udara-terburuk-di-2026>; Bernama, 2026, "Haze crisis worsens as unhealthy API readings force sweeping school closures in Putrajaya, Selangor and Rompin," *Malay Mail*, (October 9, 2026), <https://www.malaymail.com/news/malaysia/2026/10/09/haze-crisis-worsens-as-unhealthy-api>

Indicator (second wave)	Where it stands (mid-October 2026)	Direction
Consumer prices and inflation	Headline 3.28 percent (September), core 2.84, volatile food 5.03. Contributors include chili, chicken, rice, and eggs.	Rising slowly, within target
Household welfare and demand	Q2 household consumption +5.06 percent. Bulog stock 4.5 Mt (early October). 1 Mt of stabilization rice and 1 Mt of food aid for October to December. Retail rice Rp15,769 per kilogram (September).	Supported by stocks and aid
Public health	277,075 respiratory infection cases in six provinces by October 12, 62,400 of them in children under five. Schools in Palangka Raya moved online. Haze emergency in Sarawak, school closures across peninsular Malaysia, and a 2026 high of 192 on Singapore's PSI (October 9).	Severe, rising
Tourism	August arrivals about 1.6 million (+6.27 percent y/y). 1,673 flights affected by smoke between August 11 and October 9, 907 cancelled.	Nationally firm, locally hit
Trade and exports	January to August surplus \$7.25 billion. August surplus \$3.55 billion after a July surplus of only \$0.12 billion. Imports up 19.84 percent in January to August. Coal and palm-oil barges delayed.	Thinning
Production cost	Hydropower shortfall in South Sulawesi, costlier freight on the Mahakam and Barito.	Rising regionally
Public finances	Deficit 1.24 percent of GDP to September, full-year outlook about 2.8 percent. Disaster budget raised to Rp1.1 trillion. BNPB requests Rp5.67 trillion more in on-call funds.	Widening, close to the ceiling

Table 4.2. The second wave at mid-October 2026: where the indirect channels stand.

4.1.3 The Macroeconomy in the Data

At the top of the economy, the shock is not yet visible. Growth in Q2 was 5.29 percent, above the 5.0 percent counterfactual used in the model. Third-quarter data, which will cover the peak of the fire season, will be released in November. Inflation is inside its band. Unemployment and poverty data were last collected before the dry season, so they cannot yet show any effect. The deficit reached 1.24 percent of GDP by September, and the full-year outlook of 2.8 to 2.85 percent is 0.1 to 0.2 points of GDP above the budget.¹¹⁴ The rupiah and the policy rate reflect pressures that began before the El Niño.

Indicator (macro)	Where it stands (mid-October 2026)	Direction
Economic growth	Q2 5.29 percent y/y, H1 5.45 percent. Full-year forecasts 5.2 percent (World Bank), 5.1 percent (IMF), up to 6.0 percent (government).	Firm, slowing
Inflation	3.28 percent in September, up from 3.19 percent in August.	Rising within the band
Government budget	Deficit of 1.24 percent of GDP to September. Full-year outlook about 2.8 percent. 2027 budget passed with a deficit of 2.40 percent.	Widening
Employment	Open unemployment 4.68 percent (February 2026). Agriculture 3.80 percent growth in Q2.	No post-shock data
Rupiah and external balance	About Rp17,900 per dollar in early October, after an intraday record of Rp18,201 in June. Reserves \$146.3 billion (September). BI rate 5.75 percent.	Stabilized, fragile
Poverty and welfare	8.07 percent, 22.93 million people (March 2026).	No post-shock data

Table 4.3. The macroeconomy at mid-October 2026: a firm headline with no post-shock readings yet.

readings-force-sweeping-school-closures-in-putrajaya-selangor-and-rompin/238306 (both accessed on October 13, 2026).

¹¹⁴ Wahyudi, E., 2026, "APBN September 2026 defisit Rp319 triliun, Menkeu klaim masih on track," *Fortune IDN*, (October 9, 2026). <https://www.fortuneidn.com/news/apbn-september-2026-defisit-rp319-triliun-menkeu-klaim-masih-on-track-00-my5jv-0tlf92> (accessed on October 13, 2026).

4.1.4 Validation of the June Prognosis

Table 4.4 sets the June prognosis for a super El Niño beside the evidence to date. The physical channels have arrived as expected, and on the rivers and in the hydropower of South Sulawesi they have arrived harder. The price, growth, and poverty channels have not yet moved as expected. Three reasons explain most of the gap. First, the food-import buffer in the June central run was set at a moderate 40 percent, while Bulog entered the season with high stocks, which is closer to a strong buffer. Running the model with an 80 percent buffer lowers the modeled inflation rise for a super El Niño from 4.4 points to 2.0 points. Second, the June model was annual, and the second wave peaks two to three quarters after onset. The dated layer of ENSONINAD26, described below, makes this timing explicit. In the central case it puts headline inflation at 3.2 percent in July to September 2026, close to the 3.28 percent observed in September, and places the peak at 10.8 percent in April to June 2027. For a super El Niño alone, it gives 3.1 percent for July to September 2026 and a peak of 7.3 percent in April to June 2027. Third, the rice harvest effect is lagged. The crops harvested so far were planted before the drought, and the crop at risk is the one that should be planted in the coming months. The June prognosis therefore holds for the physical first wave, overstated the speed of the price channel, and remains open on growth, jobs, and poverty.

Indicator	June prognosis (super El Niño)	Observed to mid-October 2026	Assessment
Fire and haze	Forestry and peat output –16 percent. Health and tourism costs 0.66 percent of GDP.	202,011 ha burned by July. 1.16 million SiPongi hotspots to October 12. 277,075 respiratory cases by October 12. Transboundary haze.	Confirmed, still rising
Food crops	Output –10 percent	Rice August –2.90 percent, September to November –11.95 percent (projected)	Emerging, larger risk in 2027
Estate crops	Output –5 percent, mostly lagged	Industry expects about 2 Mt less crude palm oil in 2027, about 4 percent	Consistent
Hydropower and water	Output –12 percent	South Sulawesi hydropower down about 70 percent	Confirmed, locally stronger
River transport	Output –8 percent	Mahakam coal volumes –30 to –40 percent, barges stopped on the Barito	Confirmed, locally stronger
Inflation	+4.4 points	About +0.4 points (3.28 percent in September), against +0.3 points in the dated central case for July to September	Lower so far, as the dated path expects
Growth	–0.68 points	Q2 5.29 percent, no visible drag	Not yet visible
Deficit	+0.60 points of GDP	Outlook widened by 0.1 to 0.2 points, disaster budget raised	Direction confirmed
Jobs and poverty	3.5 million livelihoods stressed, 1.5 million more poor	No post-shock survey yet	Not yet measurable

Table 4.4. Validation of the June prognosis for a super El Niño against observed events to mid-October 2026.

4.2 The System Dynamics Simulation Model

4.2.1 Model Architecture and the Causal Loop Diagram

System dynamics explains the behavior of a system through the structure of its connections, that is, its stocks, flows, feedback loops, and delays.¹¹⁵ The approach suits a climate shock because the shock spreads across sectors, returns through feedback, and unfolds with lags. *Fire on the Horizon* used ENSOID26, an annual model of the El Niño phase of ENSO. This paper uses ENSONINAID26, which covers both phases and places them on the calendar. ENSONINAID26 extends ENSOID26 in four ways. It adds a wet chain driven by La Nina, tropical cyclones, multi-year La Nina duration, and upstream watershed degradation. It links the two phases through nine cross-phase links, so that the dry year conditions the wet year. It adds an adaptation layer of fifteen levers in four approaches. With the adaptation layer switched off and the mode set to El Niño only, ENSONINAID26 reproduces ENSOID26 exactly, so the El Niño results of the June paper carry over unchanged.¹¹⁶

The fourth extension is a dated quarterly layer. ENSOID26 returns one set of results for a stylized event year, and its time chart counts quarters from the onset of the event. ENSONINAID26 places the two phases on the calendar from January 2026 to June 2029. It anchors the first three quarters of 2026 to the observed ONI, lets the user set the quarter in which each phase peaks, and shows in which quarter each loss is likely to arrive. Its El Niño range runs to +3.8°C, against +3.5°C in ENSOID26, with a default of +3.1°C, so that it covers the forecasts that put the 2026 peak above any observed event. The dated layer redistributes the annual results over time and leaves their size unchanged. When the two peaks fall four quarters apart, the quarterly values add back to the annual totals, so the annual and dated results in this paper agree.¹¹⁷

The new model also changes four assumptions of the June paper. First, the 2026 El Niño follows the observed ONI to September, and its peak is set at +3.1°C in October to December 2026, in line with current forecasts. ENSOID26 ran hypothetical events of a chosen strength. Second, a La Nina follows. The central case assumes a La Nina of −1.5°C that peaks a year after the El Niño, because no agency yet forecasts its timing or strength. Third, losses arrive with lags. Fire, hydropower, and river transport respond in the quarter of the hazard, food crops two quarters later, and estate crops three quarters later, where ENSOID26 booked all of them in the event year. Fourth, the dry year conditions the wet year through the nine cross-phase links, and most of these links fade when the two peaks are further apart.

¹¹⁵ Forrester, J.W., 1961, *Industrial Dynamics*, MIT Press, Cambridge, MA; Sterman, J.D., 2000, *Business Dynamics: Systems Thinking and Modeling for a Complex World*, Irwin/McGraw-Hill, Boston; Meadows, D.H., 2008, *Thinking in Systems: A Primer*, Chelsea Green Publishing, White River Junction, VT.

¹¹⁶ Landscape Advisory, 2026, *ENSONINAID26 Dated ENSO Cycle Model*, interactive model file, Landscape Advisory, Jakarta. The model and its source code are available on the Landscape website.

¹¹⁷ *Ibid.* With the two phase peaks four quarters apart, the dated quarterly values add back to every annual result in this paper.

Causal loop diagram of the ENSONINAID26 model

El Niño (dry) and La Nina (wet) chains feeding a shared second wave and a shared macroeconomic reckoning, Indonesia

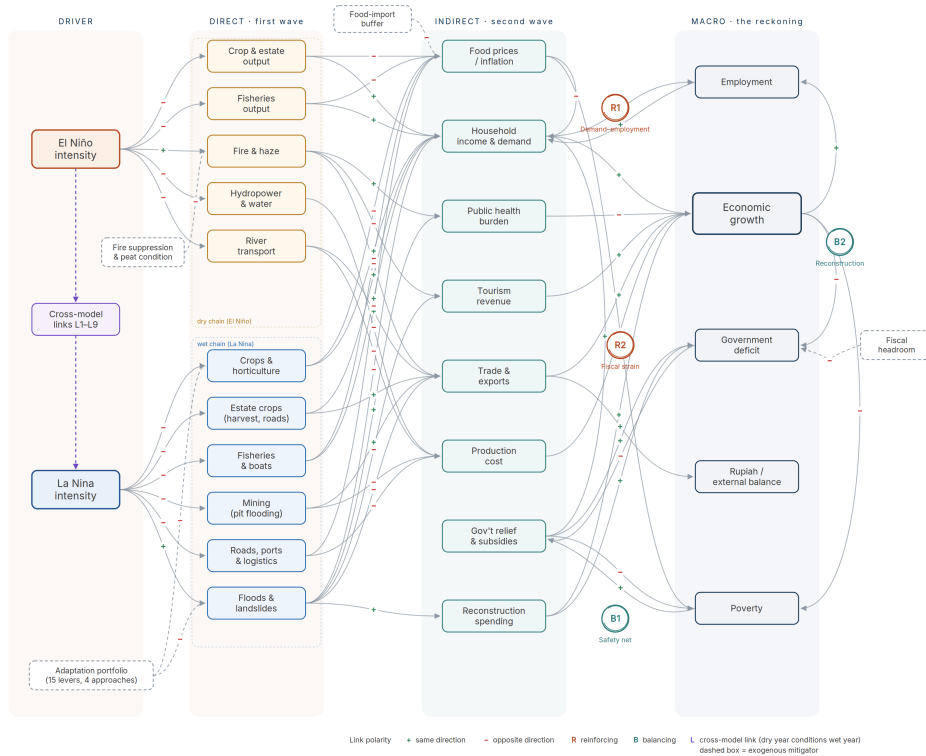


Figure 4.1. Causal loop diagram of the ENSONINAID26 model. Variables run left to right from the drivers (El Niño and La Nina intensity) through the direct first-wave sectors of each phase, the shared indirect second-wave channels, and the five macroeconomic outcomes. A "+" link means that the two variables move in the same direction and a "-" link that they move in opposite directions. Loops are marked R (reinforcing) or B (balancing). Dashed boxes are exogenous mitigators. The purple dashed link carries the nine cross-phase links through which the dry year conditions the wet year.

Figure 4.1 shows the causal loop diagram. The drivers sit on the left. The El Niño chain runs through five exposed sectors, crops and estate crops, fisheries, fire and haze, hydropower and water, and river transport. The La Nina chain runs through six, crops and horticulture, estate crops, fisheries and boats, mining, roads, ports and logistics, and floods and landslides. Both chains feed one shared second wave of eight channels and one shared set of five macroeconomic outcomes. Each arrow carries a polarity. A plus sign means that the two variables move in the same direction, and a minus sign means that they move in opposite directions. Multiplying the signs along a path gives the net direction of influence along that path. The dashed boxes are exogenous mitigators, namely the food-import buffer, fire suppression and peat condition, fiscal headroom, and the adaptation portfolio. The purple link marks the cross-phase connections.

4.2.2 Links and Equations

The annual engine of the model is a reduced-form system calibrated to national aggregates. Its main relationships are set out below, with all losses expressed as fractions of output or of GDP. The intensity of each phase is the absolute value of the ONI, scaled by a teleconnection factor that measures how strongly the Pacific signal reaches the archipelago.

Direct sectoral losses follow a capped power function of intensity. For the El Niño chain, with a reference intensity of 2.0°C,

$$L(s) = \min[m(s), a(s) \times (ONI / 2.0)^{c(s)}]$$

where $L(s)$ is the output loss of sector s , $a(s)$ is the loss at the reference intensity, $c(s)$ sets the curvature, and $m(s)$ caps the loss. The values are 10 percent, 1.4, and 22 percent for food crops, 5 percent, 1.3, and 12 percent for estate crops, 6 percent, 1.2, and 15 percent for fisheries, 12 percent, 1.3, and 30 percent for hydropower, and 8 percent, 1.3, and 22 percent for river transport. For the La Nina chain the reference intensity is 1.5°C , close to the 2010–11 event, and the losses are scaled by cyclone activity (k , from 0 to 1), watershed degradation (g , with 1 equal to today), and the number of consecutive La Nina years (n),

$$L(s) = \min[m(s), a(s) \times (|ONI| / 1.5)^{c(s)}] \times \text{modifiers}(s) \times [1 + 0.5 (n - 1)]$$

with base values of 4 percent for crops (modifier $(1 + 0.2k) \times g$), 3 percent for estate crops, 4 percent for fisheries (modifier $1 + 0.5k$), 5 percent for mining, and 2.5 percent for transport (modifier $(1 + 0.4k) \times g$). Value-added losses equal each sector's loss times its share of GDP, which is 3.0 percent for food crops, 3.5 percent for estate crops, 2.6 percent for fisheries, 1.2 percent for hydropower and water (of which 60 percent is exposed), 0.5 percent for river transport, 2.5 percent for mining, and 2.0 percent for transport.

Asset damage is modeled separately. Fire and haze damage F and flood and landslide damage D , both in percent of GDP, are

$$F = \min[2.6, 1.9 \times (ONI / 2.4)^2 \times s(f)]$$

$$D = \min[1.2, 0.45 \times (|ONI| / 1.5)^{1.6} \times (0.7 + 0.6k) \times g \times (1 - b)] \times [1 + 0.5 (n - 1)]$$

where $s(f)$ is the fire sensitivity, which falls with stronger suppression or wetter peat, and b is the flood buffer provided by reservoirs that the preceding drought has drawn down. The fire function is anchored to the World Bank's estimate of 1.9 percent of GDP for 2015, and the flood function to a strong La Nina with moderate cyclone activity, at about 0.45 percent of GDP.¹¹⁸ In the model, 30 percent of fire damage is a health cost, 20 percent a tourism cost, and 20 percent a trade cost. For floods the shares are 15, 10, and 20 percent, and a further 25 percent of flood damage spills over to other industries. Reconstruction spending equals 35 percent of flood damage.

The second wave begins with the food supply shortfall S , which is 0.7 of the crop loss plus 0.15 of the fisheries loss plus 0.05 of the estate loss in the dry phase, and 0.7 of the crop loss plus 0.2 of the fisheries loss plus 0.4 of the transport loss in the wet phase. The food price rise is

$$\Delta P(\text{food}) = \min[35 \text{ percent}, S \times (1 - \mu \times e) / 0.45 \times (1 + z)]$$

where μ is the food-import buffer, e equals 1 in the dry phase and 0.5 in the wet phase because perishables are hard to import, and z is the cross-phase stock-depletion link. Headline inflation rises by

$$\Delta \pi = 0.25 \Delta P(\text{food}) + 0.035 \Delta P(\text{food}) + 0.13 \Delta P(\text{admin}) + 0.0375 \Delta P(\text{food}) + 0.05 \times C$$

where the terms are the direct food weight in the consumer basket, the pass-through into processed goods, administered prices such as electricity, second-round effects, and the production cost index C . If headline inflation exceeds 3.5 percent, BI raises its

¹¹⁸ World Bank, 2016, *op. cit.*; the flood anchor is scaled from Bappenas, BNPB, and CELIOS event data, and sits above the ordinary-year average of 0.1 to 0.3 percent of GDP and above the 0.29 percent GDP loss that CELIOS estimated for the Senyar floods. CELIOS (Center of Economic and Law Studies), 2025, "Dampak kerugian ekonomi bencana banjir Sumatera," (December 1, 2025). <https://celios.co.id/dampak-kerugian-ekonomi-bencana-banjir-sumatera/> (accessed on September 17, 2026).

rate by half the excess, up to 1.5 points, and each point of tightening costs 0.3 percent of GDP. Household demand falls with the real-income squeeze, rural income losses, and household asset losses, net of relief and reconstruction stimulus,

$$\Delta D = \max(0, 0.1375 \Delta \pi + R(\text{rural}) + h \times A - 0.4 G - 0.3 K) / (1 - 0.15)$$

where G is the fiscal offset from relief, K is reconstruction stimulus, and the divisor is the multiplier of the demand and employment loop. Inter-industry losses equal 70 percent of each sector's value-added loss times its output multiplier minus one, with type II multipliers of 1.4 to 1.8. The growth effect is

$$\Delta g = 0.26 \times [\Sigma VA + 0.6 I + \text{tourism} + 0.5 \text{trade} + 0.5 \Delta D + 0.04 C + 0.15 A + \text{monetary drag} - 0.3 K] - 0.4 G$$

where ΣVA is the sum of value-added losses, I the inter-industry losses, and A the asset damage. Unemployment rises by 0.18 points per point of demand loss plus 0.15 points per point of growth loss. The deficit widens by relief spending, reconstruction, the cost of food imports, and lost revenue at a tax ratio of 12 percent, plus lost mining royalties in the wet phase. The poverty rate rises by

$$\Delta \text{pov} = [0.051 \Delta P(\text{food}) + 0.12 \Delta u + 0.4 D - \text{relief effect}] \times (1 + \text{scarring}) \times (1 - \text{social protection})$$

Net economic damage equals direct value-added losses plus asset damage plus inter-industry losses, minus half the fiscal offset. It is a welfare and cost concept comparable to the World Bank's accounting of the 2015 fires, and it is larger than the growth effect because much of the damage is a loss of assets and health rather than of annual output. In the full-cycle mode the model runs an El Niño year followed by a La Nina year. Damage, the growth loss, and the deficit are summed over the two years. Inflation, jobs, and poverty are reported at the peak year, and the current account at the weaker year.

The adaptation layer reduces specific loss channels. Each lever l , implemented at a share $a(l)$ of its achievable potential, cuts channel c by up to a maximum share $e(l, c)$. Overlapping levers combine multiplicatively, so that the retained share of each channel is the product of $(1 - e(l, c) \times a(l))$ across all levers, and the reduction can never exceed 100 percent.

4.2.3 Feedback Loops and Cross-Phase Links

Four feedback loops shape the path of the shock. R1, the demand and employment loop, is reinforcing. Weaker household demand reduces employment, which lowers income and weakens demand further. R2, the fiscal strain loop, is also reinforcing. Relief, reconstruction, and lost revenue widen the deficit and draw down fiscal headroom, which leaves less for the next response. B1, the safety net loop, is balancing. Relief and subsidies cushion demand and pull the poverty headcount back down. B2, the reconstruction loop, is new in ENSONINAIID26 and also balancing. Public rebuilding after floods adds demand and offsets part of the growth loss, although it widens the deficit at the same time.

Nine cross-phase links carry the dry year into the wet year. Only one of them, the reservoir buffer, dampens the wet-year damage. The other eight amplify it. Table 4.5 lists them with their values under the super and record scenarios. The compound effect of the cycle equals the damage of the full cycle minus the sum of the two phases run alone.

Link	Mechanism	Super ($\pm 2.0^{\circ}\text{C}$)	Record ($\pm 2.6^{\circ}\text{C}$)
L1 Fire scars and runoff	Burned peat and forest raise runoff and landslide risk. Peat rewetting and reforestation weaken the link.	+25 percent runoff	+32.5 percent runoff
L2 Reservoir drawdown	Reservoirs emptied by drought absorb part of the first floods. This is the only balancing link.	–8.0 percent flood peak	–9.6 percent flood peak
L3 Palm yield lag	Half of the drought-driven palm-oil loss lands in the wet year.	+2.5 points estate loss	+3.5 points estate loss
L4 Depleted food stocks	Stocks drawn down in the dry year raise the price response to wet-year shortfalls.	+15 percent price response	+21 percent price response
L5 Inflation carry-over	35 percent of dry-year inflation persists into the wet year.	+1.53 points starting consumer price index (CPI)	+2.18 points starting CPI
L6 Fiscal headroom erosion	Dry-year deficits shrink the room for wet-year relief. This extends R2.	–30 percent relief capacity	–36 percent relief capacity
L7 Household scarring	Households that sold assets in the dry year fall below the line more easily in the wet year.	+26 percent poverty response	+39 percent poverty response
L8 Lingering job losses	Part of the dry-year job losses has not recovered when the wet year begins.	30 percent persist	30 percent persist
L9 Haze and flood disease	Respiratory damage from haze raises the disease burden after floods.	+20 percent health cost	+26 percent health cost

Table 4.5. Cross-phase links in ENSONINAID26 and their values in the super and record full-cycle scenarios.

4.2.4 The Dated Quarterly Layer

The dated layer works in three steps. It builds a quarterly ONI path, turns that path into seasonal hazard indices, and spreads the annual results of each phase over the quarters in proportion to those indices, with a lag for each channel.

The El Niño contributes its peak intensity times a template of 0.3, 0.7, 1.0, 0.8, 0.4, and 0.1 for the quarters from two before to three after its peak. The La Nina contributes its peak intensity times 0.25, 0.65, 1.0, 0.75, 0.35, and 0.1 around its own peak, and the two contributions are combined. For January to September 2026 the path takes the observed values of -0.21 , $+0.95$, and $+2.16^{\circ}\text{C}$. With a peak of $+3.1^{\circ}\text{C}$ in October to December, the template alone reproduces the observed values for April to June and July to September within 0.02°C . The hazard indices in quarter q are

$$\begin{aligned}
 H(\text{fire}, q) &= \min[1.3, (\text{ONI}(q) / 2.0)^{1.8}] \times w(\text{fire}, q) \\
 H(\text{dry}, q) &= \min[1.2, (\text{ONI}(q) / 2.0)^{1.2}] \times w(\text{dry}, q) \\
 H(\text{wet}, q) &= \min[1.6, (-\text{ONI}(q) / 1.5)^{1.3}] \times w(\text{wet}, q)
 \end{aligned}$$

where w is a seasonal weight. For January to March, April to June, July to September, and October to December, the weights are 0.15, 0.25, 1.0, and 0.55 for fire, 0.2, 0.4, 1.0, and 0.8 for drought, and 1.0, 0.45, 0.2, and 0.85 for wet hazard. The fire weights follow the July to October fire season and allow for burning in late-onset years. The wet weights follow the December to March peak of the monsoon. Each phase draws only on its own window. The dry hazards count until the La Nina peak, and the wet hazard counts from the El Niño peak onward, so that a cool reading early in 2026 adds no La Nina damage.

Each annual total is then spread over the quarters. Fire and haze damage follows the fire hazard. Hydropower and river transport follow the drought hazard in the same quarter, food crops and fisheries follow it two quarters later, and estate crops three quarters later. In the wet phase, fisheries, mining, and transport follow the wet hazard at once, food crops one quarter later, and estate crops two quarters later. Inter-industry losses follow

the direct losses over three quarters with weights of 0.4, 0.4, and 0.2. Food prices follow the supply shock with a lag of one to two quarters, headline inflation follows food prices, and the GDP gap, jobs, and poverty follow the direct losses. Each quarterly series is scaled to its annual total, so the quarterly values add back to the annual results.

The two phases are then combined. Damage, the growth loss, and the deficit are flows, and they add across the phases. Inflation, food prices, jobs, and poverty are levels, and each quarter takes the higher of the two phases, so that the same households and prices are counted once. Seven of the nine cross-phase links fade by half for each year that the La Nina peak falls more than four quarters after the El Niño peak. The fire-scar link L1 and the palm lag L3 keep their full value, because burned land and delayed yields persist.

4.2.5 Assumptions and Data Sources

The model rests on published anchors where they exist and on stated judgments where they do not. Table 4.6 lists the main parameters. Nominal GDP is set at about Rp22,000 trillion, or \$1.37 trillion, and the population at 284 million, with 144 million workers, 39 million of them in agriculture. The rupiah equivalents of modeled dollar figures in this paper use the same ratio, about Rp16,060 per dollar. Baseline growth is 5.0 percent and baseline inflation 2.9 percent. The policy levers of the central runs are held at the same moderate settings as in the June paper, with a food-import buffer of 40 percent, fire sensitivity at 100 percent, fiscal relief at 30 percent, and monetary tightening switched on. The La Nina runs assume moderate cyclone activity of 0.4, one La Nina year, and today's watershed condition. The dated runs place the El Niño peak at +3.1°C in October to December 2026 and the La Nina peak at -1.5°C in October to December 2027, with the same policy settings. The grid runs from weak to record place the two peaks four quarters apart, so their annual results equal the sum of the dated quarters. The adaptation layer is set to zero in all central runs, so that the results show the exposure of the economy as it stands. Section 5 then applies the adaptation portfolios.

Parameter	Value	Basis
Nominal GDP	About Rp22,000 trillion (\$1.37 trillion)	BPS, 2024 nominal GDP
Food and beverage weight in the CPI	25 percent	BPS CPI basket
BI inflation target	2.5 percent $\pm$ 1 point	Minister of Finance Regulation (Peraturan Menteri Keuangan) 31/2024
Food-crop loss at ONI +2.0°C	About 10 percent of value added	ISEAS–Yusof Ishak Institute 2023; United States Department of Agriculture, Foreign Agricultural Service
Fire and haze damage at ONI +2.4°C	About 1.9 percent of GDP	World Bank 2016 (\$16.1 billion for 2015)
Flood asset damage at ONI –1.5°C	About 0.45 percent of GDP	Scaled from Ministry of National Development Planning (Bappenas), BNPB, and CELIOS event data
Mining loss at ONI –1.5°C	5 percent of exposed output	Adaro 2010 (94 percent of target)
Import buffer for wet-year perishables	0.5 $\times$ lever	Chili and shallot price spikes, 2010
Ordinary-year hydrometeorological losses	About \$2.1 billion a year	Ministry of Finance (Rp22.8 trillion a year); World Bank 2011 (0.3 percent of GDP)
Early-warning effect on flood damage	Up to 25 percent	Global Commission on Adaptation 2019
Flood control and drainage cost	\$1.2 billion (Rp19 trillion) a year at full scale	Order of magnitude from the National Capital Integrated Coastal Development master plan
Mangrove restoration cost	About \$3,900 (Rp63 million) per hectare	World Bank 2022
Output multipliers (type II)	1.4 to 1.8	Input–output table range
Observed ONI, 2026	–0.21, +0.95, and +2.16°C for January to March, April to June, and July to September	NOAA Climate Prediction Center, ONI
Phase peaks in the central case	+3.1°C in October to December 2026 and –1.5°C in October to December 2027	Agency outlooks for El Niño, judgment for La Nina
Seasonal hazard weights by quarter	Fire 0.15, 0.25, 1.0, 0.55. Drought 0.2, 0.4, 1.0, 0.8. Wet 1.0, 0.45, 0.2, 0.85	Hotspot and rainfall seasonality, judgment
Lags of sector losses	Dry phase, food crops 2 quarters and estate crops 3. Wet phase, food crops 1 and estate crops 2	Crop calendar and GAPKI on the palm-oil lag
Fade of cross-phase links	Half per year beyond four quarters, except L1 and L3	Judgment, illustrative
Cross-phase links, loop gains, lever effects	As described in the text	Judgment, illustrative

Table 4.6. Key parameters of ENSONINAID26 and their sources.

Several parameters rest on secondary reporting and should be checked against primary sources before policy use. These include the Bappenas estimate of climate-related losses, the CELIOS estimate for the Senyar floods, and some of the fire-cost literature. The adaptation costs are annualized public and private outlays at full implementation, and the benefits count only the losses that the model represents.¹¹⁹

¹¹⁹ Global Commission on Adaptation, 2019, *Adapt Now: A Global Call for Leadership on Climate Resilience*, GCA and WRI, Rotterdam and Washington, DC; World Bank, 2022, *The Economics of Large-scale Mangrove Conservation and Restoration in Indonesia*, World Bank, Jakarta; Menéndez, P., I.J. Losada, S. Torres-Ortega, S. Narayan, and M.W. Beck, 2020, "The global flood protection benefits of mangroves," *Scientific Reports*, 10, 4404; World Resources Institute, 2025, *Strengthening the Investment Case for Climate Adaptation: A Triple Dividend Approach*, WRI, Washington, DC.

4.2.6 Caveats and Disclaimers

The model has clear limits. It is a reduced-form national model with illustrative coefficients. It should be recalibrated against an input–output table, event-level loss data, and project-level adaptation costs before it is used for budgeting. Its results are scenario outputs and should not be read as forecasts.

Six limits matter most for this paper. First, the price channel runs hot. Against the historical record it overstates inflation in years when rice stocks were ample, as in 2015 and 2023, and fits better in years when they were not, as in 2010. Second, the fire function is calibrated to the fires before 2016. Analysis of fire carbon emissions shows that equatorial Asia now emits about a quarter to a third as much fire carbon for the same El Niño strength as it did before 2016, a shift that has not been tested at the intensity of 2026.¹²⁰ If that shift holds, the model overstates fire damage. If extreme drought overwhelms it, the model is closer to the mark. Third, the La Nina chain rests on few events. The strongest La Nina on record reached -2.0°C in 1973–74, so the record wet scenario at -2.6°C extends the damage curves beyond any observed event. Fourth, the timing rests on assumed shapes. The dated layer spreads the annual results over quarters with fixed seasonal weights and lags, and it places the La Nina peak in October to December 2027 because no agency yet forecasts its timing. Current forecasts suggest that a La Nina, if one forms, would affect the wet season of late 2027 and early 2028. Fifth, a national model hides regional concentration. Losses fall on specific provinces, districts, and households, and the national averages understate their severity where they land. Sixth, the fire and haze function reaches its cap of 2.6 percent of GDP at an effective intensity near $+2.8^{\circ}\text{C}$. At $+3.1^{\circ}\text{C}$ the model therefore adds drought, crop, water, and price losses but no further fire damage, which is consistent with the smaller fire response per unit of drought seen since 2016.

The choice of index also matters. NOAA now uses the Relative Oceanic Niño Index (RONI), which removes the tropical warming trend, and its values run lower than the traditional index. This paper maps the model scenarios to the traditional ONI, on which the 2015–16 event reached 2.6°C . The model does not include any gain in hydropower in wet years, because no quantified evidence was found. The figures are for research and discussion. They do not constitute investment, fiscal, or policy advice, and Landscape Advisory accepts no liability for decisions based on them.

4.3 The Results of the Simulations Across the Three Registers

The model was run for each phase alone and for the full cycle at five intensities, from weak ($\pm 0.7^{\circ}\text{C}$) through moderate ($\pm 1.2^{\circ}\text{C}$), strong ($\pm 1.7^{\circ}\text{C}$), and super ($\pm 2.0^{\circ}\text{C}$) to record ($\pm 2.6^{\circ}\text{C}$). Both phases use the same absolute intensity in each scenario. The record intensity matches the peak of 2015–16 on the traditional index and is close to what current forecasts expect for 2026. The results report the change from a counterfactual without El Niño or La Nina, in which growth holds at 5.0 percent and inflation at 2.9 percent.

4.3.1 The First Wave

The direct losses of each phase are of similar size, but they come from different places. Table 4.7 shows the output loss of each exposed sector and its contribution to the loss of GDP under the super and record scenarios. In the dry phase, asset damage from fire and haze dominates. At the super intensity it accounts for 1.32 percent of GDP out of a direct total of 2.08 percent, and food crops, estate crops, and fisheries follow. In the wet

¹²⁰ Landscape Advisory analysis of GFED5.1 fire carbon for equatorial Asia, 1997 to 2024, against the NOAA ONI and the Dipole Mode Index (unpublished working note, August 23, 2026).

phase, sectoral losses are spread more evenly across crops, estate crops, fisheries, mining, and transport, and flood and landslide damage adds 0.67 percent of GDP, for a direct total of 1.44 percent. Hydropower and river transport carry the largest proportional losses in the dry phase, at 12 and 8 percent of output under a super event, but their small weight in GDP keeps their contribution modest. Mining is exposed only in the wet phase, where a super La Nina cuts exposed output by about 7 percent.

First-wave sector	El Niño, super	La Nina, super	El Niño, record	La Nina, record
Food crops	10.0 / 0.30	6.3 / 0.19	14.4 / 0.43	8.8 / 0.26
Estate crops	5.0 / 0.18	4.2 / 0.15	7.0 / 0.25	5.8 / 0.20
Fisheries	6.0 / 0.16	6.6 / 0.17	8.2 / 0.21	8.8 / 0.23
Hydropower and water	12.0 / 0.09	–	16.9 / 0.12	–
River and road transport	8.0 / 0.04	4.3 / 0.09	11.2 / 0.06	6.3 / 0.13
Mining	–	7.1 / 0.18	–	9.7 / 0.24
Fire and haze assets	– / 1.32	–	– / 2.23	–
Flood and landslide assets	–	– / 0.67	–	– / 1.02
Direct total (percent of GDP)	2.08	1.44	3.30	2.08

Table 4.7. First-wave results by phase: output loss in percent of sector output / contribution to GDP loss in percent of GDP, run alone without cross-phase links.

The estate-crop figures need a note. The model books the drought-driven palm loss in the event year, while the industry expects most of it in 2027. In the full-cycle mode, link L3 moves half of that loss into the wet year, which is closer to what the industry now expects.¹²¹

4.3.2 The Second Wave

The second wave differs more between the phases than the first. Table 4.8 summarizes the channels. The wet phase produces the larger price shock, because perishables are hard to buffer with imports. A super La Nina alone raises food prices by 13.2 percent and headline inflation by 4.58 points, against 10.9 percent and 4.36 points for a super El Niño alone. The dry phase produces the larger health and tourism costs, because haze reaches millions of people for months. Inter-industry spillovers are larger in the wet phase, because mining and transport have strong links to the rest of the economy and because flood damage to roads and ports spreads to other industries. In the full cycle, the wet year inherits a higher price level and depleted stocks from the dry year, so the food price rise in the wet year reaches 18.3 percent under a super cycle and 28.5 percent under a record cycle.

¹²¹ GAPKI (Gabungan Pengusaha Kelapa Sawit Indonesia), 2026, "Dampak El Nino terkendali, industri sawit optimistis hadapi kebijakan B50 2026," (September 2, 2026). <https://gapki.id/news/2026/09/02/> (accessed on September 17, 2026).

Second-wave channel	El Niño alone, super	La Nina alone, super	Full cycle, super	Full cycle, record
Food price rise (percent)	10.9	13.2	18.3	28.5
Headline inflation rise (points)	4.36	4.58	7.78	11.90
Household demand loss (percent)	0.94	0.92	1.28	2.00
Public health cost (percent of GDP)	0.40	0.10	0.54	0.90
Tourism loss (percent of GDP)	0.26	0.07	0.34	0.57
Trade and export loss (percent of GDP)	0.38	0.38	0.83	1.25
Production cost rise (index, percent)	12.4	6.1	12.4	17.6
Relief and subsidies (percent of GDP)	0.36	0.30	0.57	0.55
Reconstruction (percent of GDP)	–	0.23	0.27	0.42
Inter-industry spillover loss (percent of GDP)	0.38	0.51	0.99	1.43

Table 4.8. Second-wave results by channel. Full-cycle prices, inflation, demand, and production cost are peak-year values. Other channels are summed over the two years.

The second wave explains why the cost of the cycle is larger than its physical damage. ENSONINAID26 books fire and flood damage as direct asset and health losses, as the World Bank did for 2015. *Fire on the Horizon* routed most of that cost through the second wave, and so reported a second wave larger than the first. The two accounts describe the same cost. Under either, the price, demand, fiscal, and poverty effects are where policy has the most leverage.

4.3.3 The Macroeconomy

Table 4.9 carries the two waves into the macroeconomic register. For each phase alone, the damage rises steeply with intensity. A super El Niño costs 2.31 percent of GDP and a record El Niño 3.69 percent. A super La Nina costs 1.83 percent and a record La Nina 2.69 percent. The full cycle costs more than the sum of its parts. Under a strong cycle the net damage is 3.45 percent of GDP, or \$47 billion (Rp759 trillion). Under a super cycle it is 4.56 percent, or \$63 billion (Rp1,003 trillion), and under a record cycle 7.08 percent, or \$97 billion (Rp1,558 trillion). Growth falls by a cumulative 1.10 to 2.06 points over the two years, and the deficit widens by 1.13 to 1.62 points of GDP in total. The distributional effects are the sharpest. Between 2.8 and 5.2 million livelihoods come under stress, and between 3.2 and 7.7 million people fall below the poverty line at the peak. With the poverty rate at 8.07 percent in March 2026, a super cycle would raise the rate by about 1.6 points.

Macro indicator	Weak ± 0.7	Moderate ± 1.2	Strong ± 1.7	Super ± 2.0	Record ± 2.6
El Niño year alone					
Net damage (percent of GDP)	0.30	0.91	1.72	2.31	3.69
Growth (points)	-0.04	-0.26	-0.53	-0.68	-1.01
Peak headline inflation (percent)	3.9	5.1	6.4	7.3	9.1
Deficit (points of GDP)	+0.40	+0.47	+0.55	+0.60	+0.71
Livelihoods under stress (million)	0.8	1.7	2.8	3.5	5.1
Additional poor (million, peak)	0.2	0.6	1.1	1.5	2.2
La Nina year alone					
Net damage (percent of GDP)	0.34	0.85	1.44	1.83	2.69
Growth (points)	-0.06	-0.25	-0.46	-0.57	-0.80
Peak headline inflation (percent)	4.1	5.3	6.6	7.5	9.3
Deficit (points of GDP)	+0.38	+0.49	+0.62	+0.70	+0.89
Livelihoods under stress (million)	0.5	1.0	1.6	1.9	2.7
Additional poor (million, peak)	0.5	1.2	2.1	2.6	3.8
Full cycle, El Niño year then La Nina year					
Net damage (percent of GDP)	0.71	1.89	3.45	4.56	7.08
Net damage (\$ billion)	10	26	47	63	97
Net damage (Rp trillion)	156	416	759	1,003	1,558
of which compound effect (points)	+0.06	+0.14	+0.29	+0.42	+0.69
Growth (points, two-year total)	-0.15	-0.61	-1.10	-1.40	-2.06
Peak headline inflation (percent)	4.5	6.4	8.9	10.7	14.8
Deficit (points of GDP, two-year total)	+0.73	+0.91	+1.13	+1.29	+1.62
Livelihoods under stress (million)	0.8	1.7	2.8	3.5	5.2
Additional poor (million, peak)	0.6	1.6	3.2	4.5	7.7

Table 4.9. Macroeconomic results across the ENSO intensity range, for each phase alone and for the full cycle, with policy levers at moderate settings and no added adaptation.

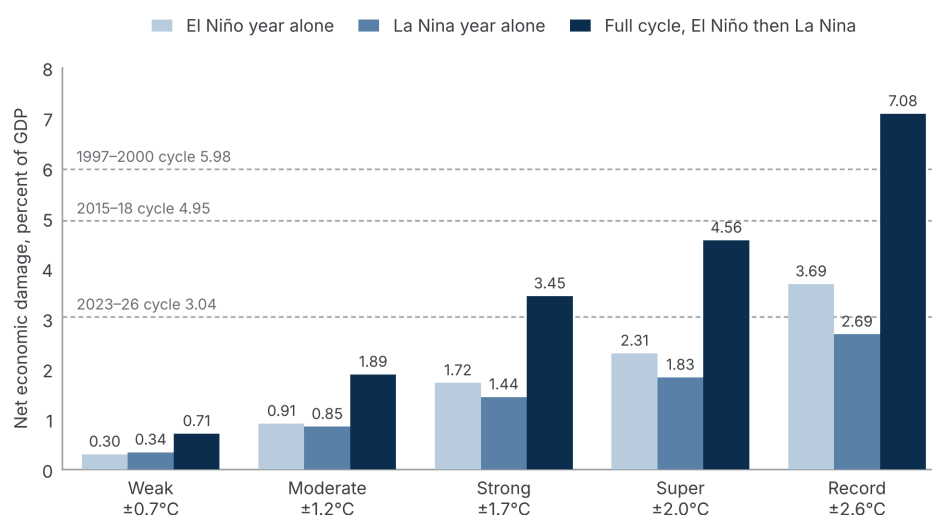


Figure 4.2. Modeled net damage by ENSO intensity and phase, in percent of GDP. Dashed lines mark the model's reconstruction of three past cycles.

The peak inflation figures in Table 4.9 need care. With the buffer at the moderate June setting, a super cycle lifts inflation to 10.7 percent in the wet year and a record cycle to 14.8 percent. As Section 4.1 showed, the model overstates the price response when rice stocks are high. Table 4.10 therefore repeats the full-cycle run with the food-import buffer at 80 percent, which reflects Bulog's current stocks. The damage is almost

unchanged, because the buffer moves costs from households to the budget. Peak inflation, however, falls to 8.0 percent under a super cycle and 10.5 percent under a record cycle, and the number of additional poor falls to 2.9 and 4.7 million. Even with a strong buffer, the wet year pushes inflation above the target band, because perishables cannot be stored.

Full cycle, strong rice buffer	Weak	Moderate	Strong	Super	Record
Net damage (percent of GDP)	0.71	1.90	3.46	4.57	7.09
Growth (points, two-year total)	-0.10	-0.49	-0.97	-1.26	-1.91
Peak headline inflation (percent)	4.0	5.3	6.9	8.0	10.5
Peak food price rise (percent)	2.7	5.7	9.6	12.6	18.9
Deficit (points of GDP, two-year total)	+0.78	+1.00	+1.30	+1.50	+1.94
Livelihoods under stress (million)	0.7	1.6	2.7	3.4	5.0
Additional poor (million, peak)	0.4	1.1	2.1	2.9	4.7

Table 4.10. Full-cycle results with the food-import buffer raised to 80 percent to reflect current rice stocks.

4.3.4 The Compound Effect and the Time Path

The compound effect measures what the dry year adds to the wet year. It equals the damage of the cycle minus the damage of the two phases run alone. It grows with intensity, from 0.06 points of GDP under a weak cycle to 0.42 points, or \$5.8 billion (Rp92 trillion), under a super cycle and 0.69 points, or \$9.5 billion (Rp152 trillion), under a record cycle. That is about a tenth of the cost of the cycle. The largest contributions come from fire scars that raise flood runoff, from depleted food stocks that sharpen the wet-year price response, from dry-year inflation that raises the wet-year starting point, and from the erosion of fiscal headroom, which cuts wet-year relief by about 30 percent under a super cycle. The results show that the two phases should be planned for together.

Figure 4.3 shows the stylized quarterly path of the cycle. Fire hazard peaks in the second quarter after onset, which corresponds to the fire season of July to September 2026. Food prices and inflation peak two to three quarters after the hazard, and the growth gap is widest in the fourth quarter of the El Niño year. The wet window then raises the flood hazard, food prices, and inflation again, starting from a price level that has not yet returned to baseline, and the growth gap widens a second time. In the model the La Nina window starts four quarters after El Niño onset. With El Niño now expected to last into the first half of 2027, a La Nina would more likely affect the wet season that begins in late 2027. The shape of the path is a better guide than its calendar.

Quarterly transmission through the 2026–27 ENSO cycle

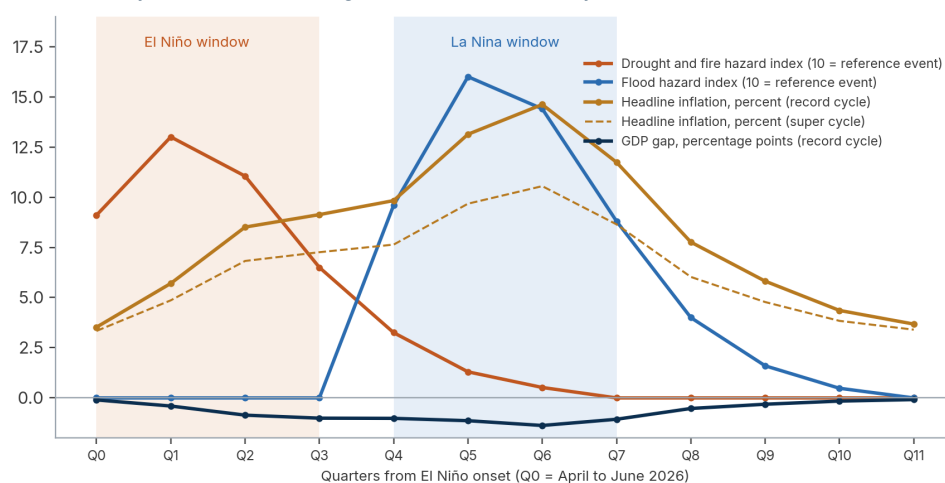


Figure 4.3. Stylized quarterly transmission through the 2026–27 ENSO cycle under the record scenario, with headline inflation also shown for the super scenario. Hazard indices equal 10 for the reference event of each phase.

4.3.5 Comparison with Past Events

Past events serve two purposes here. They test the model, and they place 2026 in context. Table 4.11 runs the model's presets for past events, which set intensity, buffers, fire sensitivity, cyclone activity, duration, and watershed condition to match each event, and sets the results beside the observed record.

The model passes some tests and fails others. Its fire damage for 2015 is 2.45 percent of GDP, about a quarter above the World Bank's 1.9 percent, which is within the range of the published estimates once health costs are valued more fully.¹²² Its inflation for the 2010–11 La Nina is 6.2 percent against an observed 6.96 percent, a close match. Its damage for the Senyar floods is 0.40 percent of GDP against the CELIOS estimate of 0.29 percent, a reasonable match given that the CELIOS figure measures lost output rather than total damage. It overstates the inflation of 2015 and 2023, when rice stocks and imports held prices down, and it overstates the national cost of Seroja, a regional cyclone that the national preset scales too widely. The 1997–98 figures cannot be compared directly, because the financial crisis dominated prices and poverty in those years.

On severity, the evidence supports the expectation that 2026 may be more severe than past events, with qualifications that matter. The ocean forcing is the strongest on record or close to it. The CPC gives an 83 percent chance that the event will exceed every El Niño since 1950, and the BoM expects a peak above any observed value. The fires are severe and approach 2015 on some measures. Burning by July exceeded the same months of 2019 and 2023 and reached about a third of the 2015 figure, and the post-2016 decline in fire per unit of drought is now under strain. The VIIRS record shows more detections in August 2026 than in August 2015 and about three quarters of the September 2015 count (Figure 2.3). The official burned area for August and September, still unpublished in mid-October, will decide where 2026 finally ranks. The economic effects so far are milder than the June prognosis and milder than 1997–98, because rice

¹²² Kiely, L., D.V. Spracklen, S.R. Arnold, E. Papargyropoulou, L. Conibear, C. Wiedinmyer, C. Knote, and H.A. Adrianto, 2021, "Assessing costs of Indonesian fires and the benefits of restoring peatland," *Nature Communications*, 12, 7044. <https://doi.org/10.1038/s41467-021-27353-x>.

stocks are high and the harvest effect has not yet arrived. The modeled full cycle is where 2026 stands out.

Event	ONI (°C)	Modeled damage (percent of GDP)	Modeled peak inflation (percent)	Modeled additional poor (million)	Observed record
El Niño events					
1997–98	+2.4	3.48	10.4	2.8	9.7 to 11.7 million ha burned. Fire costs \$4.5 billion to more than \$9 billion. Record rice imports of 5.8 Mt in 1998.
2015–16	+2.6	3.91	9.5	2.4	2.6 million ha burned. \$16.1 billion (Rp221 trillion), 1.9 percent of GDP. Inflation 3.35 percent.
2023–24	+2.0	2.11	6.7	1.2	1.16 million ha burned. Rice –1.4 percent. Imports 4.5 Mt in 2024. Inflation 2.61 percent.
2026 (record, modeled)	+2.6	3.69	9.1	2.2	202,011 ha burned by July, above 2019 and 2023 and below 2015 for the same months.
La Nina and cyclone events					
2010–11	–1.6	1.26	6.2	1.8	Inflation 6.96 percent. Rice imports 2.75 Mt in 2011. Adaro at 94 percent of target.
2020–23 (three years)	–1.2	1.88	7.8	2.7	5,402 disasters in 2021 alone, 728 dead.
2021 Seroja	–1.0	0.79	5.1	1.1	184 dead. Preliminary loss Rp3.4 trillion in East Nusa Tenggara.
2025 Senyar	–0.6	0.40	4.2	0.6	About 1,200 dead. CELIOS loss 0.29 percent of GDP. Reconstruction about Rp100 trillion.
Full cycles					
1997–2000	+2.4 / –1.6	5.98	14.6	7.2	Drought, fires, and floods during the financial crisis.
2015–18	+2.6 / –0.8	4.95	9.5	2.4	Severe fires followed by weak La Nina conditions.
2023–26	+2.0 / –0.6	3.04	6.8	1.6	2023 fires and drought followed by the Senyar floods.
2026–27 super (modeled)	±2.0	4.56	10.7	4.5	Scenario
2026–27 record (modeled)	±2.6	7.08	14.8	7.7	Scenario

Table 4.11. Past events as reconstructed by ENSONINAID26, compared with the observed record and with the 2026–27 scenarios.

A record El Niño alone costs 3.69 percent of GDP in the model, close to the model's 3.91 percent for 2015–16 and above its 3.48 percent for 1997–98. If a La Nina of matching strength follows, the cycle costs 7.08 percent of GDP, above the 5.98 percent that the model reconstructs for 1997–2000 and the 4.95 percent for 2015–18. A record El Niño followed by a La Nina of only –1.5°C would still cost 5.33 percent, and one

followed by a La Nina of -1.0°C 4.67 percent. The 2026–27 cycle would therefore be the most costly on record in any scenario in which the El Niño reaches record strength and a La Nina of at least moderate strength follows. The severity of 2026 depends less on the fires already burning than on what follows them.

5 The Policy Implications

The simulations point to where policy has leverage. Three results carry most of the weight. The cost of a strong El Niño followed by a strong La Nina is several times the cost of either phase alone, and about a tenth of it comes from the way the first phase weakens the economy before the second arrives. The price, fiscal, and poverty channels respond strongly to policy, while the size of the physical shock does not. Adaptation measures pay for themselves across a range of assumptions, and some of them pay many times over. In the super full cycle, with levers at moderate settings, the model gives net damage of 4.56 percent of GDP, a cumulative growth loss of 1.40 points, peak inflation of 10.7 percent, and 4.5 million additional poor. Strengthening the food-import buffer, fire suppression, and fiscal relief together lowers these to 3.99 percent, 1.09 points, 8.7 percent, and 3.1 million, while widening the deficit from 1.29 to 1.87 points of GDP. Weakening the same levers raises the damage to 5.05 percent and the number of additional poor to 6.3 million.

5.1 Priorities for the Current Fire Season

The fire season will run until the rains arrive, which BMKG now expects between late October and mid-November, so the fire response is the first priority. In the model, lowering fire sensitivity from 100 to 70 percent cuts the damage of the super cycle from 4.56 to 4.17 percent of GDP, a saving of about \$5.4 billion (Rp86 trillion), and it also weakens link L1, through which burned peat raises flood runoff in the following wet season. Ground capacity is thin relative to the area burning. The national fire brigade of the Ministry of Forestry fields an estimated 780 personnel across thirteen operational units in Kalimantan, and aerial water bombing cannot put out fires that burn below the surface of peat.¹²³ Suppression should therefore focus on the peat landscapes with the densest fire, and on the protected areas where a small number of sites carry most of the hotspots. Ten protected areas carried about 70 percent of the hotspots inside the conservation estate in late August and early September.

Enforcement needs to follow the fires to the parties who gain from them. By August 21 the national police had named 72 suspects in cases of forest and land fires (kebakaran hutan dan lahan, karhutla), all of them individuals.¹²⁴ By October 9 the police had named 198 individual suspects and opened 97 reports against corporations, and on October 1 the national police named four corporations as suspects. The Ministry of Forestry revoked the licenses of five companies on September 22.¹²⁵ More than Rp3.4 trillion in final court-ordered compensation for past fires remains largely uncollected, and at least

¹²³ Landscape Advisory reconstruction of Manggala Agni capacity in Kalimantan, based on 60 personnel per operational unit as reported for South Kalimantan in 2026 (unpublished working note, August 2026).

¹²⁴ Polri (Indonesian National Police) statement of August 21, 2026, as reported in the Indonesian press.

¹²⁵ Alhadjri, A., 2026, "Indonesia details crackdown, firefighting efforts as haze chokes Malaysia," *Malaysiakini*, (October 10, 2026), citing the Embassy of Indonesia in Kuala Lumpur, <https://www.malaysiakini.com/news/886741-indonesia-details-crackdown-firefighting-efforts-as-haze-chokes-malaysia>; Janati, F., 2026, "Polri tetapkan 4 korporasi jadi tersangka kebakaran hutan dan lahan," *Kompas*, (October 1, 2026), <https://nasional.kompas.com/read/2026/10/01/18123111/polri-tetapkan-4-korporasi-jadi-tersangka-kebakaran-hutan-dan-lahan>; "Indonesia revokes licenses of five companies over Kalimantan wildfires," *Antara News*, (September 22, 2026), <https://en.antaranews.com/news/432260/indonesia-revokes-licenses-of-five-companies-over-kalimantan-wildfires> (all accessed on October 13, 2026).

one concession with an unpaid judgment for the 2019 fires burned again in 2026.¹²⁶ Collecting existing judgments and sanctioning repeat concessions would add weight to prevention without new legislation.

5.2 Priorities for the Months Before a La Nina

The window for the wet phase is the dry season of 2027. If a La Nina forms in the second half of 2027, its floods will arrive in the wet season that begins late that year. Several measures need that lead time. Food stocks come first. In the super cycle, a food-import buffer of 70 percent instead of 40 percent lowers peak inflation from 10.7 to 8.7 percent and the number of additional poor from 4.5 to 3.2 million. Without a buffer, peak inflation would reach 13.6 percent and the number of additional poor 6.5 million. Bulog should therefore rebuild its rice reserve after the current drawdown, and import contracts should be arranged early rather than during a price spike. Rice stocks alone cannot absorb a wet-year shock, because chili, shallots, and vegetables spoil. Cold storage, wider regional sourcing of horticulture, and better market information would strengthen the weakest part of the buffer.

Watersheds and drainage come next. The damage of the super cycle rises to 4.87 percent of GDP if upstream degradation worsens by a fifth, and falls to 4.41 percent if it improves by a tenth. Cyclone activity matters as much. A Senyar-class cyclone raises the damage to 5.08 percent and the number of additional poor to 5.4 million. A La Nina that lasts two years raises the damage to 5.67 percent, and one that lasts three years, as in 2020–23, to 6.77 percent. The Senyar floods showed how deforestation turns heavy rain into disaster, and the government has since suspended or revoked permits in affected watersheds.¹²⁷ River dredging, drainage, reservoir operating rules that use the drought drawdown as flood storage, slope stabilization, and the protection of upper catchments should be scheduled for the 2027 dry season. The reconstruction program for Aceh, North Sumatra, and West Sumatra is an opportunity to rebuild to a higher standard in the provinces most likely to flood again.

5.3 Social Protection and Public Finance

Social protection is where the model finds the largest effect on poverty per rupiah. Adaptive social protection, meaning shock-responsive top-ups to the Family Hope Program (Program Keluarga Harapan, PKH) and the Non-Cash Food Assistance Program (Bantuan Pangan Non-Tunai, BPNT) and wider coverage of near-poor households, avoids about 1.6 million additional poor in the super cycle at an annual cost of about \$0.56 billion (Rp9 trillion) at 70 percent of its potential. The food aid already approved for October to December 2026 follows this logic. The scarring link L7 shows why the second phase needs the same protection. Households that sold assets in the dry year fall below the poverty line more easily in the wet year.

Public finance is where the response can defeat itself. More fiscal relief lowers the growth loss of the super cycle from 1.40 to 1.23 points and the number of additional poor from 4.5 to 4.3 million, but it widens the two-year deficit effect from 1.29 to 1.73 points of GDP. With the 2026 deficit already projected at 2.85 percent of GDP, a strong to record cycle that adds 1.1 to 1.6 points over two years would press against the 3 percent ceiling. The draft 2027 budget assumes 6.0 percent growth and 2.5 percent inflation, and these assumptions do not appear to allow for a continuing El Niño in the first half of 2027 or a La Nina in the second. Disaster risk finance offers a way to fund the response without springing the fiscal strain loop. In the model it speeds recovery and

¹²⁶ Landscape Advisory compilation of enforcement records, 2015 to 2026 (unpublished working register, August 2026).

¹²⁷ Butler, R.A., 2025, "Sumatra's 'natural' disaster wasn't natural," *Mongabay*, (December 15, 2025).

moves 40 percent of reconstruction off the emergency budget, with a benefit–cost ratio of about 3.4. The Rp14 trillion disaster pooling fund, parametric insurance, and pre-arranged contingent credit should be sized for a two-phase cycle rather than a single event.

Monetary policy should look through the first-round food shock. The inflation of both phases is driven by supply. In the model, switching off the tightening rule lowers the growth loss of the super cycle from 1.40 to 1.17 points. The model does not capture the risk that higher inflation expectations or a weaker rupiah would feed back into prices, so the result overstates the case for inaction. BI raised its rate in May and June for reasons of currency stability. The appropriate course is to rely on the joint central and regional inflation-control teams, food logistics, and administered-price management for the food shock, and to reserve rate changes for second-round effects and exchange-rate pass-through.

5.4 The Adaptation Portfolio

Resilience investment lowers the loss ceilings themselves. ENSONINAI26 represents fifteen measures in four approaches, sectoral, economy-wide, nature-based, and engineering. Table 5.1 compares four portfolios against a baseline of no added measures. The current policy portfolio implements each measure at 25 percent of its achievable potential. The nature-led portfolio raises nature-based solutions to 80 percent, and the engineering-led portfolio does the same for engineering. The integrated portfolio implements all measures at 70 percent. The benefit–cost ratio annualizes the avoided damage at 2.5 stress events a decade and adds the ordinary-year losses that the same measures avoid. A second ratio adds co-benefits such as carbon storage and livelihoods, in line with the triple dividend approach.¹²⁸

Portfolio	Avoided per cycle (\$ billion)	Share avoided (percent)	Cost per year (\$ billion)	Benefit – cost ratio	Ratio with co-benefits	Residual damage (percent of GDP)	Residual poor (million)
Full cycle, super (±2.0°C)							
Current policy	12.2	20	1.80	1.9	2.6	3.67	2.9
Nature-led	21.3	34	2.50	2.4	3.2	3.01	2.2
Engineering-led	16.9	27	3.41	1.5	2.0	3.33	2.2
Integrated	29.3	47	5.05	1.7	2.3	2.42	1.3
Full cycle, record (±2.6°C)							
Current policy	18.8	19	1.80	2.9	3.5	5.70	4.9
Nature-led	33.8	35	2.50	3.7	4.5	4.61	3.7
Engineering-led	25.6	26	3.41	2.1	2.6	5.20	3.6
Integrated	45.3	47	5.05	2.5	3.1	3.77	2.0

Table 5.1. Adaptation portfolios in the super and record full-cycle scenarios.

The integrated portfolio avoids \$29 billion (Rp466 trillion) of damage in a super cycle and \$45 billion (Rp723 trillion) in a record cycle, close to half of the net damage in both. It cuts the number of additional poor from 4.5 to 1.3 million under the super cycle. It costs about \$5.1 billion (Rp82 trillion) a year and returns 1.7 to 2.5 times its cost, or 2.3 to 3.1 times with co-benefits. The nature-led portfolio returns the most per dollar, 2.4 times in a super cycle, and avoids almost as much El Niño damage as the integrated portfolio, because peatland rewetting acts on the largest single loss. The engineering-led portfolio avoids more La Nina damage than the nature-led one but costs more, and returns 1.5 times its cost. All portfolios return more in a record cycle, because the losses they avoid are larger.

¹²⁸ World Resources Institute, 2025, *op. cit.*

Measure (at 70 percent of potential)	El Niño damage avoided (\$ billion)	La Nina damage avoided (\$ billion)	Total avoided (\$ billion)	Poor avoided (million)	Annual cost (\$ billion)	Benefit-cost ratio
Sectoral						
Food crops	1.57	1.09	2.66	0.72	0.42	1.7
Estate crops	0.79	1.15	1.94	0.01	0.21	2.3
Fisheries	0.64	0.70	1.34	0.14	0.10	3.2
Energy and water	0.39	0.38	0.77	0.04	0.28	0.9
Transport and logistics	0.16	0.83	0.99	0.23	0.35	0.9
Mining	0.00	0.87	0.87	0.00	0.17	1.2
Economy-wide						
Early warning and anticipatory action	1.73	2.89	4.62	0.42	0.08	17.1
Adaptive social protection	0.00	0.00	0.00	1.62	0.56	welfare
Disaster risk finance	1.09	1.77	2.85	0.00	0.21	3.4
Nature-based						
Peatland rewetting	5.69	2.75	8.44	0.49	0.24	9.2
Reforestation and watersheds	1.18	2.62	3.80	0.38	0.42	2.7
Mangroves and coasts	0.21	1.11	1.32	0.13	0.17	2.3
Engineering						
Flood control and drainage	0.00	3.64	3.64	0.41	0.84	1.5
Reservoirs and irrigation	1.40	1.15	2.55	0.37	0.56	1.4
Resilient infrastructure	0.08	1.44	1.52	0.24	0.42	1.2

Table 5.2. Returns to individual adaptation measures in the super full cycle, each run alone against no adaptation. Rows do not add up to the portfolio because measures overlap. "Welfare" marks a measure whose return is fewer poor people rather than avoided damage.

Table 5.2 shows the individual measures. Early warning and anticipatory action return the most per dollar, about seventeen times their cost, because seasonal forecasts, fire danger ratings, flood warnings, and pre-agreed triggers are cheap and act on both phases. Peatland rewetting avoids the most damage of any single measure and returns about nine times its cost. The evidence from the 2019 El Niño supports this. Restored peat in Sumatra and Kalimantan had up to 22 percent fewer hotspots than comparable unrestored peat, although it still burned far more than intact peat forest.¹²⁹ Disaster risk finance, fisheries measures, reforestation, estate-crop water management, and mangroves all return two to three and a half times their cost. Flood control, reservoirs, and resilient infrastructure return less in this model, because their main benefit, the continuity of services, lies partly outside what the model counts. Energy and water measures and transport measures return slightly less than their cost when judged on disaster losses alone.

5.5 Timing and Coordination

Every lever in the model works only if it is in place before the shock lands. For the fire season that time has largely passed, and the remaining task is suppression, health protection, and enforcement. For the La Nina the time is the next twelve months. Stocks must be rebuilt, drainage cleared, warnings and triggers agreed, social registries updated, and financing arranged before the rains of late 2027. The measures cut across ministries. The food buffer sits with the National Food Agency and Bulog, fire and watersheds with the Ministry of Forestry and BNPB, forecasts with BMKG, financing with

¹²⁹ Salmayenti, R., D.V. Spracklen, and J. Holden, 2026, "Tropical peatland restoration reduces fire occurrence," *Geophysical Research Letters*. <https://doi.org/10.1029/2025GL121564>. The study matched restored and unrestored peat across about 4,000 square kilometers for 2015 to 2019. Figures as reported in the authors' own summaries.

the Ministry of Finance, prices with BI and the inflation-control teams, and social protection with the Ministry of Social Affairs. The causal loop diagram shows that the transmissions cross all of these mandates, so the response needs a single plan for the whole cycle.

Lever or instrument	Channel it acts on	Model result it changes (super cycle)	Timing window
Fire suppression, peat rewetting, and enforcement against repeat burners	Fire and haze, health, tourism, and flood runoff through link L1	Damage 4.56 → 4.17 percent of GDP. Peat rewetting benefit–cost ratio about 9.	Now, through the end of the 2026 fire season, and before the 2027 dry season
Food stocks and early import contracts, with cold chains for perishables	Food prices, household demand, and poverty	Peak inflation 10.7 → 8.7 percent. Additional poor 4.5 → 3.2 million.	Rebuild stocks during 2027, before the wet season
Adaptive social protection for near-poor households	Household demand and poverty, and scarring through link L7	About 1.6 million fewer poor at about \$0.56 billion (Rp9 trillion) a year	Food aid now, top-up triggers ready before the wet season
Watershed protection, drainage, reservoir rules, and flood control	Floods and landslides, transport, and crops	Damage 4.87 percent with worse watersheds against 4.41 percent with better ones	2027 dry season
Early warning and anticipatory action	All direct channels in both phases	Benefit–cost ratio about 17	Continuous, with triggers set before each season
Disaster risk finance and fiscal headroom	Deficit, relief capacity, and recovery, through loops R2 and B2	More relief lowers growth loss 1.40 → 1.23 points but widens the deficit 1.29 → 1.73 points. Disaster risk finance ratio about 3.4.	2027 budget cycle
Supply-focused monetary stance	Inflation, growth, and the rupiah	Growth loss 1.40 → 1.17 points without tightening against the food shock	Through the cycle, tightening only for second-round effects
Integrated adaptation portfolio	All loss ceilings in both phases	About half of net damage avoided, \$29 billion (Rp466 trillion) per super cycle, benefit–cost ratio 1.7	Medium term, built between events

Table 5.3. Policy synthesis: each lever, the channel it acts on, the modeled result it changes in the super full cycle, and its timing window.

6 Concluding Note

This paper followed the 2026 El Niño from the forecast of June to the fires of October, and extended the analysis to the La Nina that may follow. It used ENSONINAI26, a system dynamics model that traces both phases through the same sectors, the same second-wave channels, and the same macroeconomic outcomes, and links the two phases through nine channels by which the dry year weakens the economy before the wet year.

The June prognosis has held for the physical first wave. Fire has burned more land by July than in the same months of 2019 and 2023, and it has killed people and wildlife, filled hospitals, closed schools and airports, and carried haze across borders. Hydropower and river transport have failed in places more severely than the model assumed. The price, growth, and poverty channels have moved less than expected, mainly because rice stocks are high and because the harvest effect lags into 2027. Those channels remain open, and the months around the turn of the year will show how far they move.

The model results show that the cost of the full cycle is much larger than the cost of the El Niño alone. A super cycle costs about 4.6 percent of GDP and a record cycle about 7.1 percent, or \$63 billion (Rp1,003 trillion) and \$97 billion (Rp1,558 trillion). The two-year growth loss reaches 1.4 to 2.1 points, and 4.5 to 7.7 million more people could fall below the poverty line at the peak with moderate buffers, or 2.9 to 4.7 million with the strong rice buffer now in place. About a tenth of the cost of the cycle comes from the damage that the dry year passes to the wet year.

The 2026 event is more severe than past events in its ocean forcing. It has not yet matched 2015 in burned area. Its economic cost will exceed that of any past cycle if a La Nina of at least moderate strength follows. No agency yet forecasts that La Nina, and the wet-phase results should be read as a stress test. History and climate research both suggest that the risk is real.

The policy conclusions follow from the structure of the model. The fire response is the task of the coming weeks. Food stocks, watersheds, drainage, early warning, social protection, and disaster finance are the tasks of the coming year. The adaptation portfolio would avoid about half of the modeled damage and return two to three times its cost. The figures are scenario outputs of a reduced-form model with the limits set out in Section 4.2.6. They show the order of magnitude of the risk and the points where policy can reduce it. Landscape Advisory will update this assessment as the official burned area for August to October, the third-quarter national accounts, and the next ENSO forecasts are published.

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