Congo Basin deforestation threatens regional rainfall and global cocoa supply

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Key points

- The tropical rainforests of the Congo Basin regulate rainfall both locally in Central Africa and across West Africa, but deforestation risks jeopardising this vital water source.
- New ZCA analysis finds that deforestation in the Congo Basin could disrupt rainfall and significantly reduce cacao yields, resulting in substantial losses for producers and rising costs for importers.
- The West African countries of Ivory Coast, Ghana and Nigeria, along with several Central African nations, account for more than 70% of global cacao production. Ivory Coast, the biggest producer, could see cumulative losses of almost 1.6 million tonnes by 2050.
- Falling yields will be increasingly costly for importers as the impacts of deforestation accelerate over time. Deforestation is projected to contribute 11% of the total cocoa price in 2030, rising to 40% by 2050.
- In 2050, Europe could end up paying USD 33.8 billion more for the equivalent of its current annual imports due to Congo Basin deforestation. With normal market growth and the price impacts of extreme weather factored in, Europe's 2050 cocoa imports could total USD 84 billion, nine times the 2025 cost.
- EU importers could face cumulative costs of USD 256 billion by 2050, almost double the global chocolate industry's 2024 market value of USD 130 billion.
- The Netherlands, Belgium and Germany – the biggest EU importers of Ivory Coast cocoa – could pay USD 13.1 billion, USD 6 billion and USD 4.4 billion more in 2050 for current shipment volumes, respectively, due to deforestation price impacts.
- Our analysis found a critical window for intervention, as impacts remain manageable through the 2030s but accelerate dramatically after 2040.
- Funding forest conservation in the Basin will be cheaper for the EU than the cost of inaction. EU importers could benefit from USD 1.8 to USD 6 in avoided costs for every dollar invested, depending on the conservation approach.

- All conservation scenarios analysed showed promising returns, even at a 50% success rate, with community-led restoration showing the biggest benefits.

The Congo Basin's rainforests drive regional rainfall

Rainforests are crucial for sustaining life on Earth, playing a vital role in carbon sequestration and hosting exceptional biodiversity. But, forests have an even more profound importance for our climate than carbon storage – they regulate the Earth's temperature and freshwater flows.

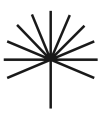
Plants recycle 80–90% of rainfall back into the air in a vital feedback loop that sustains the global water cycle and cools the planet. Forests generate water in a process called evapotranspiration: Trees draw up groundwater through their roots and release it from their leaves, returning water to the atmosphere where it turns into clouds and falls as rain, creating a natural cooling system. In tropical areas, this recycling is so effective that air moving over forests produces at least twice as much rainfall as air moving over non-forested land.

The moisture forests release creates rainfall both locally and further away. A well-known example is the Amazon's 'flying rivers', massive flows of water vapour generated by trees and carried by atmospheric currents, which deliver rainfall across Latin America up to thousands of kilometres away.

This type of long-distance climate link is called a teleconnection. In some parts of the world, losing a forest-rainfall teleconnection may present a "more imminent threat even than global warming".

A less-studied but equally vital teleconnection exists between the Congo Basin in Central Africa, which contains the world's second-largest tropical rainforest after the Amazon, and West Africa. The Congo Basin's tropical rainforests generate up to 83% of local rainfall – more than the Amazon – keeping the climate humid and fuelling ongoing rainfall. This moisture does not just sustain the Congo Basin, as seasonal winds carry it hundreds of kilometres westward to deliver almost one-fifth of rainfall in West Africa.[1]

[1] West African forests themselves have an important teleconnection: they provide up to 30–40% of the total annual rainfall in the Ethiopian Highlands.



Deforestation disrupts this natural system

Deforestation disrupts the natural process of water recycling, as cleared forest can no longer pump moisture into the atmosphere. In the Congo Basin, this could result in rainfall reductions of up to 40%. The high proportion of local rainfall controlled by the rainforest means that the Basin could be the region in the world where deforestation will have the biggest impact on rainfall.

Forest loss also disrupts the natural cooling system. Without the cooling effect of evaporation, the solar radiation that would normally drive evapotranspiration creates hot, low-pressure zones which alter regional wind patterns. These interact with West Africa's monsoon winds, which bring the region's crucial rainy seasons, in a climate teleconnection, causing the monsoon rain band to shift inland during the Northern Hemisphere summer and reducing rainfall along the West African Guinea coast.[2] Climate models show the disruption of this teleconnection could decrease rainfall by up to 20% along the Guinea coast during the rainy season.[3]

Deforestation in the Congo Basin, driven by small-scale agriculture and settlements, is a growing concern. If current rates of forest loss and degradation continue, 27% of the forest could be destroyed by 2050,[4] directly threatening local rainfall and the moisture transport systems that millions across Africa rely on for water and agriculture. The destruction places farmers' livelihoods and commodity supply chains at risk, making forest conservation in the Congo Basin a critical environmental security issue.

Congo basin deforestation puts African cocoa production at risk

One commodity at risk from the reduced rainfall is cocoa, produced from the seeds (cocoa beans) of the cacao plant, *Theobroma cacao*. Three out of four cocoa beans come from Africa, with the West African countries of Ivory Coast, Ghana and Nigeria, along with several Central African nations in the Congo Basin, accounting for more than 70% of global cocoa production.

Cacao can only thrive in a narrow band around the equator, called the 'cocoa belt', as it requires specific temperature and moisture conditions to grow. It is particularly

[2] The coastal tropical region of West Africa that lies along the Gulf of Guinea.

[3] This effect is also compounded by extensive local deforestation – for cocoa production as well as other commodities – within West Africa itself, which is believed to reduce local precipitation in adjacent forests by up to 50%. Local deforestation is also increasing the occurrence of extreme climate events in the region.

[4] Compared to 2020.

sensitive to drought because it evolved in the humid Amazon Basin and has not adapted to the water stress from West Africa's prolonged dry seasons. As a result, global cocoa supplies are particularly vulnerable to climate and land-use changes in the region.

Cacao cultivation in Africa is mostly low-tech, performed by smallholder farmers and relies almost entirely on rainfall, rather than irrigation. This rain-fed system makes crops highly dependent on reliable rainfall – a critical vulnerability given the crop's low drought tolerance. Seasonal dry spells can severely reduce yields, and prolonged droughts can devastate entire harvests.[5]

Scientists believe that once forest loss exceeds a critical threshold, an irreversible ecological shift or 'tipping point' could be reached and the forest's rain pump mechanism lost. Once gone, the mechanism cannot be fully restored, leading to persistently drier conditions locally and across West Africa, with cascading effects for supply chains. The threshold could be as low as 30% forest loss, or even lower, and Central Africa is estimated to have already lost 9% of its forests since 2000.

Impacts will be felt throughout the cocoa supply chain

Cocoa is not an easy raw material to replace in the confectionery industry, given its distinctive flavour and properties. As a result, prices tend to rise sharply when global cocoa supplies are low and buyers compete for limited stocks. The supply is highly inelastic, meaning production cannot be easily ramped up in response to a crisis, and even modest supply shocks trigger dramatic price swings.

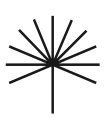
For example, prices rose more than 400% in 2024 following crop failures in West Africa due to unseasonal wet weather followed by drought during the rainy season, driven by climate change.[6] Swiss chocolate maker Barry Callebaut dropped its annual sales forecasts for 2025 due to "unprecedented volatility" in cocoa prices, resulting in a 20% drop in share prices.

Despite Africa's dominance in cocoa production, the continent only reaps a small fraction of the value of the global cocoa industry. Farmers earn less than 7% of the final price when cocoa is sold as a chocolate, one of the smallest shares in the supply chain.[7] Europe, the world's largest importer of cocoa beans, captures the most profits

[5] Poor adaptation to local conditions also makes cacao trees susceptible to disease – a major contributor to reduced harvests in recent years.

[6] Climate change is increasing the frequency of flooding and heatwaves in West Africa, and is anticipated to increase the severity of dry spells, reduce rainfall, and shift the timing of wet and dry seasons for parts of the West African cocoa belt.

[7] Many farmers live in extreme poverty, often earning less than USD 1 a day, yet are reliant on this source of income.



in the higher-value stages of processing and manufacturing. The Netherlands and Belgium, for example, import cocoa beans, process them, then export cocoa products at a premium.

New ZCA analysis shows how deforestation could reduce production and destabilise global cocoa markets

New analysis by Zero Carbon Analytics shows how deforestation in the Congo Basin could disrupt cocoa production in the nine countries that make up three-quarters of global supply: Cameroon, the Central African Republic, Equatorial Guinea, the Democratic Republic of the Congo, and the Republic of Congo in Central Africa, and the West African countries of Ivory Coast, Ghana, Gabon and Nigeria.

Using deforestation trajectories and regional climate dynamics,[8] research on how cocoa plants respond to drought,[9] and the behaviour of cocoa in commodity markets,[10] we projected how declining rainfall could reduce production and destabilise global cocoa trade.

[8] Smith et al. (2023) projected that Congo Basin forest loss could reduce rainfall in the basin by 8-10% on average by 2100. We extracted country-specific forest loss percentages for Cameroon, the Central African Republic, the Republic of the Congo, the Democratic Republic of Congo, Equatorial Guinea and Gabon from Figure 4c. To capture how sensitive each region's rainfall is to forest loss, we used Smith's country-specific rainfall decreases for 2100 and translated forest loss percentages into rainfall reduction percentages for each country. For Ivory Coast, Ghana and Nigeria, we synthesise evidence from two climate modeling studies: Nogherotto et al. (2013) modeled complete removal of Congo Basin forest and found this reduced monsoon rainfall along the Guinea Coast by up to 20% (see Figure 2 in source). Since our analysis uses the partial deforestation trajectory from Smith et al. (2023), we linearly scale Nogherotto's estimates, acknowledging this assumes a linear relationship that may not hold across all deforestation levels. Duku & Hein (2021) simulated 50% tree cover loss in the Guineo-Congolian region and found rainfall reductions in West Africa of approximately 5-10% (Figure 5, panel a, in source), consistent with our linearly scaled estimate.

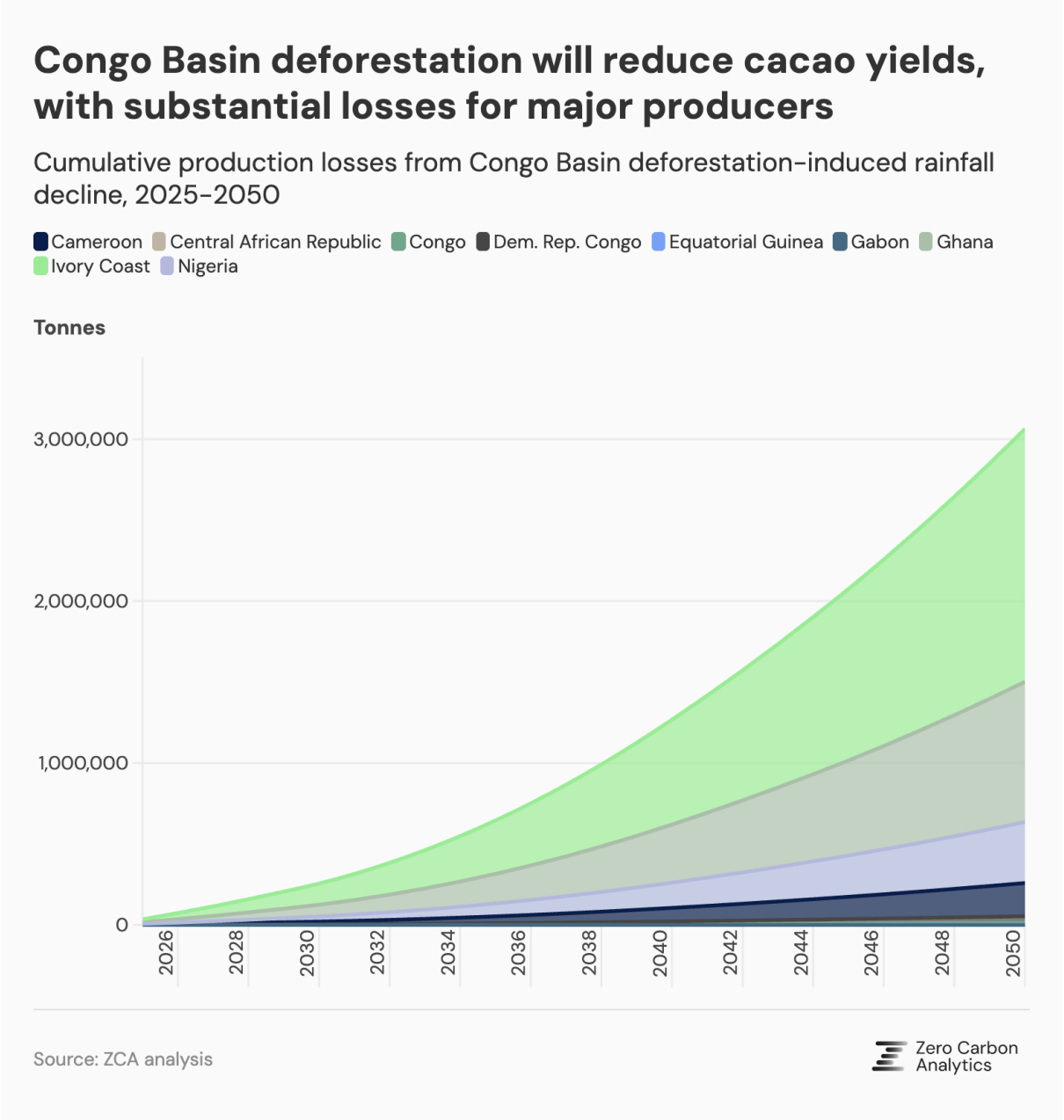
[9] We drew from controlled field studies of cocoa in West Africa showing that 67% rainfall reduction causes 31% yield loss in cocoa trees, and scaled this to our rainfall reduction trajectory. We used an exponential decay function to capture the non-linear response of plants to water stress, where each additional percentage point of drought inflicts disproportionately more damage.

[10] To model cocoa price responses to production scarcity, we implemented an exponential function reflecting commodity market dynamics. We calculated a 'scarcity multiplier' as exp(6.5 × production loss share), capped at 4.0× (400% increase), where production loss is derived from deforestation-driven yield declines. The coefficient of 6.5 captures cocoa's extreme supply inelasticity, with relatively small supply reductions generating outsized price increases (a 10% production loss yields a 1.92× price multiplier, while a 20% loss approaches the 4.0× maximum). The multiplier is applied to baseline price projections of annual growth, a climate risk premium and adjusted for long-run demand elasticity (-0.57).

African cocoa producers could face substantial yield losses due to rainfall decline caused by deforestation

Our analysis showed that deforestation-induced rainfall decline is projected to reduce cacao yields in all nine assessed countries, with cumulative losses totalling 256,000 tonnes across the nine countries by 2030, and 3.06 million tonnes by 2050 (Figure 1).

Figure 1



Major cocoa producers could face substantial losses, which could destabilise local economies. Ivory Coast, the biggest producer, could see cumulative losses of almost 1.6 million tonnes by 2050, around 80% of its current annual production volume. Cocoa is the biggest export commodity in Ivory Coast, making up roughly one-third of exports.

Losses could total 866,000 tonnes in Ghana, 377,000 tonnes in Nigeria and 205,000 tonnes in Cameroon by 2050. Cocoa accounts for more than half of agricultural exports in all three countries.

Deforestation will have an increasingly big impact on cocoa prices

Our model projected how the price of cocoa would change until 2050, and how much deforestation would impact future prices. We looked at three components that drive cocoa price and compared their impacts over time. The components were:

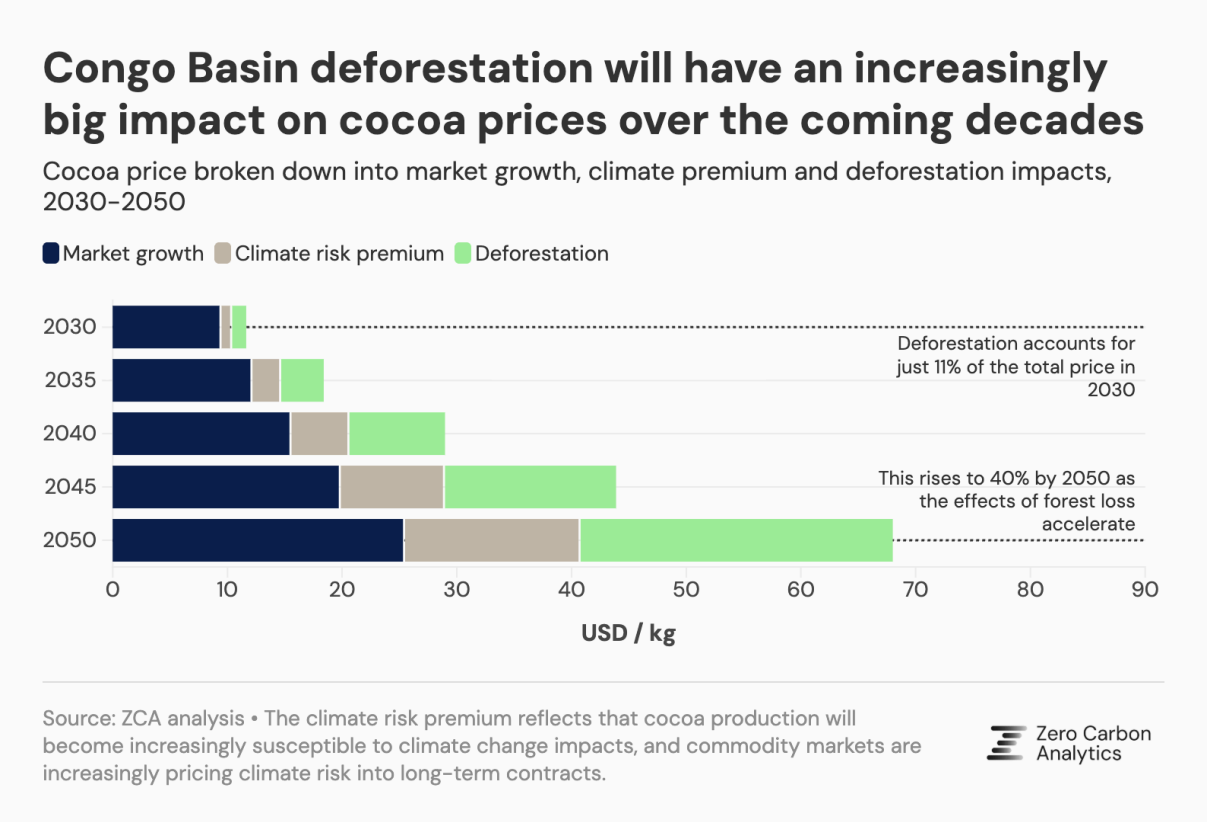
- **Baseline market growth**, the projected annual growth of the cocoa market[11]
- **A climate risk premium**, as cocoa production becomes increasingly susceptible to climate change impacts[12] and commodity markets are increasingly pricing climate risk into long-term contracts[13,14]

[11] Based on the International Cocoa Organisation (ICCO) historical trends of a 5.1% compound annual growth rate (CAGR) 2000-2020, which excludes the dramatic price spike observed over 2024-2025.
[12] Analysis indicates that by 2050, increased drought severity will impact 80% of cocoa production in Ivory Coast and virtually all production in Ghana. Most areas will experience modest increases, but substantial portions will face moderate drought intensification.
[13] We included a 2% climate risk premium to capture forward-looking market expectations of climate impacts. Recent research shows that climate risk has significant predictive power for agricultural commodity prices, with investors willing to pay up to 295 basis points annually to access climate risk information. A 2024 study on EU cocoa markets found that extreme drought events alone could increase prices by 110-180% during crisis years by 2050 under climate change scenarios RCP2.6 and RCP8.5, respectively. Again, our climate premium, which compounds to a 209% increase by 2050, is broadly consistent with these estimates. Our climate premium is also consistent with estimates from sovereign bond markets, where countries highly exposed to climate risk face risk premiums of 1.13% to 2.75%, and with growing evidence that physical climate impacts are materially priced into commodity and capital markets. While bond risk premia aren't directly transferable to commodity pricing, they indicate the scale of climate risk being priced into markets. The NGFS (2024) further notes that investors are now adjusting expected returns across asset classes to account for nature-related physical risks such as deforestation, biodiversity loss and food system disruption.
[14] Our deforestation analysis focuses on systematic, gradual climate impacts, meaning it may underestimate costs from acute climate risks, including extreme weather events. The 2024 cocoa crisis, which triggered 400% price increases, shows how acute climate shocks can generate economic impacts far exceeding our model's projections. Similarly, El Niño-Southern Oscillation (ENSO) events have caused yield losses of up to 89% in major cocoa-producing regions.

- **The cost of yield losses from deforestation and price increases** as supplies shrink.

Our projections showed that deforestation will have an increasingly big impact on cocoa prices (Figure 2). Until 2030, normal market growth is expected to account for the majority of cocoa price (>80%), with climate risk and deforestation having a relatively small impact. In 2030, we project a cocoa price of USD 11.6 per kilogram, lower than the peak price of almost USD 13 per kilogram seen during the 2024 supply crisis.

Figure 2



By 2050, Congo Basin deforestation will persistently reduce rainfall and cocoa production, resulting in shortages and triggering exponential price increases.[15] Our projections show a cocoa price of USD 68.1 per kilogram in 2050 - almost six times the

[15] Our model includes a demand elasticity adjustment that provides some tempering effect as high prices reduce consumption. We use a long-run demand elasticity of −0.57 based on economic research on global cocoa markets. Cocoa's limited substitutability keeps demand relatively inelastic, meaning price increases largely persist because there is no alternative for buyers to turn to. Our model assumes static production systems, with no adoption of drought-resistant cacao varieties or irrigation.

2030 price.[16] By this time, normal market growth will account for just 37.3% of the price, the climate premium will contribute a modest 22.5%, and deforestation will have the biggest impact, driving 40.2% of the price.

Without deforestation, normal market growth plus the climate risk premium would result in a 2050 price of USD 41 per kilogram, just over three times the peak price during the 2024 supply crisis. Deforestation risk escalates this price by nearly two-thirds.

Production losses would cost major EU cocoa importers

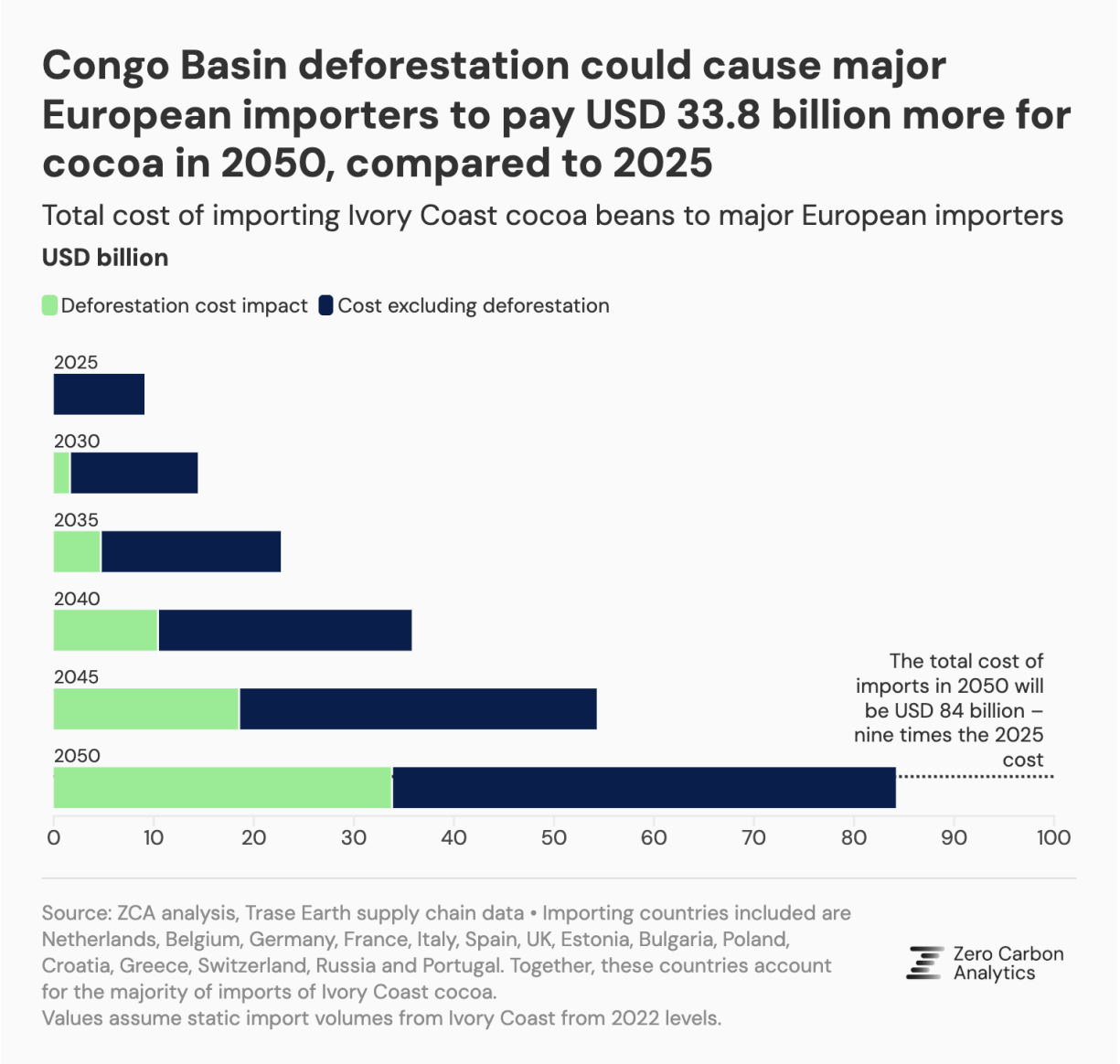
The rising price of cocoa could have significant cost implications for importers, particularly in Europe. Using Trase Earth's data on cocoa exported from the Ivory Coast,[17] the region's biggest cocoa exporter, we estimated what increased cocoa prices could mean for the 15 European countries that account for the majority of imports: The Netherlands, Germany, Belgium, France, the United Kingdom, Italy, Spain, Estonia, Bulgaria, Poland, Croatia, Russia, Portugal, Greece and Switzerland.[18, 19]

Assuming shipment volumes remain stable at 2022 levels, deforestation could result in these countries together paying USD 33.8 billion more for cocoa imports in 2050 than in 2025 (Figure 3). Including baseline market growth and the climate premium, the total costs exceed USD 84 billion – nine times the 2025 cost. Without the impacts of deforestation, the 2050 costs drop to USD 50 billion, or 5.5 times the 2025 value.

These importers could face cumulative additional costs of USD 256 billion by 2050, if no conservation action is taken to protect or restore forests – almost double the entire global chocolate industry's 2024 market value of USD 130 billion.

[16] As a robustness check, we tested a Bayesian weighting approach that dynamically adjusts scenario probabilities based on system stress indicators (forest loss rates, rainfall reduction intensity). This approach results in a 2050 cocoa price of USD 81/kg versus USD 68.1/kg in our main model – a difference of 20% – suggesting our central estimates may be conservative. The Bayesian approach helps quantify uncertainty about the severity and timing of climate impacts while confirming our core finding that deforestation-driven climate impacts pose substantial economic risks to cocoa production.
[17] We used 2022 export data and assumed static imports from 2022 levels for all years into the future.
[18] From the Trase Earth dataset we extracted the trade volume (in tonnes) and multiplied this by our price estimates for different years, broken down into normal market growth, climate premium and deforestation components.
[19] Listed in order of export volume from biggest to smallest.

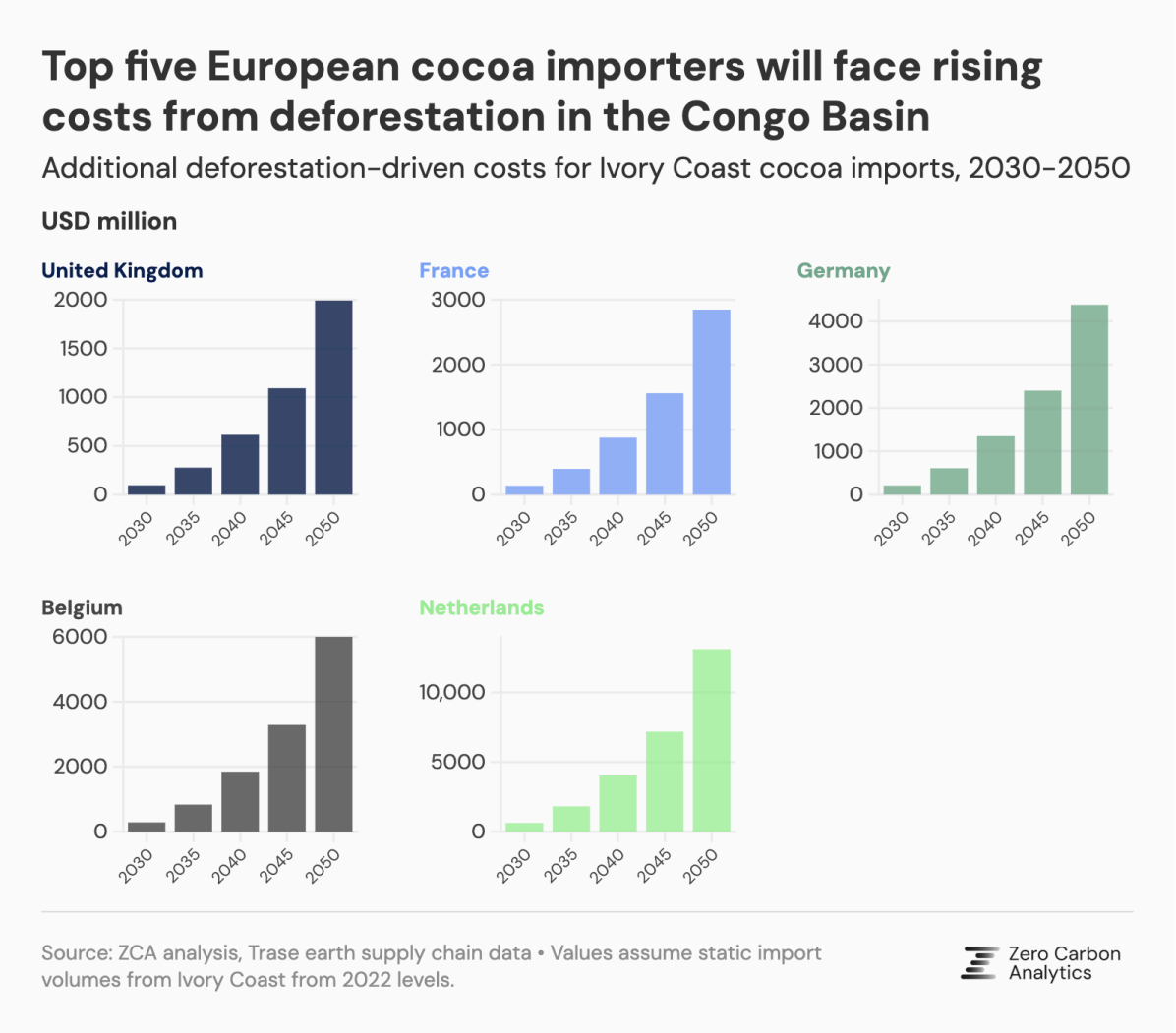
Figure 3



For the Netherlands, the biggest importer of Ivory Coast cocoa, rainfall decline due to deforestation could mean shipments cost an additional USD 1.8 billion in 2035, USD 4 billion in 2040 and USD 13.1 billion in 2050, compared to 2025. Combined with normal market growth and climate disruption, this results in a 2050 cost for the same volumes of almost USD 33 billion (Figure 4).

Belgium and Germany, the next biggest importers, could see deforestation raise the cost of shipments by USD 6 billion and USD 4.4 billion in 2050, respectively, bringing overall costs to between USD 15 billion and USD 11 billion.

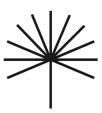
Figure 4



To put these figures into perspective, the additional cost for the Netherlands in 2050 equals around 3% of its 2025 annual government budget, or nine times the controversial higher education cuts that sparked debate in April 2025. For Belgium, the 2050 cost increase represents around 1% of GDP, and in Germany, the additional cost it equivalent to the funds earmarked for supporting companies' green transition.

There is a critical window for intervention

While impacts remain manageable through the early 2030s, they accelerate dramatically after 2040, transforming from millions to billions in annual costs. This trajectory suggests that without immediate action to halt deforestation, annual import costs could exceed what major buyers can absorb, undermining the viability of the Ivory Coast's cocoa sector and passing costs on to consumers.



New EU regulations, expected by 2026, will require cocoa imports to be deforestation-free. In response, the European Investment Bank (EIB) issued a EUR 100 million loan to the Ivorian national investment bank (Banque Nationale d'Investissement, or BNI) to support sustainable cocoa production, youth and female employment, and traceable, certified supply chains in Ivory Coast.

In addition to promoting sustainable cocoa production, Ivory Coast and the EU are collaborating on large-scale reforestation and forest protection initiatives aimed at reversing decades of environmental degradation. These efforts are supported by an additional EUR 150 million investment from the EIB, which is helping to finance the country's national forest preservation, rehabilitation, and expansion strategy.

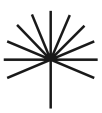
Analysis shows that Congo Basin conservation is cheaper for the EU than the cost of inaction

Comparing Ivory Coast cocoa trade data with the future cost of deforestation reveals a clear economic case for importers to invest in forest conservation in the Congo Basin. The projected cost impacts of deforestation for all EU countries up to 2050 are enough to fund comprehensive conservation for multiple decades, preventing damage and supporting sustainable development across Central Africa. The EU is the largest importer of Ivory Coast cocoa, importing 1.16 million tons across 12 EU countries in 2022.

We compared the cumulative costs the EU could face by 2050[20] against recent investments made in conservation interventions in the region[21] and found that funding

[20] All values used in the intervention analysis are present-value adjusted. Present value calculations employed a 3% discount rate over 25 years (2025-2050), with annual additional costs calculated as import volumes (tonnes) × 1000 × deforestation price impact (USD/kg), discounted to 2025 present value using standard financial formulas: PV = 1/(1+r)^n, where r is the discount rate and n is the number of years from the base year. USD 256 billion here, when present-value adjusted, results in a value of USD 146 billion.

[21] The interventions include Regreening Africa, which focuses on FMNR in Ghana and Rwanda and has an average implementation cost of USD 115 per household every six years, as well as the Northern Congo Agroforestry Project, which includes cocoa-banana agroforestry at USD 1005 per hectare, and subsistence-type agroforestry at USD 861 per hectare, which are one-off costs.



actions to prevent deforestation in the Congo Basin[22] could be economically beneficial, offering viable economic returns for sustainable finance.

We compared six conservation scenarios, each involving different shares of three intervention types:

- Farmer-Managed Natural Regeneration (FMNR), a low-cost land restoration technique focused on growing trees and shrubs, including for food and timber
- Subsistence agroforestry, where trees are integrated into agricultural land to bolster food security
- Cocoa-banana agroforestry, or the co-growing of cocoa and banana trees.

Our conservation scenarios ranged from a low-cost community approach weighted towards FMNR, to a food security-focused scenario that is predominantly subsistence-based, and scenarios implementing different levels of agroforestry (Figures 5a and 5b).

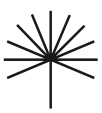
All of the intervention scenarios provide clear benefit-cost ratios by 2050,[23] when they are anywhere between 50% to 100% successful at preventing deforestation-induced price increases.[24] Investments in conservation in the Congo Basin are robust, meaning they maintain positive returns even when projects are only 50% successful.[25]

[22] We defined our target intervention area based on the Congo Basin area deforested over 2003-2017. We used the geographic bounds from Smith et al. (2023), which encompass the Congo Basin forests whose loss affects rainfall in cocoa-producing regions and for which we based our climate-economic model on. We extracted grid cells (Smith et al. Figure 1a) with non-negligible tree cover loss (>5%) over the period 2003-2017. This resulted in an intervention area of 427,477 km2 (or 21.7% of the Congo Basin broadleaf evergreen forests). We calculated population sizes by overlaying WorldPop spatial data and extracted the population density (people/km2). Based on this, we calculated an average population density for our intervention area. Surveys report that the average household size in the region is 5 people. Using this together with our people/km2, we were able to estimate how many households are in our intervention area for targeting.

[23] Benefit-cost ratios (BCRs) were calculated as present value of avoided EU import costs divided by present value of intervention investments, with economic viability defined as BCR ≥ 1.0.

[24] The analysis calculates the potential reduction in deforestation-driven cocoa price increases under varying intervention success rates (50%, 70%, 100%) to determine what portion of those projected price increases can be prevented, while maintaining full program costs regardless of outcomes. For example, a 50% success rate means that interventions successfully prevent 50% of projected deforestation (and therefore 50% of the associated modelled price impacts), but 100% of program costs are still incurred.

[25] Our estimates are likely conservative because we have only included Ivory Coast, which accounts for approximately 50% of cocoa production in Africa, meaning the total economic impact of regional deforestation on EU importers could be larger when including other major producers such as Ghana, Nigeria and Cameroon.



Figures 5a and 5b

Investing in Congo Basin conservation promises avoided import costs for the EU

Cost-benefit ratios for different conservation scenarios in the Congo Basin, at different project success rates

	100% success	75% success	50% success
Low-Cost Community Approach	6.00	4.20	3.00
Food Security Focus	5.40	3.80	2.70
Diversified Portfolio	4.90	3.40	2.50
Income Generation Focus	4.40	3.10	2.20
Equal Agroforestry Mix	3.70	2.60	1.80
Cocoa/Banana-Dominant Strategy	3.60	2.50	1.80

Source: Zero Carbon Analytics analysis • A 6.00 cost-benefit ratio implies that the EU would benefit from 6 USD in avoided cocoa import costs for every 1 USD invested. Success rate refers to the success at preventing deforestation, and therefore deforestation-induced price increases. Full program costs are maintained, regardless of outcomes.

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Congo Basin conservation scenarios, focused on different types of deforestation interventions

Scenario name	Description
Low-Cost Community Approach	40% FMNR, 30% Subsistence Agroforestry, 30% Cocoa/Banana Agroforestry
Food Security Focus	30% FMNR, 50% Subsistence Agroforestry, 20% Cocoa/Banana Agroforestry
Diversified Portfolio	25% FMNR, 40% Subsistence Agroforestry, 35% Cocoa/Banana Agroforestry
Income Generation Focus	20% FMNR, 20% Subsistence Agroforestry, 60% Cocoa/Banana Agroforestry
Equal Agroforestry Mix	0% FMNR, 50% Subsistence Agroforestry, 50% Cocoa/Banana Agroforestry

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The scenario that emphasises community-led restoration, which focuses on FMNR, showed the highest benefits. Returns range from 3:1 at 50% success to 6:1 at 100% success, meaning the EU could benefit from USD 3 to USD 6 in avoided costs by 2050 for every dollar it invests in community-led restoration.

Agroforestry-focused strategies showed slightly lower cost-benefit ratios, but still promise returns and may prove more sustainable in the long term, as they generate direct income streams that provide farmers with ongoing economic incentives to maintain projects, and give access to food and fodder.

The choice between strategies should ultimately depend on project-specific objectives, whether that be immediate cost-effectiveness, long-term sustainability, community ownership, or economic resilience.