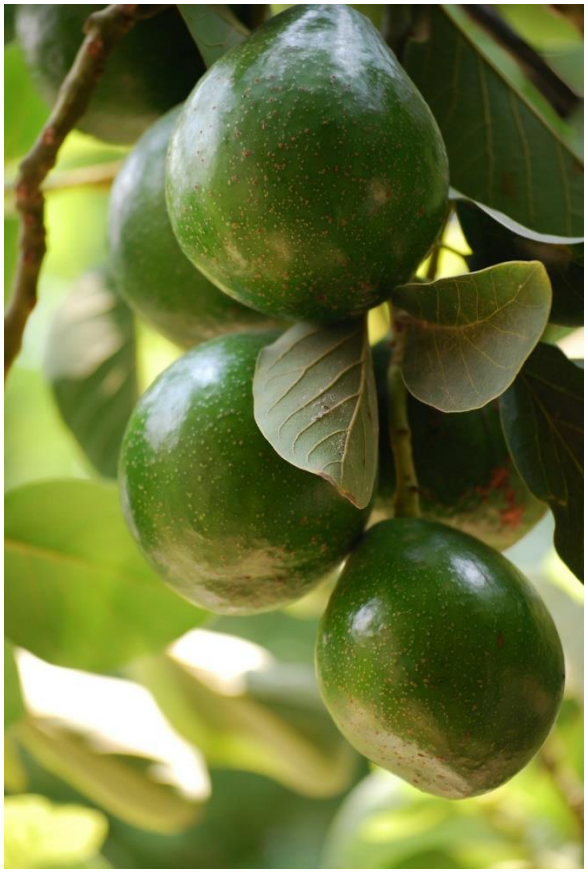
Getting Smashed

The climate danger facing avocados

May 2024



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Introduction

Avocados are a fruit of the *Persea americana* tree believed to be native to Mexico or Central America. They were cultivated by the Aztecs who called them 'ahuacacauahuitl' or 'testicle fruit'. Spanish conquistadors corrupted this to aguacate and the English further, to avocado, helping to avoid the European blushes a direct translation might engender.

Although there are around 500 varieties of the tree[1], one, Hass, has come to dominate the global export market. Its thick skin makes it more reliable to transport unscathed, the trees are easy to propagate, they produce fruit by their second or third year - earlier than some other varieties - and have a longer harvest season than many other varieties. There are clearly many advantages to Hass cultivation. However, since many of the millions of commercial avocado trees are genetically descended from that single Hass mother tree[2], it does mean that much of the global market is reliant on a crop with very little genetic diversity to draw on to be able to adapt to the changing climate. Further, around half of wild relatives of the *Persea* trees have been assessed to be endangered or vulnerable due to encroachment on wild areas by agriculture. This potentially reduces the genetic diversity available to breed new varieties that may better cope with the changing climate.[3]

"In Burundi climate change is a huge problem, especially for avocado growers. We are experiencing hot temperatures, heavy rain and erosion which is having a terrible impact on farmers productivity and their income."

- Jolis Bigirimana, avocado farmer, founder & president, Farmer's Pride Burundi

Avocados have become something of a controversial fruit, because of their environmental impacts and the role they have been forced into in intergenerational culture wars, where an Australian millionaire has claimed millennials could get on the housing ladder if only they didn't spend their cash on avocado toast[4].

Environmentally, avocados are a thirsty tree and this means they can put pressure on water supplies in areas that are water stressed. Since much water is exported with the fruit, this means that there is further depletion of water within the source ecosystem. The CO_2 emissions from the long distances covered in transporting avocados to international markets, as well as the energy-intensive temperature controlled conditions they require in transit, have meant that their impact on the climate is higher than some other export crops. In some areas, including Mexico, avocado production has become so lucrative that it is serving as a driver for deforestation, further contributing to CO_2 emissions, as well as to biodiversity loss.

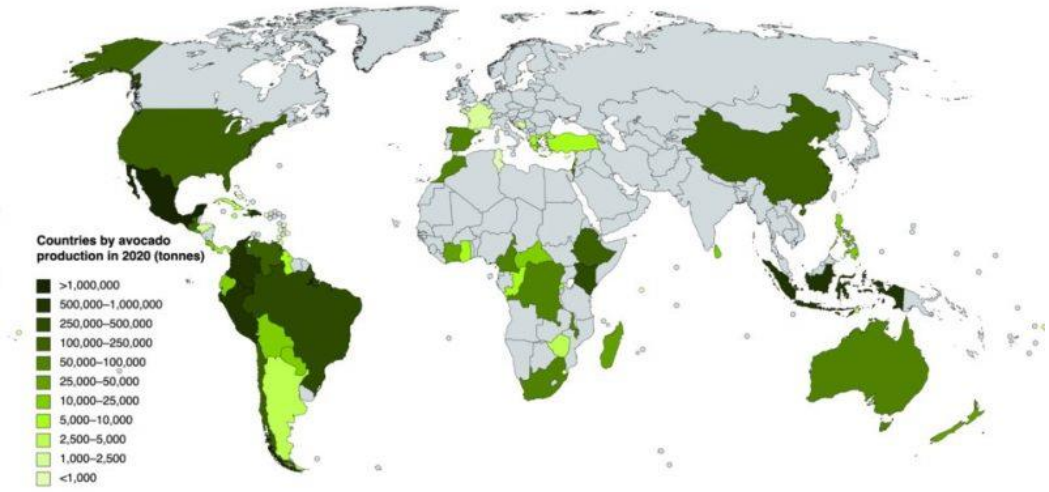
But avocados themselves are vulnerable to climate impacts. Their need for water means they can suffer in regions that are receiving less rainfall because of climate change. They also have heat tolerance limits that may be challenged with the increasing numbers of heatwaves being seen around the world. Their growth and viability as a crop in the changing climate in the current major producing areas of Mexico, Spain, Chile, and Colombia is projected to shift. Overall areas deemed highly suitable for growing avocados are expected to decline by 14-41% globally by 2050, depending on the climate scenario, but moderately suitable second tier areas will grow by only 12-20%[5]. Avocado production may not be down and out with climate change, but this would cause major problems for current growers with many being put out of business.

However, unlike some cash crops, including coffee, cocoa and tea, avocado production has the potential to offer small-scale farmers the choice between whether to consume the fruit or to sell them as cash crops. This choice can improve farmer resilience by giving them options within prevailing conditions: the case study on Burundi in this report explores this opportunity in more depth.

Avocados are highly nutritious and contain healthy fats, vitamins and minerals that are essential for human health. They are also being researched for potential activity against diseases, including cancer.

The global avocado market

Countries by avocado production 2020[6]



In 2022, the UK was the seventh largest importer of avocados in the world accounting for 3.31% of imports of the fruit, behind the US (43.1% of imports with a value of US$3.15 billion), the Netherlands (11% and US$802 billion), France (6% and US$438 million), Canada (4.6% and US$336

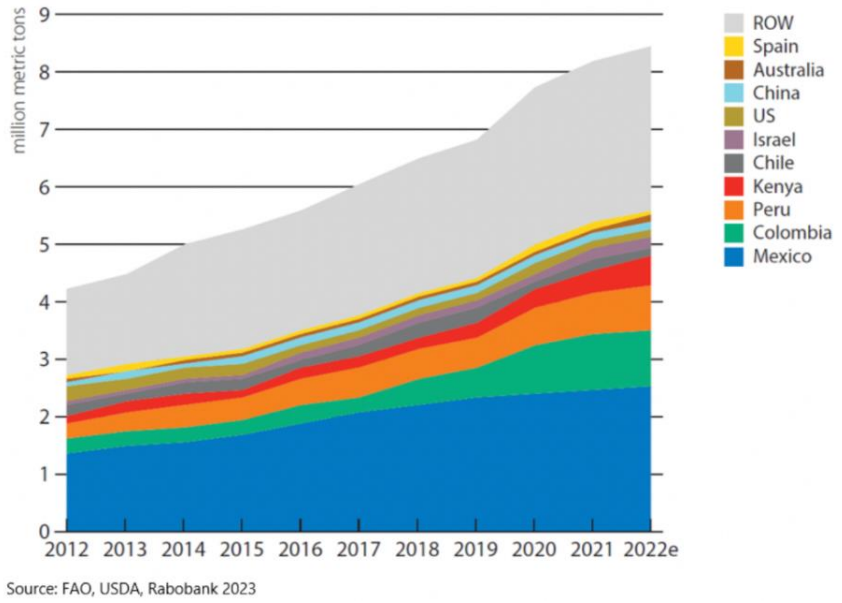
million), Spain (4.25% and US$310) and Germany (3.96% and US$289 million). That same year, avocados were the 539th most traded product with a total value of US$7.3 billion – 0.031% of total world trade[7].

Demand in the US has risen rapidly, from just over 1kg per capita in 2000 to 4.18kg in 2022[8]. This is thought to be in response to the perception that avocados are a superfood[9], because of their richness in important nutrients.

Mexico dominates the export market, with a 44.5% market share, worth US$3.25 billion. Peru, Spain, Chile and Colombia are also significant exporters, respectively with 13.5%, 5.74%, 3.6% and 2.72% of market share. The Netherlands is not a grower, but ranks highly - 9.91% of goal exports - because of its reexport business.

There is also rapid growth in exports from Morocco (up 64.9% from 2021-2), Israel (up 63.4%, Mexico (up17.4% and South Africa (up 6.9%)[10]. Overall, the market for avocados is one that continues to grow rapidly.

Figure 1: Global avocado production advanced at a rapid pace



Source: FAO, USDA, Rabobank 2023

Figure 1[12]

Diversification in the regions where avocados are grown means that harvesting seasons allow for year-round availability of avocados in the main markets of the US and Europe. Mexico can provide year-round harvesting, but its output dips in June and July, when production in California and Peru peaks. Europe benefits from exports from Peru, Colombia, Spain, South Africa and Kenya to ensure year-round supply[11].

Avocados and climate change

The study cited in the introduction revealed that by 2050, highly suitable areas for avocado growing will decrease globally by 14% under an RCP 2.6 emissions scenario and by 41% under an RCP 8.5 scenario.[13]

Like most plants, avocado trees have clear ideas about the kind of conditions they find acceptable. The trees are sensitive to frost, and don't appreciate salinity, which means that irrigation water needs to be of high quality[14]. They don't appreciate standing in water, but are quite thirsty, not least because their shallow root balls mean that they are exposed to what water is available near the surface and can't access water that is less susceptible to evapotranspiration from greater soil depths[15]. The trees can tolerate temperature ranges between -2°C to 35°C, but if there are periods of extended heat, the trees will struggle to grow and set fruit. Avocado trees appreciate moderate humidity levels of around 45-65%[16]. Too much sun can burn the tree's leaves and so they can benefit from shade from taller trees or from protective covering: access to water can reduce this risk, but it can weaken the tree if sufficient damage is allowed to occur.

A study in the Limpopo region of South Africa found that climate change could increase the demand for irrigation by at least 8.7% by 2050 and up to 17.4% by 2080, and while there was some potential to mitigate the risk that avocado water needs would exceed available irrigation capacity, there was still a 45% frequency of years where insufficient water was available, indicating a significant risk of multi-year droughts[17]. Eighty-seven percent of industry respondents to a survey in that region also acknowledged they they'd observed shifting weather patterns and that the higher temperatures and lower rainfall were negatively affecting avocado crop yields. Since around 6,000 permanent farming jobs and an additional 2,000 casual jobs have been created by avocado production, climate change also risks important social impacts for these workers. The study recommended installing water harvesting and storage, the use of mulch to reduce evapotranspiration, windbreaks and canopy management[18].

Many of the avocados grown for trade are the Hass variety, because the thick skin makes them easier to transport intact. This puts the global avocado industry at great risk because of the sheer lack of genetic diversity within the trees[19]. Some varieties appear to be tolerant of higher heat than the Hass, such as Reed, Lamb Hass and Mexicola, and perhaps these are genetic lines that could increase the resilience of the avocado trade to heat-related climate impacts, along with wild species that have not been used to expand the genetic diversity of commercial cultivars. Alternatively, zones of avocado production may simply shift, with growers needing to take into financial account the 3-4 years the trees require before they produce their first fruit[20].

Changes to their preferred climate conditions are not the only ways climate change can make life more difficult for the avocado trees. Fungal diseases can proliferate in high density growing conditions because of more frequent pruning of the trees, but heavy rainfall can increase spore production and infection, and rain splash is one mechanism of infection. Trees that are stressed by other factors, such as poor irrigation, nutritional stress and large-scale insect attack are also more susceptible to succumbing to fungal diseases[21]. Climate change can therefore be seen not just as a direct threat to tree viability but one that interacts in complex ways with other components of the agricultural ecosystem.

Other environmental impacts of avocados

Avocados have environmental impacts in their production and preparation for readiness for market.

Avocados are a thirsty crop: it can take 320 liters of water to grow a single avocado[22]. The water footprint of avocados is around four times that of oranges and ten times that of tomatoes[23]. Since they tend to be grown for export markets, this means that this water is exported from its home ecosystem, and may therefore exacerbate any drought impacts of climate change locally. The UK's avocado water footprint is over 25 million cubic meters of water annually, enough to fill 10,000 Olympic-sized swimming pools. And this is taken from regions in countries including Peru, South Africa, Chile and Israel that are already water stretched[24].

Avocado trees are susceptible to fungal diseases. Fungicides may be applied during growth phases, but there has been research on integrated pest management techniques that help to identify pests and to use biological control and nonchemical methods[25] and to find synergistic approaches that manage pests while minimizing detriment to insect pollinators of the avocados[26]. These are not always used, however, and in Mexico, there are reports of the agrochemicals being used causing health impacts on local communities, including respiratory impacts and stomach problems during times of orchard fumigation. There are also fears that contamination of water supplies is causing liver and kidney problems in a lakeside village[27].

Even when methods to reduce agrochemical use are employed in the field, post-harvest application of fungicides is commonly used to reduce fruit loss, and this means that harmful chemicals are being used as

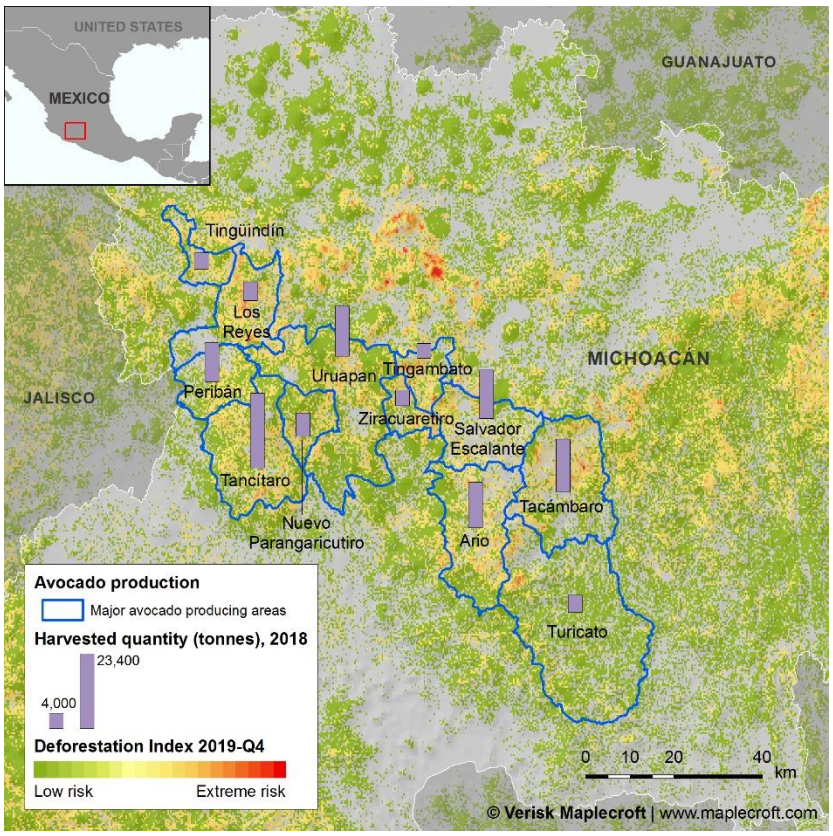
part of the avocado export trade. However, comforting for consumers, one study found that the pesticides tested were present in negligible quantities in the edible part of the fruit, ascribed to the "low peel penetrability" of the fruit's skin[28]. This finding was born out by a study that sampled avocados in the US market for pesticide residues and found that less than 2% of samples showed their presence; avocados topped the list of produce with the lowest amounts of residues in study samples[29].

Country case studies

Of the main producers of avocados, we look at the following in more detail.

Mexico

Mexico's main export market is its neighbor to the north, the US; however, the Netherlands has become an increasingly important market, increasing from 2% of Mexico's export share in 2010 to 9% in 2019[30]. However, avocados play an important role in Mexican cuisine, particularly guacamole, and as of 2013, the average Mexican consumed over 9kg of the fruit per year, meaning that the domestic market absorbed about half of production[31]. Much of Mexican production is by small famers: as of 2020, there were approximately 34,000 growers and 84 packers, with many cultivating less than five acres (just over 2ha). The country's industry body further states that avocado production has created about 78,000 direct and permanent jobs and 310,000 indirect and seasonal jobs[32].



The sheer value of the Mexican avocado crop has caught the eyes of the drugs cartels and other criminal organizations. Growers in Michoacán, in western Mexico have been subjected to land grabs or extortion, as criminal gangs have reportedly made £150 million per year selling so-called blood avocados onto the UK market[33]. In addition to the social harms that the drug spillover into avocado production is having, environmentally the gangs are expanding production through deforestation: this is already a challenge for Mexico, but the involvement of organized crime groups make enforcement of the law more difficult and also leads to larger scale loss of the mature pine forests[34] in what is one of the seventeen most biodiverse countries in the world[35].

As well as deforestation for their production adding to atmospheric CO_2 concentrations, climate change threatens to reduce the growing areas available for growing Hass avocados in Mexico. One study estimated that, for the country as a whole, a current potential of 54,597 km^2 of growing area could be reduced by 31.1% by 2050 under a (RCP2.6[36]) scenario of under 2ºC of global warming and as much as 43% under a (RCP8.5[37]) scenario of around 5ºC of warming. In the state of Michoacán, 22,5561km^2 would be reduced respectively by

59% and 72.3%[38]: a major export commodity for Mexico faces significant threats from climate change. (*Map of avocado production*[39])

Spain

Avocados were one of many fruits and vegetables the Spanish conquistadors brought back from the "New" World, but it was not an immediate hit[40]. Currently much production is centered on the southern coast of Spain, but the needed supply of water is increasingly making avocado growing difficult in that region because of more frequent heatwaves[41]. In the 2022 heatwave, the reservoir nearest to what is Europe's largest avocado-growing area in Malaga Province only had 12% of its former volume. Some farmers responded by uprooting avocado trees and remaining trees dropped their fruits. Such heatwaves have become more frequent because of climate change: what was a once in every 10 years event is now expected once every 2.8 years[42]. In 2023, the avocado harvest was expected to be 60% smaller than that of 2022[43] as another heatwave enveloped the region. An attribution study found that present elevated greenhouse gas concentrations in the atmosphere made the heatwaves 2.5ºC hotter in Europe that if humans had not changed the global atmosphere[44].

Peru

Avocados were introduced to Peru in the fifteenth century. Following the government's crackdown in the 1990s on the Communist terrorist and criminal group the Shining Path, which had caused political and social instability in the country, Peru has developed its avocado industry to become the second biggest global avocado exporter, with the EU as its biggest market. Local varieties of avocados were supplanted by the Hass variety for export markets, eroding the genetic diversity of planting.

Water use is an issue for much of Peruvian avocado growing areas. In the Olmos zone, 38,000ha of trees were planted in the desert. This means that there is less of a problem with fungal diseases in these dry and agriculturally 'virgin' zones than some other regions experience. However, although the temperatures were suitable for avocado crops, water has had to have been brought in through irrigation projects bringing water from the Andes through a 20km tunnel for the crop to be viable. The 75,000ha of orchards in the northern Chavimochic zone rely on open water infrastructure, making the orchards more vulnerable to droughts, as the water faces greater evaporation. The coastal river valleys, with 10-12,00ha of avocado orchards are similarly water stressed and vulnerable[45]. El Niño and La Niña phases of the El Niño climate oscillation (ENSO) both affect harvests. La Nina contributes periods of dryness along the west coast of tropical South America, exacerbating water availability problems in already-stressed zones[46]. El Niño conversely leads to warm seas and greater rainfall in Peru[47]. Extreme ENSO events may become twice as frequent under high greenhouse gas emission scenarios[48].

Chile

Chile has been growing commercial varieties of avocados for over 100 years and the ~36,000 hectares under avocado production are centered in its central zones due to the climatic conditions there. Cultivation expanded greatly in the 1980s because of the opportunities of the increasing demand of the global market. While different varieties are sold on the domestic market, over 99% of the avocados for export are the Hass variety. Three quarters of the exports are to Europe, meaning that there are large transport carbon dioxide emissions associated with Chile's trade[49].

Chile has struggled with increasing problems of fungal diseases of the avocado trees, coinciding with a drought between 2011-16. In Chile, the trees are densely planted, which means that they need pruning more often than they might otherwise[50]. This increases the risks of infection through the pruning wounds[51].

There have been issues with illegal abstraction of water by the big plantations to the detriment of local people who now have to use water trucked in: there have been convictions for this unauthorized water use. The lack of water availability has meant that local people cannot practice agriculture themselves and so people have been leaving the land[52]. Lack of water availability has been exacerbated by a 13-year drought[53]. The drought has been reinforced by a heatwave in 2022, where temperatures exceeded 40ºC, and overall harvests were expected to be the worst in seven years. This heatwave is estimated to have an estimated return of 20 years, but increasing climate change will make such heatwaves more common and hotter. The 2022 heatwave was made 60 times more likely, and 1.4ºC hotter, because of human-caused climate change[54].

Burundi

Burundi is a very different producer to the big exporters outlined above. Not a major global exporter but avocados being used as an essential tool to tackle food security.

Burundi is one of the Least Developed Countries[55] and is in the lowest five countries on the Human Development Index[56]. It has a high malnutrition rate, with nearly two thirds of children under five years old reported as being undernourished; the Global Hunger Index categorizes the country's hunger situation as "alarming[57]". Even during the harvest season families spend up to two thirds of their income on food and finding sufficient nutritious food can be challenging. The landscape is hilly, prone to erosion and landslides, and climate change is exacerbating vulnerabilities of the 90% of the population who work in the agricultural sector[58].

In 2009, Burundi's President Pierre Nkurunziza initiated a program of avocado tree planting with the aims of both improving the nutrition of his countryfolk and providing jobs for millions of unemployed young people in both farming and in the processing plants. Rural people were provided with avocado seeds and within three years 8 million trees have been planted. The campaign has been extended to distribute pineapple and banana plants[59]. For small-scale farmers, avocados represent an important source of nutrients to help reduce malnutrition[60]. It also helps keep the water used to grow the fruit locally, rather than exporting it. Avocados also provide opportunities to export the excess fruit to neighboring Tanzania[61], where the better-quality Burundian avocados can command 3 to 4 times the price of the locally grown fruit[62]. The avocado trees are sometimes used for shorter-term gain: some have been cut down for charcoal making or for firewood for brickmaking, which has had effects on the supply of avocados in local markets[63].

Burundi is not immune to climate change impacts: the 2022 drought inspired sufficient desperation in a national newspaper for it to call into question the wisdom of the President's policy of revitalizing agriculture[64]. The World Weather Attribution group found that for East Africa that year, low rainfall in the long rains was consistent with the climate models and are twice as likely due to anthropogenic climate change, but that that, together with the high evapotranspiration observed, would not have led to drought at all had there not been 1.2ºC of global warming. The hotter temperatures increased soil desiccation and exacerbated the drought[65].

Case Study: Jolis Bigirimana, avocado farmer, founder & president, Farmer's Pride Burundi

"In Burundi climate change is a huge problem, especially for avocado growers. We are experiencing hot temperatures, heavy rain and erosion which is having a terrible impact on farmers productivity and their income.

"We only have a very short period of rainfall here in Burundi and during that period avocado growers used to water their plants. But because of climate change the weather is now more extreme and this has affected our productivity. It now costs us a lot of money to water our crops which has affected our income and is a threat to our livelihoods.

"Climate change also reduces soil fertility which leads to an extra cost of buying fertiliser which reduces our incomes further.

"Because there is no irrigation system, farmers have to pay a water seller to bring water for the crops. If we had some irrigation that would much better and reduce costs. But we lack the infrastructure and need more investment.

"We need to see richer, polluting countries to cut their carbon emissions which is driving this extreme weather and also provide climate finance to help us adapt to the changing climate."

Nutrition and health benefits

It's understandable why Burundi's President is championing the nutritious crop for his people. Avocados are a good source of fibre and monounsaturated fats (the good type), which can act to reduce low density ('bad') cholesterol and thereby reduce heart attack and stroke risks[66].

Avocados also offer their consumers a wide range of vitamins and minerals, including vitamins C, E K1, B6 and folate, as well as the essential minerals copper and potassium[6768]. Vitamin C helps maintain healthy blood vessels, skin, bones and cartilage[69]. Vitamin E also contributes to skin health, as well as eye health and good immune system function[70] and reduces bodily inflammation[71]. Vitamin K helps with blood clotting[72] and helps slow bone loss[73]. Vitamin B6 helps formation of hemoglobin, the chemical which transports oxygen

around the body while folate helps the formation of the red blood cells which carry the hemoglobin[74]. Folate may also help reduce risk of prostate and colon cancer, and can help address folate-deficiencies associated with depression[75]. Copper is also used by the body to produce red and white blood cells and hemoglobin and potassium balances fluid levels in the body and helps the heart function properly[76]. That's a lot of health benefits packed into a small fruit.

There may be more health benefits in store. Avocados have been shown to contain cytotoxic chemicals that work against certain cancer cell lines, including for breast, colon, liver, lungs, larynx, leukemia, esophageal, oral, ovary, and prostate cancers in the body. A 2007 *in vitro* study found that a chemical isolated from avocado leaves had synergistic effects with tamoxifen, a major drug used against breast cancer[77]. A decoction of avocado leaves has been traditionally used in Nigeria for the treatment of tumors[78]. Despite these interesting findings, there are few clinical trials looking at the direct correlation between avocado consumption and cancer prevention and treatment[79].

Avocados are not universally healthy, however. Some people with an allergy to birch pollen may have a cross-reaction triggered to avocados. People with serious latex allergies similarly should be cautious about eating avocado[80], as the allergenic protein in latex is very similar to one found in avocados[81].

Conclusions and recommendations

Avocados are healthy and in high demand, but climate change is reducing the areas where they can be viably produced. They are also very thirsty which can compound the problem of climate driven water stress. Some farmers can choose whether to consume some of their avocado yield but many need to diversify away from avocados as part of adapting to climate change. Consumer patterns in richer importing countries may be affected as availability of avocados goes down and prices go up.

Increase in climate finance to boost adaptation

- This year's COP29 in Baku will see climate finance as its primary focus, with nations negotiating a new long term finance goal for people suffering from climate breakdown. There is a major need for finance which helps people to adapt to the impacts of the climate crisis. Avocado growers and others in agriculture who rely on a stable climate for their livelihoods need support to diversify their income, develop more resilient varieties of plant and help them adjust to a climate that they have done almost nothing to distort.

Tackle the root cause by cutting emissions and accelerate the transition from dirty to clean energy

- The extreme weather that threatens avocados, and the livelihoods of their growers, will only get worse if carbon emissions continue to rise. Developed countries at COP28 in Dubai committed to transition away from fossil fuels in this decade but Governments, including that of the UK, are handing out licenses to drill for new oil and gas, directly undermining the COP28 agreement. They must stop and urgently invest in clean, affordable, renewable energy.

Make polluters pay to provide funds for loss and damage

- Given we are already seeing people facing the impacts of climate change beyond the limits of mitigation and adaptation, we need to get serious about loss and damage. The time has come for polluters to start paying the bill for their actions and being forced to take responsibility for the mess they have caused. The vast profits of fossil fuel companies should be taxed and that revenue fed into the Loss and Damage Fund to assist people that have lost the most to climate change.

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