CHAPTER 8

Climate-Smart Coffee

Abstract Coffee is grown widely along a tropical bean belt stretching across Central and South America, Africa and Asia. Brazil alone produces over two million tonnes a year and global production now tops ten million tonnes annually—over two billion cups of the stuff every day. Coffee's life-cycle carbon footprint ranges from around 70 grams per cup for instant to as much as 150 grams per cup for filter coffee. Major pests and diseases like leaf rust and the coffee berry borer are predicted to become even more prevalent under a future climate. In the highlands of Ethiopia—coffee's birthplace—warmer and wetter conditions in the future may allow fungal diseases to spread to higher altitudes and so threaten areas that are so far fungus free. Moving farms uphill, using shade and irrigation, and potentially switching to new hybrid varieties can all boost resilience and help reduce emissions. Access to training, advice and technology remains a major barrier to this for many coffee farmers.

Keywords Shade coffee • Agroforestry • Ethiopia • Arabica • Robusta • Hybrids • Rift Valley • Coffee berry borer • Diversification

Whether early morning rocket fuel, work meeting mainstay or after-dinner indulgence, coffee is a beloved drink for many millions of us around the world. Our long-standing love affair with it can be traced back to ninth-century Abyssinia (modern Ethiopia) and the province of Kaffa in the

D. Reay, *Climate-Smart Food*,
https://doi.org/10.1007/978-3-030-18206-9_8

southwestern highlands that gave this caffeine-rich infusion its name [1]. Legend has it that a goatherd named Kaldi first discovered wild coffee plants. One hot afternoon in the hills, Kaldi's goats started behaving very oddly. They jumped and skipped, sprinted and surged up the slopes ahead of him. Kaldi saw that the nearest goats were busy eating some sort of red berries from scattered, low-growing bushes. He collected a handful of the berries and tasted them—they were bitter and had large seeds. Kaldi spat them out, but already a feeling of elation was spreading through him. His heart rate quickened, new energy surged through his weary legs. These unappetising berries were the reason for the prancing and leaping of his goats, now he felt like prancing and leaping too.

Collecting more of the precious fruit, Kaldi headed down into the valley to tell his story and present his super-charged berries to the abbot of the local monastery. The abbot was wary. Was this the devil's work? Some sort of poison perhaps? Kaldi looked okay, although he couldn't keep still for long. The abbot had his monks make a brew of the crushed berries and asked his novices to try some. First one, then two, then all of them grinned as their energy levels surged. The abbot and his monks soon found that chewing on just a handful of Kaldi's berries could keep them awake and alert throughout their long nights of prayer. Word quickly spread about the wonder drink from Kaffa. Coffee was born.

By the fifteenth century coffee plants were being cultivated on the Arabian Peninsula, and by the seventeenth century it was being drunk in the chattering coffee houses of London, Paris and Rome. Today coffee is grown widely along a tropical bean belt stretching across Central and South America, Africa and Asia. Our appetite for it is huge. Brazil alone produces over two million tonnes a year and global production now tops ten million tonnes annually (Fig. 8.1). That's over two billion cups of the stuff every day [2].

For dozens of developing countries, coffee has become the aromatic keystone of their economies. In the nations of Burundi and Uganda for example, it accounts for over half of all foreign currency earnings. Worldwide, over 100 million people rely on it for their livelihoods [3], with the US and Europe being the biggest coffee importers [4]. Global trade is now worth around $10 billion each year—second only to petroleum in the rollercoaster ride of international commodity prices [5].

Around two-thirds of the coffee we drink is called Arabica and is produced from roasting the twinned large seeds (coffee beans) encased in the berries of the *Coffea arabica* plant. Most of the rest is known as Robusta

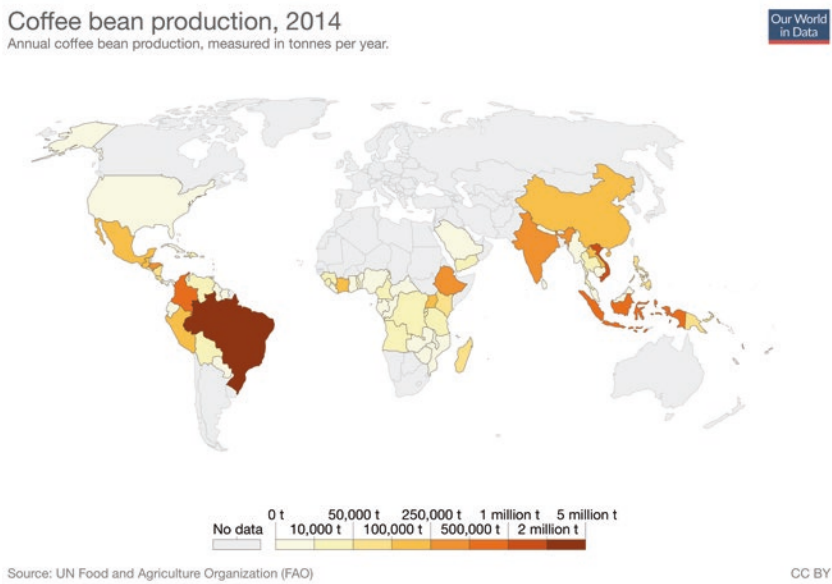

Fig. 8.1 Global coffee bean production in 2014 by country of origin (Source: Hannah Ritchie, Our World in Data) [6]. Available at: https://ourworldindata.org/grapher/coffee-bean-production

coffee and comes from the *Coffea canephora* plant—a close cousin of Arabica first reported in the Democratic Republic of Congo. Robusta, as its name suggests, is easier to cultivate, can have bigger yields, and is more resistant to disease thanks to its high concentrations of caffeine and antioxidants. It also tends to have more of a bitter taste than Arabica and so is most commonly found in lower cost instant coffees. Exploiting the differences between the delicate premium bean-producing Arabica and the tougher Robusta may hold the key to ensuring a climate-smart future for our daily fix.

Both plants enjoy a tropical climate, rich soils and plenty of rainfall (around 1,800 millimetres a year). They produce their first crop of rich red berries 2 to 3 years after planting and can go on for a further 30 years as productive plants [5]. Arabica is the fussier of the two, requiring a distinct rainy and dry season and a year-round temperature range of 15 to 24 degrees Celsius. Above and below this range growth rates start to plummet, with frost damage likely as the plants approach zero. Robusta is even more sensitive to the cold, but seems to thrive at higher temperatures and can cope without there being defined wet and dry seasons.

Our own daily coffee-high in West Lothian comes courtesy of a blend of ground Arabica filter coffee. It includes beans sourced from South America and Africa, with Ethiopia (coffee's birthplace) being the biggest African producer of the particular high strength rocket fuel we have come to love. Ethiopia has an ideal climate for coffee growing, its swathes of high-altitude land mean it can produce some of the best-quality beans in the world, and in large quantities. Coffee provides a livelihood for some 15 million Ethiopian smallholders and their families, almost a fifth of the population. The evergreen forests, high moisture and cooler mountain temperatures of the highlands allow for slower-growing coffee plants that make for premium coffee beans.

Ethiopian farmers mostly hand pick their ripe red coffee berries. For the top-priced beans only the reddest, ripest berries are picked, while for lower grade coffees all the berries are picked in one go. Once picked, the clock starts ticking on getting the crop processed—growers have just 12 hours to get their precious harvest to a washing station (called a pulpery) before it starts to degrade [7]. The pulperies collect ripe berries from all the farmers in the vicinity and soak them in water for 2 to 3 days. This allows removal of the pulpy outer layers to leave the twin 'beans' encased in a slippery skin. These seeds are then dried and the inner skin removed to produce green coffee beans ready to be shipped to the big auction houses of Addis Ababa and Dire Dawa. Export to the consumers of the world is usually via container ship, the precious cargoes then being delivered to roasting plants where the distinctive flavours and aromas of the coffee are brought to the fore—the longer the roasting, the darker the coffee.

The final leg in the life of our roasted beans depends on their destination. Some are shipped as whole beans to be ground to order in one of the countless thousands of coffee shops that now inhabit our streets and shopping centres—in the UK alone we have over 20,000, such coffee shops serving us more than two billion cups of coffee a year [8]. For filter coffees, the beans are ground, bagged and sent to retailers, while for instant coffee the ground coffee is made into a series of stronger and stronger brews. The powerful liquor is then either frozen to minus 40 degrees Celsius in a vacuum (freeze dried) or dried by spraying droplets through a stream of hot air (spray dried).

All of these stages play a role in the total carbon footprint of our coffee, with the growing stage and how we as consumers then choose to prepare and drink it being the prime ones. On the plantations, it is again the use of nitrogen fertilisers that tend to dominate coffee's climate change impact. More greenhouse gas comes from land use change and soil disturbance, and from the energy used in irrigation and pesticide production. Because filter coffee uses more coffee per cup (around 9 grams) than that of the instant types (around 2 grams) its carbon footprint from the growing phase is bigger: over 20 grams of greenhouse gas emissions per cup for filter coffee, versus under 10 grams per cup for instant.

Processing and packaging tips the climate scales in the other direction, with instant coffees needing more packaging and so generating higher emissions there. The packaging for the espresso capsule or pod-type coffees that have become the latest dust-gathering gadget in many kitchens has an especially big carbon footprint, being almost ten times that for the filter coffee and representing the single biggest part of the capsules coffee's climate impact [9]. The capsules themselves can also be hard to recycle [10]. Transport and distribution then add their own top-ups to each coffee's carbon footprint before we then get to decide what the final climate bill will be.

Coffee's life-cycle carbon footprint ranges from around 70 grams per cup for instant to as much as 150 grams per cup for filter coffee. Boiling water and the energy used for making and washing of the coffee cups is a major player, racking up almost half of the total emissions. As such, we have considerable power to make our daily pick-me-up lower carbon. Boiling only the water required [11] will slash these 'consumption' phase emissions. Likewise, avoiding waste—measuring out the perfect amount of grounds and reheating lukewarm drinks—and using a reusable coffee cup can ease the total emissions over time [12, 13]. An estimated 2.5 billion disposable coffee cups are used in the UK each year, resulting in 30,000 tonnes of rubbish [14]. Only a fraction of this is currently recyclable.

Since Kaldi's goats provided the first documented caffeine buzz over a thousand years ago, coffee drinking has become a major player in the global climate impact of our food and drink. The two billion or so cups of coffee drunk each day mean our worldwide coffee addiction is now responsible for around 70 million tonnes of emissions each year. Moving from our households back along the lengthy coffee supply chains are numerous other opportunities to reduce its climate impact, from lower-emission ships and trucks in its transport, to the use of renewable energy in its processing and roasting phases.

A climate-smart approach needs all this and more—providing a lower carbon cup of coffee, that is resilient and that brings its growers secure livelihoods. For the millions of smallholders who grow coffee in Ethiopia the battle to achieve this is already raging.

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Our love for Arabica coffee beans combined with its pernickety growing requirements and a changing climate make for an expensive cocktail. While consumption has doubled in the last 35 years, global production of these premium beans has been hobbled by severe weather and disease outbreaks.

In Ethiopia the coffee-growing heartlands are to be found in the Rift Valley and in the cool tropical forest areas to the west and east of this. At altitudes of 1,000–2,000 metres, these high forests provide the ideal growing conditions for Arabica coffee plants—the shade they provide protects the coffee plants from extremes in sunlight and temperature while also maintaining humidity. The right amount of rainfall, and at the right time, is crucial. But annual rainfall has been decreasing in south-west Ethiopia since the 1950s and the timing and length of the rainy season has become more and more unpredictable. In 2015 a severe drought hit the Harar coffee zone in the eastern highlands. Plants began to wilt and their leaves to curl. As the drought progressed the leaves fell and the few beans that did grow became deformed. By the end of the dry season in early April large numbers of coffee plants, covering many hundreds of hectares, lay dead [15]. In the following year much of the country was hit by an even more severe drought, the worst in 50 years [16].

Rising temperatures make such drought impacts more likely—drying the soils faster, putting extra stress on the plants and reducing the quality of the beans. By the middle of this century average temperatures are set to have increased by over 2 degrees Celsius across much of Ethiopia, with the end of the century seeing in excess of 4 degrees Celsius of warming [17]. At the same time average rainfall across Ethiopia is actually likely to increase, but with a greater risk of extreme rainfall events (causing soil erosion and flooding) and more unpredictability in the timing of wet and dry seasons [15].

Coffee growers in Ethiopia and around the world must face the spectre of pest and disease attack too. Some of the biggest current threats, such as Leaf Rust and the coffee berry borer, are predicted to become even more prevalent under a future climate. Leaf Rust is a fungal disease that is endemic to Ethiopia that has now spread to all coffee-growing regions of the world. Across the million or so hectares of plantations in Colombia an outbreak of Leaf Rust was blamed for the loss of more than a third of production between 2008 and 2011 [18]. In the highlands of Ethiopia, warmer and wetter conditions in the future may allow this fungus to spread to higher altitudes and so threaten areas that have so far been fungus free.

The coffee berry borer appears to be on the march too. A decade ago it was never seen in plantations above about 1,500 metres, yet warming is today allowing it to spread to ever-higher altitudes and with further warming it has the potential to affect over three-quarters of plantations [19]. This costly insect is the most important coffee pest worldwide, causing damage estimated at over $500 million a year and so putting at risk the more than 25 million livelihoods that depend on the industry [20].

The bitter brew of higher temperatures, more unpredictable rainfall, and increased attack from pests and disease means that over half of the current coffee-growing areas in Ethiopia risk being squeezed out of existence by climate change [21].

To escape drought, heat and pests impacts at lower altitudes, more and more growers are expanding their coffee farming higher up the mountain slopes. The Ethiopian government is helping to support this kind of active adaptation, with new plantations being encouraged at heights of over 3,000 metres (a kilometre higher than the norm) [22]. In fact, as Ethiopia's climate changes, some areas are likely to see coffee-growing conditions becoming much better even while others falter.

In the Rift Valley and to its southwest, the area suitable for Arabica coffee is expected to expand through until the middle of the century. This is especially true of higher ground, where warmer conditions will allow successful production in areas that were previously too cold. For a climate-smart response, good access to such locally-specific information is vital. Over in the southeast and eastern highlands, in already drought-hit areas like Harar, the situation looks more worrying. Major declines in the area suitable for coffee are predicted, with complete loss of all viable areas possible in the second half of the century. For Ethiopia's millions of smallholder coffee farmers the future lies somewhere between an extreme of no action—where huge swathes of production are lost, to one of proactive strategies and migration in which coffee farming could boom to four times its current size [23].

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The migration of coffee growing to areas more suitable in a future Ethiopian climate certainly makes sense in terms of increased resilience. To achieve this in a climate-smart way—accounting for its impacts on greenhouse gas emissions and on productivity too—will require careful planning and assessment of the new areas. The specific soil, drainage and shading needs of the Arabica plants need to be met alongside their climate requirements. In some areas there are risks of conflict with other land uses and, because the coffee plants often grow best in shade, planting of companion shade trees in currently unforested areas will be needed. Where successful, such tree planting offers a good opportunity to combine coffee migration with increased carbon uptake.

This practice of shade-coffee is already widely practised around the world including, as we have seen, in combination with bananas (Chap. 7) [19]. For those coffee farmers in Ethiopia already battling the impacts of drought, heat and disease it may boost resilience and extend the viable lifetime of their plantations. The shade trees can cut the temperatures under the canopy by around 4 degrees Celsius compared to unshaded areas, and can serve to reduce damage from intense rainfall or desiccating winds [15].

Down on the ground, mulching of soils to reduce water loss and supress weeds can be effective, while irrigation in drought-prone areas also has the potential to increase resilience in a future climate. The use of irrigation by smallholders remains limited though, and much greater awareness and financial support is required before it reaches its full potential. An effective strategy that is already commonly used is that of terracing (creating flat areas of land bounded by embankments). Such terracing allows farmers to better control drainage and soil moisture, and so to limit drought risks.

For the coffee plants themselves, a climate-smart approach includes good matching of their fertiliser and water needs with what is supplied. As nitrous oxide emissions from nitrogen fertiliser use is one of the biggest components of coffee's carbon footprint, limiting fertiliser inputs to only what is needed for optimal growth benefits both the farmer's profits and the climate [24].

For pesticide use, too, the sharing of good practice and provision of more sustainable alternatives can improve productivity and reduce pollution risks. Many coffee growers rely on the highly hazardous insecticide Endosulfan to fight the ravages of the coffee berry borer. This toxic chemical is, however, a persistent organochlorine, meaning that once it enters the food chain it can accumulate and become toxic to animals and humans—for smallholder farmers in the developing world pesticide exposure has become the leading occupational hazard [25]. As an alternative to Endosulfan, coffee growers in Colombia, Nicaragua and El Salvador have successfully used improved field hygiene methods (such as removing damaged or fallen berries), trapping of the female borers with alcohol attractants, and promotion of biological controls like the insect-killing fungus *Beauveria bassiana* [26].

In some areas no amount of improved care will save the premium Arabica coffee plant and instead it will have to give way to its more heat-tolerant cousin 'Robusta'. The price per kilo of coffee produced may fall, but if total production is increased and gives a more reliable income then smallholder coffee farmers in increasingly marginal growing areas can be better protected.

Beyond switching to Robusta, alternative coffee plant varieties—such as new hybrids of Arabica and Robusta—arguably offer the greatest potential for more drought, pest and disease resistance. Work is underway to establish which existing varieties show the most genetic diversity, with the hope that from these will come hybrid plants better suited to specific areas and better adapted to what climate change will throw at them [27]. The so-far-identified 124 wild coffee species of the world are vital to these efforts, yet 60 per cent of these are now on the edge of extinction due to habitat loss [28].

Here, and across the range of climate-smart approaches for coffee, good research, information and support are vital. In Kenya, Ghana and Zambia, an expanding Pest Risk Information Service is combining weather data, computer models and local crop monitoring to give farmers early warning on pest and disease attacks [29]. Such extension services, finance and opportunities to share best practice between farmers could make all the difference in a changing climate. In addition to improving information and advice on growing practices and migration planning, these farmer-level support systems can open up opportunities to new markets, better prices, and core resilience services like crop insurance [30].

The world's coffee growers are in the midst of a literal uphill struggle to meet soaring demand in the face of increasing pressures from climate change and disease. As a global commodity its carbon footprint is large and the number of livelihoods that depend on it huge. Climate-smart approaches today, from bright berried bushes in Ethiopia to our morning caffeine fix in Scotland, can help to ensure coffee will still be keeping our great grandchildren awake tomorrow.

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