



Climate-Smart Tea

Abstract Tea is second only to water as the world's most popular drink. Total production has grown to around 5 million tonnes a year, with the industry as a whole valued at \$20 billion. Its carbon footprint totals 25 grams of emissions per comforting cup, mainly the energy used to boil water. In the UK almost 60,000 tonnes is wasted each year simply because too much was made or it went cold before we could drink it. Tea plants face climate risks from flood, drought and heat, as well as from increases in disease and pest attack, such as the already highly damaging tea mosquito bug. The use of agroforestry, soil management and carefully planned drainage can all help increase resilience to severe weather impacts. New tea varieties also offer the chance to increase disease resistance. Moving cultivation to new areas is likely to be the only option in some areas as the climate envelop for tea shifts further in the coming decades

Keywords Assam • Agroforestry • Heat stress • Carbon footprint • Shade trees • Drainage • Soil management • Tea mosquito bug • Cover crops • Mulch • Rainfall capture

The crumbled leaves that infuse the daily cuppa of billions are still largely handpicked just as they've been for centuries. Harvesting machines might be faster, but these also tend to mangle the leaves and can damage the precious bushes. Instead, just the top bud and two leaves on new shoots are

carefully plucked every week or so in early spring, and then again in summer. This regular plucking keeps the bushes in a perpetual state of neat new growth and ensures they are always at a convenient table-top height for harvesting [1]. Tea bushes are a long-term investment, with many being over 50 years old and so needing generations of care and attention to ensure they produce the very best quality leaves [2].

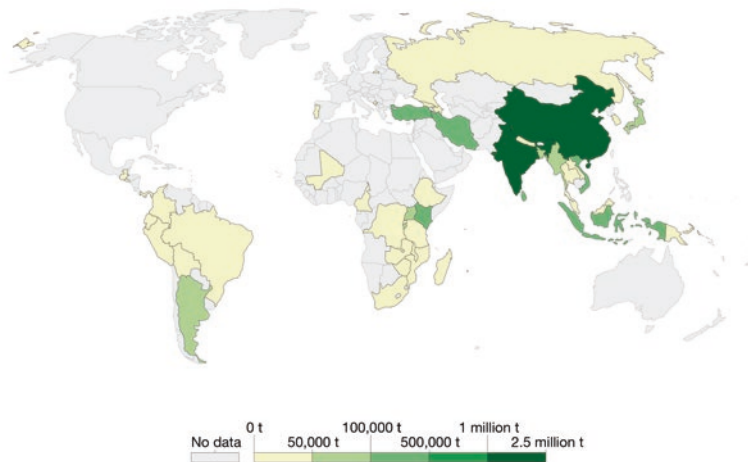
Like much of our daily food and drink, tea tends to clock up some very long distances between plantation and shopping trolley. Though China is now the world's biggest producer (Fig. 4.1), much of it is still produced by the tea-growing giant that is India, with regions like Darjeeling and Assam being world-famous for the quantity and quality of their tea.

Our own neat box of aromatic tea bags contains a blend grown in Assam—a high plateau in the north of India that is responsible for over half of all Indian production [4]. In terms of its carbon footprint, the growing and processing (sorting, drying and the oxidation that turns leaves from green to black) are the main sources of emissions before our

Tea production, 2014

Annual agricultural production of tea, measured in tonnes per year.

Our World
in Data



Source: UN Food and Agriculture Organization (FAO)

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Fig. 4.1 Global tea production in 2014 by country of origin (Source: Hannah Ritchie, Our World in Data) [3]. Available at: <https://ourworldindata.org/grapher/tea-production>

tea reaches us [5]. Despite long travel distances, transport emissions are relatively low with most being exported by sea using large shipping containers. Once in our cupboards and caddies though, making the tea with boiling water becomes the biggest component of the overall carbon footprint, weighing in at around two-thirds of the total 25 grams of emissions per comforting cup (equivalent to 12 kilograms per kilogram of dry tea) [6].

One helpful trend that should cut the carbon footprint of each cup of tea is the move towards more renewable energy. As more comes on line, so the electricity that powers our many millions of kettles is becoming lower carbon. Even more important at the household level is cutting waste. First, the boiling of too much water leads to wasted energy use and so emissions—boiling half a litre of water, instead of the quarter litre actually required, will balloon the carbon dioxide footprint of an average cup of Kenyan tea from a trim 25 grams to a far-weightier 42 grams [6] (around three-quarters of us still boil more water than we need [7]).

Then comes the covert climate penalty incurred by wasting the tea that has been made. Each year in the UK, households generate around half a million tonnes of waste from the tea they make. Most of this is unavoidable, such as used tea bags and leaves destined for the compost bin, but almost 60,000 tonnes is wasted simply because too much was made or it went cold before we could drink it [8]. The emissions avoided by making only what is needed and reheating those forgotten lukewarm cuppas really add up—with a life-cycle carbon footprint that can top 10 kilograms for each kilogram of tea, current wastage racks up hundreds of thousands of tonnes of unnecessary greenhouse gas every year.

Our insatiable thirst for the liquid gold that is tea dates back millennia. Threats to the world's precious supplies have been enough to spark protests, blockades and even wars in the past [9]. In the eighteenth century, Britain's own efforts to secure imports by fixing the market resulted in American colonists showing their anger by throwing a shipment of tea into Boston harbour. This Boston Tea Party signalled the demise of British rule in America.

Today, tea is second only to water as the world's most popular drink. Total production has grown to around five million tonnes a year [10] with the industry as a whole valued at \$20 billion [11]. The days of a British empire wielding its power to manipulate global tea markets may be long gone, but in the lush fields of northern India climate change is laying a heavy hand on the supplies of millions.

Assam is well known for the full-bodied flavour of its tea, with the neatly clipped swathes of bushes that cover its rich floodplains usually luxuriating in a tropical mix of monsoon rains and temperatures in the high-20s Celsius. In recent years though, things have become more unpredictable, and much more dangerous. In the summer of 2013 temperatures in Guwahati—Assam’s economic centre—soared into the high-30s Celsius, breaking previous records, forcing schools to shut and causing several deaths from heat stress [12]. The following year, more high temperatures combined with months of little or no rainfall to trigger drought warnings across the state [13]. Then, in 2016, torrential rains caused landslides and floods that took the lives of more than 60 people [14]. As well as the immediate risk to life and limb, these waves of extreme weather events also signalled dangerous times for the livelihoods of Assam’s estimated 1.2 million tea workers [2].

* * *

The tea gardens of Assam thrive on the plentiful rains that sweep over them each summer. With more extreme wet spells though [15], a triple threat emerges. First, heavy downpours erode soils and strip away precious nutrients. Bushes in low lying and poorly drained soils may find their roots become waterlogged. If this goes on too long then the roots begin to rot and survival of the whole plant is put at risk [16]. Tea bushes that escape waterlogging then have to run the gauntlet of the pests and diseases that can thrive in the wetter conditions.

Tea plays host to an army of pests and diseases that between them can attack every part of the plant. Diseases like Violet Root Rot are a common risk in heavy wet soils, while the airborne Blister Blight fungus attacks young shoots and can spread rapidly in moist, foggy conditions [1]. Tea plant pests are broadly divided into those that chew on the plants and those that suck on them. Of most concern to tea farmers across India and globally is one of the suckers: the Tea Mosquito bug [17].

Both the nymphs and the adults of the Tea Mosquito draw sap from newly emerged buds and shoots. The affected areas first develop irregular brown spots, the leaves then begin to dry and curl up. Eventually the multiple sucking injuries turn the new-growth leaves black and unusable. In bad cases the growth of the whole plant is stunted. Even mild infestations can cause lasting damage, as when the eggs of the Tea Mosquito bug are laid on the plants’ stems they cause them to crack and dieback.

These bugs were first recorded in Java in the nineteenth century, then in India in 1968, and have since become a menace to tea growers all over the world [17]. They have been blamed for large yield losses in Africa, and have destroyed entire tea harvests in some parts of Asia. In India, eight out of ten tea-growing areas are now infected, causing up to half of the annual crop to be lost.

As temperature and rainfall patterns change, the spread and impact of this sucking pest are set to change too. Higher rainfall, humidity and temperature have all been linked to faster bug population growth and an increase in attacks on the leaves of tea. Likewise, more rainy days in North Eastern India seem to allow the bugs to extend their attacks much later into the growing season. The powerful (and now banned) pesticide DDT was apparently effective at controlling the initial outbreaks that hit India in the late twentieth century. Since then a variety of other insecticides have been tried, but the bugs have become resistant to many and their march through the tea gardens of Assam has continued.

After extreme wet spells, a real sting in the tail for Assam's tea farmers comes when they are finally able to access their fields and harvest any surviving crop. When tea plants grow in very wet conditions key chemicals in their leaves are effectively diluted down [18]. These compounds define tea quality and help give Assam's strong breakfast tea its distinctive flavour. So, on top of losing some bushes to root rot, others to Tea Mosquito bug attacks, and having a poor harvest overall, the tea itself is often of low quality and hard to sell.

It's the increasingly unpredictable nature of rainfall that is posing the most immediate concerns for Assam's tea growers. While during one part of the growing season they must cope with the deluges and waterlogging problems of too much rain, at other times it might be severe drought that threatens the tea gardens. Such impacts of climate change are likely to be felt everywhere through major price hikes. If the kind of losses predicted for major tea-growing nations, such as India and Sri Lanka, are realised, then the cost of tea is set to increase by more than a quarter over the next decade [19].

Like all plants, tea has an optimal temperature range. This can vary somewhat between different varieties, but most thrive in the well-watered warmth of low to high-20s Celsius common to big tea-growing regions such as Assam. Go too far above or below this range and growth will slow or stop altogether.

Over the past century in Assam temperatures have been increasing [4, 20]. As the region warms further through the twenty-first century so the risk increases that its tea-friendly climate envelope will begin to shift and disintegrate. At the same time as average monthly temperatures in the summer have crept up, so the tea yield has waned. For every degree they go above 28 degrees Celsius the yield is cut by around 4 per cent [2]. Projected average temperatures by the middle of this century are some 2 degrees Celsius higher than today [21] and so, without adaptation, tea yields in Assam could keep on falling.

Whether extreme heat waves—with temperatures soaring into the high-30s Celsius—will cause even bigger impacts remains unclear. So far, most tea plants in Assam seem able to cope with short periods of such extreme heat [2], though for the region’s multitude of tea pickers such heat waves bring a real risk of heat stress and illness [22].

For the plants it’s a combination of higher temperatures with longer drought periods that can pose a particular risk. Under such conditions they conserve their diminishing water supplies by shutting down photosynthesis, and so growth. Hot conditions mean that soils dry out much more quickly and, with longer periods with no rain, the whole year’s tea harvest can be knocked back [2]. The rains in the south bank area of Assam have decreased over the last 30 years [4], with a series of dry winters and springs meaning that the tea gardens are often already short on water before the growing season begins. Total rainfall in Assam by 2050 is not expected to change all that much, but its timing and the potential for more intense periods of both drought and flood pose a very real risk to its future as a tea-growing nirvana [4].

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With many tea growers around the world facing yields being halved or worse as extreme weather impacts intensify, efforts to boost resilience have taken on renewed urgency. Much of the progress on making tea production climate-smart has been focused on water, and how best to deal with too much and too little.

To tackle heavy rainfall, and the waterlogging of plant roots that can then occur, soil drainage can be a very effective, with optimal drainage estimated to boost yields by up to 50 per cent [4]. Actually achieving such optimal drainage is difficult. Too much, and the tea plants might well stay safer in heavy monsoon rains, but will then be especially vulnerable to

drought stress in the dry season. The undulating topography and patchwork of tea gardens in Assam makes getting drainage just right for every patch a complex task. Changing drainage in one place may increase flood and waterlogging risks in another, while widespread drainage can mean nutrient and pesticide leaching during rainstorms is made even worse.

As more intense downpours risk more soil erosion, adaptations that protect the soils can help protect the whole tea garden [4]. Mulching around plants and incorporation of composts help to improve soil structure and boost water-holding capacity—a boon for nutrient retention and reduced waterlogging, as well as drought resilience. The mulches and composts come from everything from old tea waste and weeds, to worm casts and tea clippings.

In some areas, so-called cover crops serve the dual purpose of soil protector and compost source. These short-lived crops are often grown alongside young tea plants to suppress weeds. Many are legumes and so are also able to pull off the microbial root magic that is fixing nitrogen from the air. This then reduces the need for artificial fertilisers too. Once large enough, the cover crops become a nutrient-rich green manure that can then be incorporated back into soils.

Trees can also make an excellent growing companion to tea bushes. Planted in amongst the tea plants or along the margins of the tea gardens as shelter belts, the trees help to stabilise soils and protect them from the scouring effects of any heavy rainfall. Such deliberate tree planting in agriculture—agroforestry—is a popular climate-smart practice for many crops around the world. It not only has the potential to buffer crops and soil from heavy downpours, but also gives added protection from extreme drought and heat, and can lock-up carbon dioxide to boot.

In Assam, trees rising up above the neatly clipped understory of tea are a common sight. The trees are carefully spaced and nurtured so as to give the best balance of light, temperature and water possible—too much shade risks slowing tea growth and encouraging more attack from pests like the Tea Mosquito bug [1].

During the dry season the trees and their deep roots help to conserve soil moisture and protect the tea plants from extreme heat and scorching. The shade they cast improves the overall efficiency of tea growth, with their diffuse canopies also giving more protection from high winds and hailstorms. As a bonus, the steady fall of shade-tree twigs and leaves helps to boost the structure and organic matter content of the soils.

Shade trees can improve carbon storage too. The total amount of carbon locked up in the living biomass of these areas is estimated at over 50 tonnes per hectare [23]. Of this, the shade trees make up around 70 per cent of the stocks and, together with the tea bushes that surround them, sequester around five tonnes of carbon per hectare each year.

In the most severe hot and dry spells that are likely to beset Assam in coming years, shade trees and mulching may still not be enough. Here, the harvesting and reuse of rainwater can help to give tea growers that extra bit of protection. By creating reservoirs and ponds, farmers can capture more of the heavy monsoon downpours and then later use this same water to irrigate their plants and soils—applying any collected water in the early evening keeps the amounts lost to evaporation to a minimum and helps to bump up soil moisture levels when the plants are at their most thirsty [11].

As with any crop, relying on the success of just one type of tea growing in one particular place often increases the risk of failure of the whole harvest. Planting other crops with different harvest times and different vulnerabilities to drought, pests or floods can ensure that, if one harvest fails, there's at least another to deliver some income. In Assam, this kind of diversification is usually in the form of planting spice crops like black pepper alongside the tea gardens. Some of the more enterprising farmers have even taken to using their rainwater collection ponds to grow fish. The mud-loving Grass Carp is a favourite.

These carp are native to Asia and are well adapted for the weed-filled warmth of Assam's drainage ponds and reservoirs. They feed on submerged vegetation, and with good conditions, young fish can quickly grow to a harvestable size. These fishy grazing machines can also help to prevent drainage ditches and shallow ponds becoming clogged with vegetation—one trial release of grass carp to weed-choked ponds in India reportedly cleared the afflicted ponds within a month [24]. Its impressive ability to Hoover up plant material has made the grass carp a popular choice for fish-livestock farming. Here, manure from ducks, pigs or other livestock is deliberately added to ponds to accelerate plant growth, which in turn boosts the growth of the fish and yields a useful extra income [25].

A wider mix of what is grown on tea plantations (including in the ponds) can therefore give farmers more resilience as they face a future of more frequent and intense extreme weather events. To tackle the increasing threat of pest and disease attacks though, such as from the Tea Mosquito bug, diversification of the tea plants themselves can be a powerful weapon in the climate-smart armoury.

We consumers are increasingly demanding tea that is free from all pesticide and herbicide residues, so tea growers are having to try and walk the tightrope between maintaining tea quality and keeping the tide of pests, diseases and weeds at bay. Tea plant clones help them to do this by providing plants selected for specific traits. The very first tea clone was developed and used in India in 1949 (before then all tea in the world was grown from seed). The clones are grown from selected cuttings and so allow characteristics such as resistance to a certain disease or greater drought tolerance to be brought out. As more and more clones have been developed, so the array of tea plants available to give resilience in different locations and conditions has expanded [4]. By definition, clones are identical, so tea growers tend to use them within a wider mix of tea plant types. This reduces the risk of one severe weather event or disease wiping out the whole crop—the new clone plants might all be good at giving resistance to a certain disease, but that’s little comfort if they are then all destroyed by drought [26].

Where pesticides do still have to be used, the amounts can be limited by managing the tea gardens to keep pest numbers low and pre-empt their attacks. By more frequent plucking of leaves, more of the crop can be harvested before the pests get to the new shoots. Frequent plucking can also be directly targeted at the pests—removing the bugs from the plants before their numbers can increase to damaging levels. Using the natural enemies of tea pests has also become a successful ploy for many growers. These predators, such as some types of wasp and praying mantis, provide a natural control on pest numbers. They can be deliberately released to mop up infestations or can be encouraged by ensuring that any pesticides used target only the pests and leave these natural predators safe to do their work [1].

As climate change intensifies in Assam and around the world, so tea growers will need to make more and more use of a range of climate-smart practices. For some, the vagaries of tea prices combined with severe harvest losses will mean a move away from tea production altogether. For others, a change in location—migrating their tea gardens in line with the changing climate envelope—may be the only long-term solution.

Universal access to the various climate-smart techniques and management practices, from high-yielding tea clones and irrigation to diversification and soil improvement, remains a major barrier in many areas. Still, real progress is being made. Availability and use of improved tea clones is expanding, with real hope that the key to longer-term climate resilience may lie in the very DNA of the tea plants themselves.

In 2017 a team of Chinese researchers managed to sequence the entire tea genome [10]—an impressive feat given the tea genome is an especially large one made up of around 37,000 different genes. The work helped identify exactly where traits like drought, heat and pest resistance (as well as flavours) are derived from. For tea breeders, this genetic blueprint has huge potential to allow more climate change-resilient tea plants to be selected. It also opens up opportunities for targeted genetic modification to enhance those particular plant traits best suited for a particular region and its projected climate [27]. In Kenya, a new variety of purple tea has already been developed that is especially rich in antioxidants. These make it very valuable for use in health products and food preservation, and also more resistant to environmental stresses, pests and diseases [4].

Improving the links between tea growers, policy makers and researchers, to share best practice and jointly develop solutions, has been a focus of recent initiatives in Assam and elsewhere. By engaging directly with farmers and community leaders, training and field demonstrations can mainstream novel techniques and approaches. New market opportunities, such as generating income from carbon credits, certification and rebranding, could also be unlocked. Government involvement can provide climate-shock safety nets to tea farmers through guaranteed crop insurance and sustainable tea prices—while more investment in research will accelerate development and use of new tea varieties, climate change is not going to wait for us [4].

Globally, our most precious of hot drinks faces an uncertain future. Viable zones for tea production will shift, providing new benefits for some and huge risks for others. Facing these opportunities and threats in a climate-smart way will help farmers to proactively address climate change and ensure we all still get our daily infusion of liquid gold.

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