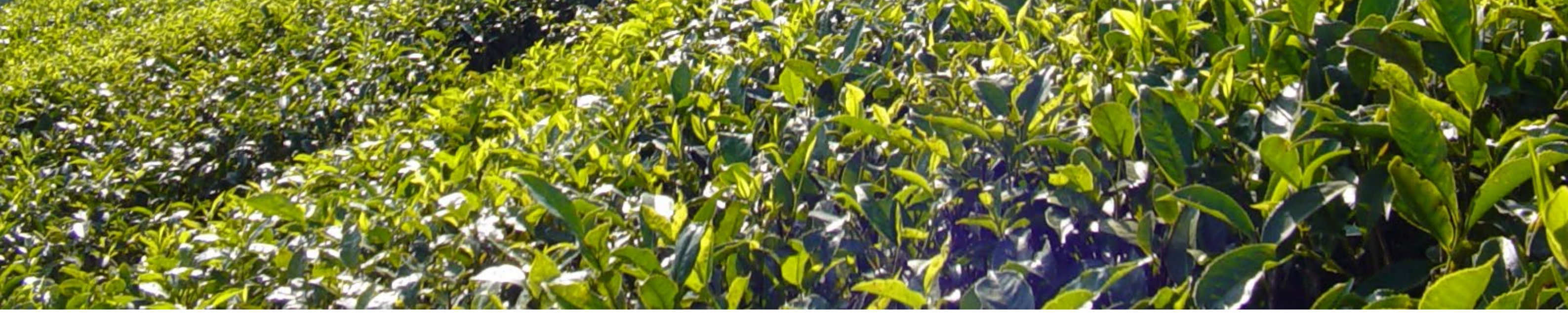
Managing long- term risks in the tea sector in Malawi, Kenya and Rwanda

Key insights from the Future Climate for Africa Programme



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ABOUT FUTURE CLIMATE FOR AFRICA

Future Climate For Africa (FCFA) is a £20 million programme funded by the UK Department for International Development (DFID) and Natural Environment Research Council (NERC). It is generating fundamentally new climate science focused on Africa and piloting the use of improved medium- to long-term (5 to 40 year) climate change information in development projects. The goal of FCFA is to reduce disruption and damage from climate change and to safeguard economic development and poverty eradication efforts over the long term. The programme is being implemented by five research consortia: African Monsoon Multidisciplinary Analysis 2050 (AMMA-2050), Future Resilience for African Cities and Lands (FRACTAL), Improving Model Processes for African Climate (IMPALA), (Integrating Hydro-Climate Science into Policy Decisions for Climate-Resilient Infrastructure and Livelihoods in East Africa (HyCRISTAL), Uncertainty Reduction in Models for Understanding Development Applications (UMFULA), with support from a cross-programme Coordination, Capacity Development and Knowledge Exchange (CCKE) unit.

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1. TEA: A CLIMATE-SENSITIVE CROP

1.1. Tea in Africa

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Globally, tea is the second most consumed beverage after water. However, very few regions in the world have climate conditions suited to growing tea. Tea production is mostly limited to tropical and subtropical regions of the world, which have warm temperatures and sufficient rainfall (Chang, 2015). In regions suitable for tea production, the crop is a vital source of income for rural dwellers and is an important cash crop for export markets.

Tea is a major contributor to the economies of Kenya and Malawi, accounting for 4% of total GDP (and 22% of total export earnings) in Kenya and 7% of total GDP (and 10% of total export earnings) in Malawi (Simoes and Hidalgo, 2011). Africa is fast becoming a major producer in the international tea market, with an increasing share of global markets and the expansion of tea producing regions. New developments and the growth of tea production across African countries requires careful consideration in terms of current and future climate suitability.

Unlike many other crops, tea plantations have lifespans of multiple decades. This makes it necessary for investment in the industry to be based on sound knowledge of the impacts of current climate variability and future climate change. Tea plants are particularly sensitive to the climate, with climate conditions outside of ideal ranges and climate extremes severely affecting the yield and quality of tea crops. Climate-smart decision-making and early adaptation actions are vital to ensure the sustainability of the sector and safeguard rural livelihoods dependent on the production of tea in Africa.

1.2. The climate's influence on tea crops

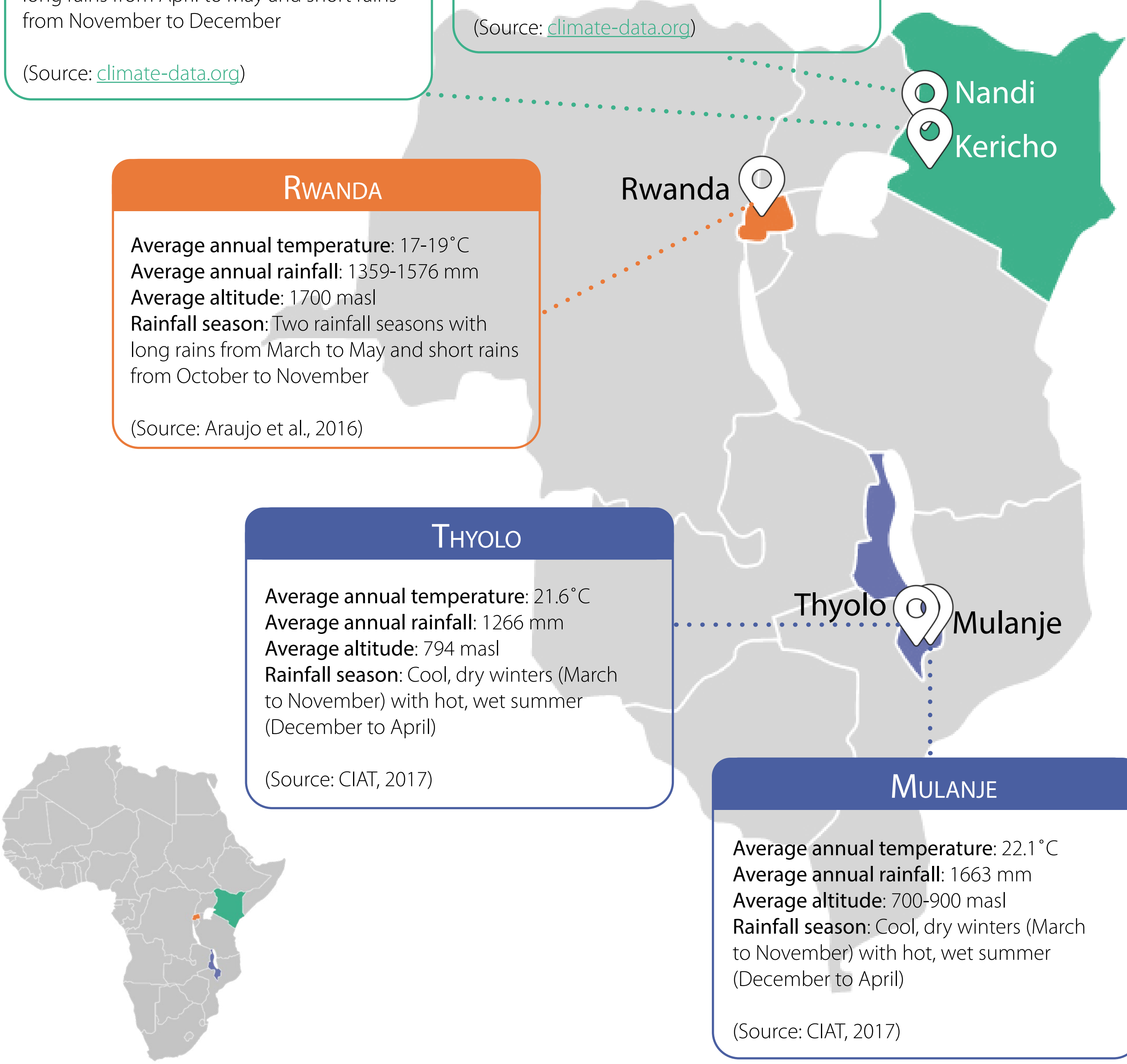
Climate conditions are extremely important for the yield and quality of tea production. Ideal conditions for growing tea include warm temperatures with wet conditions throughout the year. The rate of growth of tea leaves is suited to small temperature ranges, with daily averages of 18 °C - 22 °C being optimal for high-quality yields (Watkiss et al., 2016). Leaf growth correlates to warmer temperatures as growth is faster during higher temperatures, however, above specific heat thresholds plants can be negatively impacted by heat stress (CIAT, 2017). The suitable temperature range and heat threshold vary depending on the geography of the plantation and the variety of tea grown.

Rainfall also has a significant influence on yields and the quality of tea production. Ideally, tea requires annual rainfall exceeding 1200 mm. However, the distribution of rainfall is more important than the total annual rainfall, with 120 mm of rainfall per month being important for maintaining soil moisture (CIAT, 2017). A lack of rainfall can affect the quality and quantity of yields as more rainfall can speed up plant growth but could also lower the overall quality, while dry periods can lead to slower growth but superior quality (Ahmed et al., 2014). While dry periods can lead to improved quality of yields, extended dry periods negatively affect growth as plants can only withstand a limited amount of water stress and reduced soil moisture until yields decline significantly (Watkiss et al., 2016). Rainfall variability can impact various stages of tea production as late rains and dry periods delay the planting of tea crops and heavy rains can interrupt the fertilisation of established plants (FAO, 2016).

1.3. Future Climate for Africa's research on tea

The Future Climate for Africa (FCFA) Programme carried out research on the impacts and adaptation options for tea plantations through two studies: a risk assessment in Rwanda as part of a larger Green Climate Fund (GCF) project and the FCFA applied research fund project titled 'Climate Information for Resilient Tea Production (CI4Tea)' in Mulanje and Thyolo (Malawi) and Nandi and Kericho (Kenya). See figure 1 for location and climate of FCFA study sites.

The tea sector of each country is considerably different. In Kenya and Rwanda, the majority of tea is produced by smallholder farmers and cooperatives, while in Malawi the vast majority of tea is produced by large estates.



Kericho

Average annual temperature: 18.1˚C
Average annual rainfall: 1735 mm
Average altitude: 2002 masl
Rainfall season: Two rainfall seasons with long rains from April to May and short rains from November to December

(Source: climate-data.org)

Nandi

Average annual temperature: 17.4˚C
Average annual rainfall: 1551 mm
Average altitude: 2052 masl
Rainfall season: Two rainfall seasons with long rains from April to May and short rains from November to December

(Source: climate-data.org)

Rwanda

Average annual temperature: 17-19˚C
Average annual rainfall: 1359-1576 mm
Average altitude: 1700 masl
Rainfall season: Two rainfall seasons with long rains from March to May and short rains from October to November

(Source: Araujo et al., 2016)

Thyolo

Average annual temperature: 21.6˚C
Average annual rainfall: 1266 mm
Average altitude: 794 masl
Rainfall season: Cool, dry winters (March to November) with hot, wet summer (December to April)

(Source: CIAT, 2017)

Mulanje

Average annual temperature: 22.1˚C
Average annual rainfall: 1663 mm
Average altitude: 700-900 masl
Rainfall season: Cool, dry winters (March to November) with hot, wet summer (December to April)

(Source: CIAT, 2017)

2. THE IMPACTS OF CLIMATE CHANGE AND CLIMATE EXTREMES ON TEA

Tea plants are particularly sensitive to their surrounding climate, therefore, any changes to their climate could result in significant impacts on the yield and quality of the crops. Current climate variability routinely influences tea production in Africa, with extreme weather resulting in yield losses. Understanding current and future climate risks, and their impacts on tea quality and yield, is vital to inform the necessary practices and adaptation actions needed.

2.1. The changing climate of tea growing regions

How the climate has changed in recent years

Temperatures in east and southern Africa have been increasing significantly since the mid-twentieth century, particularly in terms of seasonal mean temperature (Niang et al., 2014). Tea growing regions within Africa have been experiencing warmer maximum and minimum temperatures, and unprecedented heat waves (Araujo et al., 2016; Mittal et al., 2017; Mittal et al., 2019).

Rainfall over tea growing regions is affected by inter-annual variability. Extreme rainfall variability has been observed to increase over the second half of the twentieth century, with more frequent droughts and heavy rainfall events (Araujo et al., 2016). While periods of high and low rainfall are common, the trends vary. Some regions, such as Rwanda, have not observed a clear trend in rainfall change (Araujo et al., 2017). Other regions, such as Malawi and Kenya, have observed a declining trend in annual rainfall (Mittal et al., 2017; Finney et al., 2019). In Kenya, the decline in annual rainfall may be due to less overall rainfall during the East African long rain season as a result of the rainfall season starting later and ending earlier (Wainwright et al., 2019).

How will the climate change in the future?

Climate change is expected to result in temperatures increasing across tea growing regions in Africa (Finney et al., 2019). By mid-century temperatures in Kenya, Malawi and Rwanda could increase between 1 - 3 °C and further by 2 - 5 °C by the end of the century (Araujo et al., 2016; Mittal et al., 2017; Finney et al., 2019). As average temperatures increase, the number of days with above-average temperatures and heat waves will occur more often and last longer (Bornemann et al., 2019). Warmer temperatures may also reduce the occurrence of cold snaps.

Projections for future rainfall over tea growing regions are more uncertain than those of temperature increases. On average projections suggest slightly more annual rainfall in the future for Rwanda and Kenya and slightly less for Malawi; however, projections range between increasing and decreasing rainfall with no clear signal for the future changes (Araujo et al., 2016; Mittal et al., 2017). Some studies have attempted to indicate how the seasonality of rainfall may change; while still uncertain, these suggest later onset and shorter rainy seasons for Southern Africa (including Malawi), an early end to long rains with more rainfall and later end date for short rains in Kenya, and more rainfall during wet seasons for Rwanda (Dunning et al., 2018).

Navigating future climate uncertainty

It is important to acknowledge that climate projections are inherently uncertain and are significantly influenced by global efforts to reduce emissions. Although projections cannot tell us with full certainty what the future climate will look like, they provide valuable insight into the potential changes. For more information on climate projections and uncertainty, please refer to the FCFA guide: ***How to understand and interpret global climate model results.***

Despite uncertainty in the average rainfall, projections indicate there will be an increase in rainfall variability and extreme rainfall events. Projections suggest tea growing regions may receive more rainfall during intense rainfall events with less rainfall during light rainfall events (Kendon et al., 2019). It is likely that dry seasons will receive even less rainfall, with more dry days and dry spells lasting longer (Bornemann et al., 2019). These changes in the climate of tea growing regions will have significant direct and indirect impacts on the tea industries in Kenya, Malawi and Rwanda.

2.2. Climate risks for tea production

Temperature extremes:

As mentioned previously, tea plants grow best in regions with little variation in temperature. Heat waves can cause heat stress in plants, soil moisture deficits and inefficiency of irrigation systems. As temperatures increase, the associated risks from heat stress are likely to increase. Over the next century, the occurrence of consecutive days with maximum temperatures above upper thresholds will increase the risk of leaf scorching and water stress which can lead to crop losses (Mittal et al., 2021). In addition to high temperatures, sudden drops in temperatures or cold snaps (when temperatures drop below 6 °C or 12 °C in Kenya and Malawi respectively) also pose a risk to tea plants, as they may result in frost which can scorch leaves and reduce yields for up to 3 months (FAO, 2016). However, in the future higher temperatures will reduce the likelihood of cold snaps (Mittal et al., 2021).

Co-producing climate metrics

Climate change is likely to have varying direct and indirect impacts on tea growing regions. The Ci4Tea project adopted an approach to co-produce key tea-specific climate indices (or parameters that measure the impacts of climate conditions e.g. temperatures at which plants experience heat stress) to tailor climate information for tea production. Identifying key climate indices and thresholds, such as heat stress thresholds and consecutive dry days, can help enhance understanding of the impact of climate change on the quality and productivity of tea crops.

Annual average temperatures:

Changes in temperature may also shift the regions suitable for growing tea as low-lying areas become too warm and new areas at higher altitude become more suitable (Watkiss et al., 2016). Low-lying tea growing regions in Kenya, Malawi and Rwanda are particularly vulnerable to increasing temperatures. As these areas become warmer, tea plantations will need to shift to higher altitudes; however, this may not be possible in some regions. While shifting to high altitudes offer initial benefits to increase tea production, the risk of current plantations becoming unsuitable could result in large losses in growing regions (Watkiss et al., 2016; FAO, 2016). It is important to understand that the shift in suitability towards the higher altitude areas is a gradual shift. Therefore, as the temperature from climate change increases, tea planted in currently cool (but future warm) areas will only see the benefits in the medium to long term. This is such that cooler temperatures slow the growth of tea leaves but can also produce a higher quality product as the tea tips contain a more intense flavour. Therefore as the temperature increases in these areas, the yield of tea plants should increase over time (if planted in a climate which is currently "too cool").

Rainfall:

Changes in rainfall and rainfall extremes can also significantly impact tea production. Future projections for Kenya and Malawi remain uncertain about whether rainfall distribution and the number of rainy days a year will change (Mittal et al., 2021). Still, it is expected that rainfall variability will increase with climate change (Kendon et al., 2019). This increased variability could mean tea growing regions experience less rainfall during dry periods and more erratic and intense rainfall during rainy seasons.

Drought:

Drought, or long periods without rainfall, can significantly impact tea production. The number of consecutive dry days (days with less than 1 mm of rain) and the length of dry spells (more than 10 days with less than 1 mm of rain) can lead to increased soil water deficits, plant drying and declines in yields (Mittal et al., 2021).

The increase in dry days and dry spells, particularly during dry seasons, may place great strain on tea growers, particularly when paired with increasing temperatures which can increase evapotranspiration and make irrigation inefficient.

Heavy rainfall:

Climate change is also expected to result in more intense rainfall days. While wetter periods can benefit tea plants' growth, too much rainfall can negatively impact tea production. An increase in heavy rainfall events may enhance the risks of soil erosion and landslides in hilly landscapes and flooding in some areas, e.g. on valley floors (Watkiss et al., 2016). Heavy rainfall can lead to loss of soil and soil nutrients and significantly decrease the productivity of tea farms.

Pests and disease:

In addition, climate change may shift the distribution and range of pests and diseases affecting tea plants (Watkiss et al., 2016). Higher temperatures may influence the likelihood of pests affecting tea plantations (FAO, 2016). Various pests which affect African tea cultivators such as red spider mites, termites and thrips typically thrive under hot and dry conditions, spreading rapidly during dry seasons until they are dispersed after the first rains (Rattan, 1992; Hazarika et al., 2009). While most pests thrive under dry and hot conditions, some pests such as tea mosquito bugs may be more abundant during wet conditions.

Climate conditions can also influence the occurrence of diseases which affect tea plants. Leaf diseases are often closely linked to moisture, and tea plants are susceptible when plants have been weakened by weather events such as hail, waterlogging and strong cold winds (Rattan, 1992). Droughts may also promote the spread of diseases - for example, stem and branch canker often occur after prolonged dry spells (Rattan, 1992).

Why African tea producers need to consider climate change

As tea plantations have long lifespans of around 80 years, the impact climate change may have on tea growing regions needs to be a consideration for current and, especially, future planned tea plantations. Tea plantations take approximately 3-5 years to become fully established for harvesting, but 10 -15 years to produce an overall positive financial return, but can then be successfully harvested for multiple decades. As tea is largely sensitive to the climate of the region, changes in the climate conditions will have a potential impact on the yields and could affect the suitability of future tea production. Similarly, the increasing occurrence and intensity of climate extremes, such as droughts and heavy rainfall events, could have significant impacts on tea producing regions. Careful consideration of how future climate change could affect tea growing areas across Kenya, Malawi and Rwanda is extremely important. To ensure that the tea sectors are sustainable, producers need to plan for and adopt appropriate adaptation strategies that can minimise the negative impacts of climate change.

These issues are more important for new tea production areas. Many regions are looking to expand production and are identifying new sites. These sites will need to grow tea in the climate of the future, not the past, and it is critical that new plantations are situated in areas with suitable climates to ensure production over the coming decades. These land-use decisions involve lock-in, i.e. decisions taken now will have an influence for decades that will be difficult or costly to reverse.

3. THE IMPLICATIONS OF CLIMATE CHANGE FOR TEA GROWING REGIONS

3.1. The impacts on tea estates and smallholder farmers in Africa

The growing risks of climate change could reduce the productivity and quality of tea within Africa, but the effects will also be determined by what happens in other tea growing regions. While there has been a historical increase in the price of tea globally, the impacts of climate change could increase this further due to scarcity. Although the increase in tea price is beneficial for the market, most of the profits from tea remain within consumer countries and multinational companies. The benefits are, therefore, less apparent for the local tea estates and smallholder farmers who bear the burden of increased input costs or reduced production as a result of climate change.

Temperature, heavy rainfall events, an increase in pests and diseases, and droughts have historically and will continue to impact the quality and yield of tea. As a result, tea producers will need to introduce additional measures to continue to meet international tea demand. This process could have significant additional input costs as producers may need to increase their use of pesticides and fertilisers and possibly adopt some form of soil moisture management or irrigation (Chang and Brattlof, 2015). These higher input costs, in conjunction with production losses from extreme weather events, could impact livelihoods in tea growing regions. In Kenya, some tea producers are already indicating a 30% decrease in cash earnings as a result of climate variability (FAO and SIDA, N.D.). If tea yields decrease, there will be a greater need for adaptation in the tea sector, which will mean the input costs and management costs could be higher and therefore reduce the margins for the tea industry or else lead to higher prices for consumers. The level of impact will vary locally, depending on the relative changes, and how this affects the comparative advantage of a producer or region, as compared to other tea producing areas.

Will current and new investments in tea plantations pay off over the life cycle of the tea plant?

The long lifespan of plantations means it is important to consider what the future climate might look like. Existing tea plantations will likely need to implement a range of adaptation options to respond to current and future climate risks. To safeguard future tea yields, existing farms will need to consider the most appropriate adaptation strategies, and whether the benefit of these options justifies the cost over the long term. In some instances, it may be necessary to take on higher costs in the near term in order to benefit in the long term.

In regions where new developments are proposed, both current and future suitability should be carefully considered. The expansion of tea estates and the establishment of farms in new regions require significant land-use decisions and lock-in investments to ensure consideration of the risks and uncertainties of future climate change. In some instances, current and near-term suitability may present opportunities for financial returns. However, in the longer term, yields and production may be negatively impacted by changing conditions. Current and future tea plantations should be proactive in adapting to changing climate conditions and prioritise early adoption of low-regret adaptation options. This includes options that are effective in addressing the current adaptation deficit, but also future-orientated, low-cost options that build resilience, flexibility or robustness, as well as capacity building, research and information.

3.2. The impacts on major producers outside of Africa

The general risks of climate change on tea production across the world will be similar to those expected in Africa, but impacts will vary strongly with local conditions and context. China, India and Sri Lanka are the largest export markets for tea outside of Africa. These three South-East Asian countries face similar challenges due to increasing temperatures, longer and more intense dry spells and stronger monsoon rains (Hijioka et al., 2014). In China, where tea varieties are adapted to high temperatures, tea production could benefit from the expansion of suitable growing regions (Chang, 2015). However, growth in tea production is still likely to be limited by changes in rainfall. China may also become a larger player in the black tea market as green tea quality may decline (Chang, 2015). In India, where tea is already growing at upper-temperature thresholds, increasing global temperatures could lead to declines of up to 40% in tea yields for the country (Chang, 2015). Similarly in Sri Lanka, the majority of tea plantations at lower altitudes are at risk due to increased temperatures which may be exacerbated by changes in rainfall (Jayasinghe and Kumar, 2019).

3.3. How is the international tea market changing?

In the past decades, the international tea market has grown rapidly with demand increasing, and thus increasing tea production (Intergovernmental Group on Tea, 2018). Globally, there is an increase in tea production volumes for the largest global producers such as China, India and Kenya, but smaller producers such as Rwanda and Malawi have also experienced rapid growth above the global average. Despite the growth in tea production, there has not been a significant increase in the size of tea growing regions, rather increasing productivity is a response to increasing demand.

Photo credit: CCKE

Demand for tea has grown substantially in line with per capita income in emerging economies such as China and India. Further market trends indicate a growing focus on premium teas, i.e. those with a price premium due to quality, increasing recognition of the health benefits of tea, and increasing demand for ready-to-drink products (Intergovernmental Group on Tea, 2018). There is also increasing demand for high-quality sustainable tea, driven largely by a growing youth market that seeks an experience with fashionable products. This is incentivising a shift among producers from the commoditization of tea to premiumisation, allowing better quality tea leaves to fetch higher prices.

Historically tea was subject to a commodification process which saw pressure to maintain low prices while production costs increased (Intergovernmental Group on Tea, 2018). Tea is relatively costly to cultivate and harvest and, due to market control and high cost of establishing secondary processing, tea is often exported before secondary processing such as blending, packaging and marketing. This means that the bulk of the profit remains further down the value chain, and climate risks have less impact on these secondary processing steps, i.e. climate risks lie with producers. The increasing demand for premium tea, however, may offer some opportunities for tea farmers to fetch greater prices for higher-quality tea, and for sustainable, ethically-grown or organic tea.

In response to the growing demand for high-quality, sustainable tea, large companies have given considerable efforts to social and environmental standards and accreditation for tea producers. Over the past decades, the amount of tea being produced under voluntary social and environmental certifications such as Fairtrade International, Rainforest Alliance and UTZ has increased significantly. For example, 100% of tea sourced by Unilever comes from sustainably produced tea that is certified by the Rainforest Alliance.

4. ADAPTING TO THE IMPACTS OF CLIMATE CHANGE

The growing impacts of climate change on tea plantations could significantly affect the productivity of tea plants and quality of tea leaves within growing regions of Kenya, Malawi and Rwanda. Adaptation informed by climate information is extremely important to ensure the future resilience of tea production, and to avoid potential negative effects facing tea regions. Various adaptation options exist to address context-specific risks. These options can be categorised as low regret/low-cost options, climate-smart planning options or early activities for safeguarding against future climate change.

The different categories of adaptation

Low regret adaptation options:

Adaptation options which can reduce the risk tea farmers currently face as well as build their resilience for the future (i.e. good to do anyway). These options are early, cost-effective ways to help farms adapt.

Climate-smart planning:

Adaptation options which include climate resilience in current and planned activities, especially those with long lifetimes, to ensure decisions made in the near term will benefit tea production in the future climate.

Early activities to address future changes:

Starting the process of iterative adaptation planning to provide climate information, develop new technologies and adaptation options suitable for future conditions, and help inform future decision-making, including the research and monitoring processes to provide knowledge and learning.

4.1. Adaptation options for tea producers

While tea producers may face similar challenges, different farms may be dealing with a combination of different risks linked to local climate factors, soil conditions and water availability. They will also have different capacity and levels of resources available to them to implement adaptation options. While low-regret adaptation options help address the risks of both current climate risks and help build resilience for future climate change, the best adaptation options for each farm depends on the local situation/context. The effectiveness and feasibility of these options are largely dependent on how tea production is organised within growing regions and the climate and non-climatic risks facing plantations in these regions.

CLIMATE RISK	IMPACT	ADAPTATION OPTION
Increasing temperatures, longer and hotter heat waves	Leaf sun scorching	Shade trees and tree belts
		New tea clones
	Drying of soils	Climate-smart agriculture, e.g. mulching, burying prunings, using organic manure
	Growing regions becoming unsuitable for tea	Planting upslope
		New tea clones
		Diversifying crops
	Increase in extreme events	Index-based insurance
	Changes in pests and disease	Monitoring of patterns of pests and disease
		Integrated pest management
Droughts and dry spells may happen more often, last longer and be more intense	Water scarcity	Improved watershed management (e.g. ecosystem restoration and afforestation)
		Water harvesting
		Climate-smart irrigation (e.g. drip irrigation)
	Increasing soil moisture deficit	Climate-smart agriculture (e.g. mulching, using organic manure, planting grass strips)
		Investment in land management (e.g. afforestation and ecosystem restoration)
		New tea clones
Heavy rainfall events may have a higher frequency and intensity	Increasing flood risks	Improved water management (e.g. maintenance of drainage channels and ecosystem restoration)
	Soil erosion and landslides	Afforestation, tree planting and grass strips
	Waterlogged soils	Improved water management (e.g. rehabilitation of drainage channels)
		Climate-smart agriculture (e.g. soil conservation)

Low regret adaptation options | **Climate-smart planning** | **Early activities to address future changes**

4.2. Considering different adaptation options

Water harvesting and irrigation

As climate change increases the risks of drought and exacerbates water scarcity, rainwater harvesting and irrigation are adaptation options which may alleviate risks to tea plantations. The majority of tea growing regions will incur some level of yield or quality loss as a result of reduced water availability for the plants. However, if tea growers are able to adapt to the water limitations, it is expected that productivity in most regions will remain strong (Beringer et al., 2020). Rainwater harvesting and large- or small-scale irrigation projects can reduce the impacts climate change may have on decreasing the yield and quality of tea leaves. As rainfall variability has a significant impact for tea production, irrigation is an option which could help alleviate pressure associated with dry periods. However, while irrigation can alleviate the effects of drought, the option may not be feasible in all contexts, and it certainly may not be financially viable, i.e. ability to generate additional productivity to justify the investment.

Photo credit: Ilam tea garden - commons.wikimedia.org

Establishing new irrigation systems can be extremely costly (especially for large plantations where tea is planted uphill from the water source) and may increase small-scale farmers' dependence on loans in order to front the capital costs. Depending on the type of irrigation (pumped versus gravity) the systems may include high operating costs (Watkiss et al., 2016). The cost of irrigation increases as the crops get further away from the water source and are placed higher up the slopes. Similarly, the location of the crops will also influence the technology needed for efficient irrigation, e.g. more powerful pumps to move the water upslope. While irrigation is possible, the high costs may only make it accessible to the larger tea estates who have the upfront capital or ability to access larger loans. Drip irrigation technology can significantly reduce the amount of water that is needed in order to address the water deficit (in some cases up to 50%) while increasing the yield (Kigalu et al., 2008). However, drip irrigation systems are more costly and require good maintenance and sufficient knowledge of the operations to function efficiently.

There is also a broader issue of the sustainability of irrigation. This includes the availability and the price of water, and whether irrigation makes sense from an integrated water resources management (IWRM) perspective. This is important given competing demands for water, and given that there is rising demand in most countries from socio-economic change (e.g. population increase, urbanisation, etc.), which will be exacerbated by climate change. Indeed, there is a risk that increasing the dependency of tea production on irrigation will be counter-productive if future water constraints are likely. There are also concerns on the wider environmental impacts of irrigation, notably for pumped supply, due to the energy-related emissions. Solar irrigation is available, but has higher capital costs. These various issues need to be considered carefully before irrigation is adopted.

Improved watershed management

As climate change may result in more frequent and more intense heavy rainfall events, improved watershed management is important to deal with increased surface water run-off. Sustainable management and rehabilitation of drainage is vital to improve water flows, while limiting risks of flooding, waterlogging and soil erosion (Watkiss et al., 2016). There are also local- (e.g. grass strips) and catchment-level (e.g. protective forest) investments that can help manage water flows and reduce surface run-off and soil erosion. Water management practices can improve soil productivity and, therefore, directly benefit farms. However, it also offers indirect benefits through improving slope stability and reducing soil erosion and sediment loads, as well as decreasing landslide and flood risks. To effectively ensure farms are able to cope with the increasing frequency of intense rainfall events, stormwater management needs to be a collective effort across the watershed.

Shade trees and tree belts

Photo credit: Mohammed Ali - Flickr

Planting shade trees in plantations and tree belts on the outskirts of plantations can play an important role in protecting tea crops from increasing temperatures (Cracknell et al., 2013). Shade trees can reduce ambient temperatures and protect tea plants during heat waves, while also improving soil moisture by reducing evapotranspiration from the soil and tea plants, and protecting soils from drying winds (Cracknell et al., 2013). In addition to providing shade, trees strategically planted along drainage channels and along slopes can improve soil stability. (Watkiss et al., 2016). However, planting trees within densely planted tea farms may require trade-offs as this may require uprooting established plants or having less space to establish new plants. Trees may also come into competition with tea plants for water, therefore the selection of the species of trees needs careful consideration in terms of the costs and benefits for tea production.

Climate-smart agriculture

Photo credit: CCKE

Adopting good agricultural practices can improve the productivity of farms but could also build resilience of crops to climate variability. Good agricultural practices can ensure soil conservation, improve soil moisture retention and soil fertility. Practices such as mulching, burying prunings, using organic composts, envelope forking, and managing soil erosion through grass strips and tree belts help to reduce risks and can also have important co-benefits, such as reducing greenhouse gas emissions (Cracknell et al., 2013). Adopting these practices in densely planted, established fields, however, may be difficult due to space constraints. Mulching and composting may only be an option for nurseries and when establishing new plants. Tree belts and grass strips can be planted on the outskirts of fields, but should also be incorporated into establishing new crops, especially when planting along slopes as these can contribute to slope stabilisation and soil stability (Watkiss et al., 2016).

Planting new tea clones

Some varieties of tea plants are more resilient to heat, drought and cold. Planting new varieties could provide producers with additional options to help withstand climate risks (Cracknell et al., 2013). Intercropping a variety of tea clones can also ensure that some crops are able to withstand different types of climate shocks (Reay, 2019). The cycle for developing, testing, approving and implementing new varieties takes time, however, developing these new varieties is currently a focus to promote early action and to help provide more options as the climate changes.

Planting upslope and at higher altitudes

Photo credit: CCKE

As temperatures increase, the areas suitable for growing tea (optimally) may shift, with areas at higher altitudes and with cooler temperatures becoming more suitable for growing tea. Relocating or planting new areas upslope at higher altitudes could ensure that crops are better able to cope with greater temperatures (Watkiss et al., 2016). Planting may, however, be limited by the cost to relocate or acquire land at high altitudes.

Soil depth and quality may also limit the ability of plantations to shift to new high-altitude regions. The consideration of planting at higher elevation is a priority for new plantations, where it is imperative to plant for the future climate and not the past, i.e. to recognise that any expansion of new production areas needs to take account of the shift in climate, and thus the areas that will be suitable for production over the plants' lifetime.

Insurance, including index-based insurance

Photo credit: CCKE

Insurance has a potential role to mitigate the impacts of climate extremes by spreading risk. This can include the potential for index-based insurance. Index-based insurance may offer smallholder farmers greater access to capital and encourage the adoption of new technologies and practices by protecting farmers against climate risk through predetermined indexes (such as temperature or rainfall) (Global Index Insurance Facility. N.D). However, as index-based insurance is based on a predetermined index, it can only protect farmers from climate extremes such as floods, heat waves, or droughts, but will not be able to protect farmers from changing average trends such as rising temperatures. Further, the effectiveness of insurance providers to predict and observe the climate of tea growing regions can be affected by climate variability and microclimates (McSharry et al., 2016). This could result in farmers experiencing losses and not receiving payouts.

Integrated pest and disease management

Scale on tea stem - Flickr

Changing climate conditions are likely to influence the distribution of pests and diseases, and the potential incidence or severity of outbreaks affecting tea plants. Integrated management needs to ensure current and changing patterns of pests are monitored and mitigated (Reay, 2019).

4.2. Prioritising adaptation options

The implementation of adaptation options needs to be guided by local development, business priorities, and context-specific climate risks, to determine the best responses to mitigate the impacts of climate change. However, the benefit provided by adaptation should be balanced by the consideration of the costs and financial returns of the interventions. An economic analysis of options is important to understand the cost and benefits of low-regret options, as well as the considerations of the costs for early interventions for future benefits (Watkiss et al., 2016). The prioritisation of adaptation options should consider strategies which can be implemented in the near-term but avoid risks of lock-in investments which limit the ability of farmers to respond to emerging changes.

5. COUNTRY OUTLOOKS

KENYA

Tea sector of Kenya

Kenya is the largest tea producer in Africa and the third largest in the world. Kenya's tea sector is a major contributor to the country's economy, contributing to 4% of total GDP and 22% of export earnings. Kenya's tea sector is made up of approximately 700 000 smallholder farms which contribute approximately 60% of tea produced in Kenya, with large tea estates making up the remaining 40% of production. Tea is primarily grown in the highlands in the west of the country.

Photo credit: CCKE

Key climate metrics for Kericho and Nandi

The CI4Tea project, through stakeholder engagement, was able to identify locally-specific climate metrics and thresholds which influence tea yields in Kenya. Among these climate metrics, temperature and rainfall are the most important climate variables which impact tea yields. In terms of temperature thresholds that would negatively affect tea production in the Kericho and Nando regions, the CI4Tea project identified upper-temperature thresholds of more than five consecutive days with temperatures above 27 °C, and lower-temperature thresholds below 6 °C.

In terms of rainfall, the number of rainy days per year, the number or consecutive dry days and the incidence of dry periods lasting more than 10 days play a significant role in tea production in these regions.

Observed climate change in Kenya

Tea growing regions in Kenya have experienced increasing annual temperatures and decreasing annual rainfall over the past 50 years. Temperatures on average have increased by 0.02 °C per year, while rainfall has decreased by 2.94 mm each year. Tea growing regions experience large rainfall variability which negatively impacts the yields of tea. Incidences of hail, frost and soil water deficits have been increasing. (FAO, 2016).


Photo credit: CCKE

Historically, tea growers in Nandi and Kericho have not experienced a high incidence of temperatures which exceed the 27 °C threshold. Rather, decreased rainfall in combination with other extremes such as hail have negatively impacted tea yields (Mittal et al., 2021).

Future climate change

Future projections suggest annual mean temperatures will increase in Kenya by 1 - 3.5 °C by 2050. Changes in rainfall are uncertain with some projections suggesting increases and others suggesting decreases (with median ranges suggesting increases). Changes to the East African long (early end) and short rains (later end with more rainfall) could influence the amount and distribution of rainfall for Kenya (Finney et al., 2019).

Photo credit: CCKE

The increasing temperature will mean tea growing regions in Nandi and Kericho may see more incidents of temperatures exceeding 27 °C for more than 5 consecutive days. However, increased temperatures may reduce the likelihood of cold snaps below 6 °C, which could reduce the occurrence of frost (Mittal et al., 2021). The model projections for the short rains season (October to February) indicate a likelihood of increased total rainfall, but with more frequent ten-day dry spells. For the long rains (March to September), projected changes in total seasonal rainfall are more mixed, with most models suggesting a decrease in rainfall frequency and an increase in consecutive dry days.

Adaptation priorities for tea producers in Kenya

- Irrigation, including drip irrigation where feasible
- Development and piloting of new resilient tea clones
- Climate-smart agricultural practices, including mulching, burying prunings, and envelope forking
- Off-site afforestation and ecosystem restoration
- Planting shade trees in tea estates (inter-cropping) in lower (more vulnerable) areas
- Water harvesting structures
- Shifting tea regions to newly suitable, higher-altitude sites
- Crop and product diversification

Photo credit: CCKE

Key adaptation considerations in Kenya

- Kenya experiences high rainfall variability, with years that are wetter than average and years that are drier than average. Future changes in rainfall are still uncertain and average annual rainfall could increase or decrease. Investments in irrigation might be able to reduce the impacts of climate change, however, careful considerations are needed for the cost-benefit, effectiveness, and sustainability of irrigation systems.
- New and better tea varieties may be more climate resilient, however, the process of developing and planting new clones is lengthy and requires the process to begin early to adapt to future changes.
- Implementing climate-smart agricultural practices such as shade tree planting are low-regret options which could improve the productivity of tea farms and offer a buffer against the impacts of climate change.
- As temperatures increase, suitable regions for growing tea may shift in Kenya. Careful consideration of the current and future climate is essential for the planning and establishment of new tea estates.

MALAWI

The tea sector in Malawi

Photo credit: Franx - Flickr

Malawi is the second biggest tea exporter in Africa (after Kenya). Tea production accounts for approximately 7% of GDP and 10% of export earnings for Malawi. The tea sector in Malawi is dominated by large commercial tea estates which contribute 93% of the total tea production, while approximately 18 500 smallholder farms contribute to the remaining 7%. Tea is grown primarily in the Thyolo and Mulanje regions in southern Malawi and to a lesser extent in Nkhata Bay in the north (CIAT).

Key climate metrics for Thyolo and Mulanje

The CI4Tea project, through stakeholder engagement, was able to identify locally-specific climate metrics and thresholds which influence tea yields in Malawi. Among these metrics, the most important climate variables for tea yields were temperature and rainfall. In terms of temperature, the CI4Tea project identified the thresholds that would negatively affect tea production in the Mulanje and Thyolo regions; the upper-temperature threshold is more than 5 consecutive days with temperatures above 35 °C, and the lower-temperature threshold is below 12.5 °C. In terms of rainfall, the number of rainy days per year, the number or consecutive dry days and the incidence of dry periods lasting more than 10 days, play a significant role in tea production in these regions.

Photo credit: CCKE

Observed climate change in Kenya

Recent trends indicate annual and seasonal temperatures across Malawi are increasing. Since the 1970s, annual temperatures in Malawi have increased by 0.02 °C/year. Malawi has also experienced strong interannual rainfall variability with very wet years and very dry years in the past 30 years. On average Malawi has experienced a drying trend, which has been particularly evident from the 2000s (Mittal et al., 2017). In the past, periods of low yield were associated with high temperatures in combination with below-average rainfall. Droughts in 1992 and 2005, with temperatures exceeding the 35 °C threshold, led to record-low yields in the country (Mittal et al., 2021).

Future climate change

Temperatures in Malawi are expected to increase in the range of 0.5 - 1.5 °C by the 2040s, and in the range of 4 - 4.3 °C by the 2090s. Heatwaves are also expected to occur more often and last longer (Mittal et al., 2017). Changes in rainfall are uncertain with either a decrease or increase in rainfall being expected. However, rainfall intensity is expected to increase with more heavy rainfall events.

While temperature change by mid-century may still be within the current range of variability, increases by the end of the century will likely impact tea yields in Mulanje and Thyolo. Mulanje may experience more incidents of temperatures exceeding 35 °C for more than 5 consecutive days. However, the occurrence of cold snaps may decrease across both Mulanje and Thyolo, reducing the risk of frost in these regions. While rainfall changes are uncertain, it is possible that there may be more dry days in the tea growing regions. Increased temperatures coupled with less rainy days during the dry season could significantly impact tea yields (Mittal et al., 2021).

Adaptation priorities for smallholder tea farmers in Malawi

Photo credit: CCKE

- Irrigation, including drip irrigation where feasible
- Development and piloting of new resilient tea clones
- Climate-smart agricultural practices, including mulching, burying prunings, envelope forking, and using organic manure
- Planting shade trees in tea estates (inter-cropping) in lower (more vulnerable) areas
- Water harvesting structures
- Access to transport from smallholder farms to tea factories
- Increase number of factories to improve access for smallholders

Adaptation priorities for large tea estates in Malawi

- Irrigation, including drip irrigation where feasible
- Development and piloting of new resilient tea clones
- Climate-smart agricultural practices, including mulching, burying prunings and envelope forking
- Off-site and on-site afforestation and ecosystem restoration
- Crop insurance

Key adaptation considerations in Malawi:

- In Malawi, the most appropriate adaptation options may vary between large tea estates and smallholder farmers.
- Malawi experiences high rainfall variability, with years that are wetter than average and years that are drier than average. Future changes in rainfall are still uncertain, however, temperatures are expected to increase. Investments in irrigation might ensure tea production during hot and dry seasons. Although, careful considerations are needed for the cost-benefit, effectiveness, and sustainability of irrigation systems.

Photo credit: Subhadip Mukherjee-Freeimages.com

- New and better tea varieties may be more climate resilient, however the process of developing and planting new clones is lengthy and requires the process to begin early for future changes.
- Implementing good agricultural practices such as tree planting are low-regret options which could improve the productivity of tea farms and offer a buffer against the impacts of climate change.
- Access to markets, through an increased number of factories and/or transportation of tea, may ensure smallholder farmers are able to get their harvested tea leaves to marketplaces.

RWANDA

The tea sector in Rwanda

Photo credit: CCKE

Tea is one of Rwanda's biggest agricultural exports, accounting for $ 86.9 million of export revenue for the country in 2019 (approximately 7% of total exports) (NAEM, 2019). Smallholder farmers make a significant contribution to the tea sector, with 75% of green leaf supply coming from smallholder farms. The sector, which was previously government owned, was privatised in 2012, with existing factories and industrial blocks being sold to the private sector or impact investors. However, production is dominated by smallholders, usually in the form of co-operatives, centred around the factories. There are currently 18 operational tea factories servicing a planted area of approximately 24,000 hectares of tea and produced 32,127 tonnes of tea in 2019 (NAEM, 2019).

Growing conditions in Rwanda

In Rwanda, regions with high rainfall and at high altitude are favourable for growing tea. Temperature is an important variable for tea with cool average temperatures of around 19 °C, ensuring slow leaf growth and higher-quality yields. Increasing temperatures result in tea farms in lower-lying areas producing lower-quality yields.

Photo credit: CCKE

Rainfall distribution is also an important factor, with average annual rainfall above 1200 mm being important for quality yields of tea. Tea is negatively affected by rainfall variability with dry periods leading to lower yields, and periods of intense rainfall causing flooding and waterlogging of low-lying regions, and soil erosion and landslides in hilly regions.

Observed climate change

Weather records show that Rwanda is becoming hotter: the annual average temperature has increased by 0.35 °C per decade between 1971 and 2010. Minimum and maximum temperatures have increased over the past few decades, with the minimum temperature showing a larger variation. There are no clear trends for rainfall change, although there are some signs that the variation between years is becoming greater.

Future climate projection

Future climate change is likely to lead to increasing climate variability. Temperatures in Rwanda are expected to continue to rise, with an increase in the number of hot days. Global Climate Models (GCMs) indicate that Rwanda's temperature may increase by 0.9°C to 2.2°C by the mid twenty-first century, relative to the period 1970 to 1999. Rainfall changes are still uncertain, with some projections suggesting an increase and others suggesting a decrease in annual rainfall. It is, however, suggested that rainfall patterns may change with longer dry periods and more seasonal rainfall by the end of the century, although there is still some uncertainty (Dunning et al., 2018). The intensity and frequency of heavy rainfall events are expected to increase due to increasing temperatures.

Adaptation priorities for tea growers in Rwanda

- Improved water management, including climate-smart agriculture, water catchment measures, and possible soil and water management (e.g. soil moisture conservation, rainwater harvesting or small-scale irrigation)
- Planting grass strips (napier grass) and tree belts
- Introducing shade trees in tea estates (inter-cropping) in lower (more vulnerable) areas
- Upslope tea planting at higher elevation around current plantations
- Locating new plantations at higher elevations
- Development and piloting of new resilient tea clones

Key adaptation considerations in Rwanda

Photo credit: CCKE

- Rwanda experiences high rainfall variability, with years that are wetter than average and years that are drier than average. Future changes in rainfall are still uncertain, however, temperatures are expected to increase. Improved watershed management, including cleaning of drainage channels, climate-smart agricultural practices and planting grass strips and tree belts are important to ensure tea production can cope with current and future rainfall variability. However some of these interventions need to happen at the basin scale, which is costly and requires the commitment of various stakeholders.
- Tree belts and intercropping trees in low-lying vulnerable tea farms could help reduce ambient temperatures, and protect tea plants from increasing temperatures. However, inter-cropping requires trade-offs with space on tea farms.
- New and more suitable tea varieties may be more climate resilient, although the process of developing and planting new clones is lengthy and requires the process to begin early to adapt for future changes.

CONCLUSION

Tea is extremely important for the economies and livelihoods in tea-producing countries. African tea producers have been steadily growing in recent decades, with ambitions in many countries to expand production. However tea is an extremely climate sensitive plant, requiring very specific agro-climatic conditions. The expansion of the tea industry is not only restricted to these suitable agro-climatic regions, but needs to consider how climate change could impact the suitability of existing and planned plantations.

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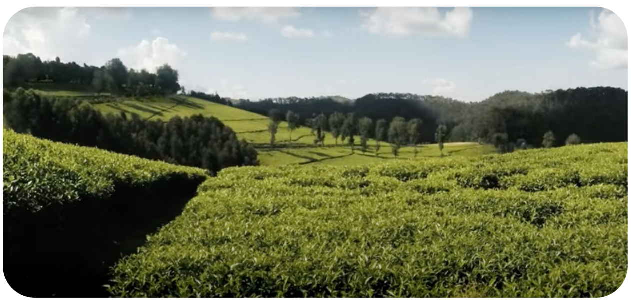
Climate change poses a significant risk to tea growing regions, not only because of changes in average climate conditions but also due to the changing intensity and frequency of climate extremes such as heat waves, dry spells and heavy rainfall. Research from FCFA has provided new understanding for how the climate might change and how this may impact tea growing regions of Kenya, Malawi and Rwanda. While projections for the future indicate that all regions are likely to experience increasing temperatures, projections for rainfall are less certain. While average rainfall may increase or decrease, it is likely that rainfall will become more variable with the possibility of fewer days of rain, more heavy rainfall and longer dry periods. The potential impacts these changes pose to tea yields and quality make it vital for tea growers to start planning for climate change.



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Although the exact changes are uncertain, the consequences of inaction could be detrimental for tea growers, and appropriate adaptation action is essential to safeguard future production. Adaptation should be prioritised inline with local contexts and development ambitions, but also need to take into account the cost effectiveness of implementation. While low regret adaptation options, such as climate-smart agriculture and tree planting, can benefit tea production regardless of change; climate-smart planning and early activities for future change are essential to ensure tea can be grown under future conditions. Considering climate information in decision-making within the tea sector is extremely important in both informing future development within the sector and identifying the appropriate adaptation action. Ensuring that decision-making takes current and future climate risks into account to ensure the sustainability of the tea industry, safeguard the livelihoods of tea growers and maintain financial returns.

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