Farmers harvesting coffee beans

Photo credit: Joseph Gachoka/World Agroforestry

CHAPTER 19

Tree Commodities and Climate Change: Impacts and Opportunities

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Highlights

- Tree commodities increase GHG emissions in Africa largely through agricultural activities and the subsequent processing of commodity-based products. Coffee and cocoa are the main contributors in Africa.
- Climate change affects coffee and cocoa systems by decreasing site suitability for the commodities. For example, in the West Africa cocoa belt, by 2050, areas with at least 50% suitability for cocoa will decline by half.
- Tree commodities contribute to adaptation efforts both positively and negatively.
- Adoption of environmentally friendly production and processing approaches and enforcement of supportive regulatory instruments may reduce the impacts of tree commodities on climate change adaptation efforts.
- Africa needs to take deliberate measures of managing its high tree commodity production regions from the impacts of climate change through science and innovations.

1. Introduction

Tree commodities from high-value tree crop plantations in Africa, including coffee, cocoa, oil palm, rubber and cashew, are rapidly expanding as domestic and global demand for their products is increasing. With the growing ambition of many tropical countries for export-oriented economies, tree commodities are becoming a key income source for millions of smallholder farmers. Nevertheless, production of these commodity crops increases often at the expense of fragile ecosystems such as forests, posing multiple environmental challenges. Before certification, labelling, and fair trade were put in place to manage the challenges associated with the expansion of plantations; the planet has already lost millions of hectares of important ecosystems, particularly forests that have been replaced by pure plantations

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over large areas. Lately, consumers' awareness about the environmental consequences of production systems that influence ecosystems has affected the conversion of forests and other critical ecosystems into commodity farms. Despite this increase in awareness, forests are still heavily impacted by the expansions of commodity crops.

Tropical forests conversion to other land uses led to emissions of millions of tons of Greenhouse Gases (GHGs) for the last several decades. For instance, the total net emission of carbon from tropical deforestation and land use was $1.0\,Pg\,\mathrm{C\,yr}^{-1}$ during 2000–2010 (Baccini et al 2012); and over a quarter of global forest loss is due to conversion into permanent land use change for the production of commodities (Curtis et al 2018). As a result, local practices of producing commodities that are consumed globally affected the global climate considerably. Moreover, such production schemes also occur at the expense of the biological diversity and other ecosystem services generated from the destroyed ecosystems that were cornerstones for ensuring the adaptative capacity of both the human population and biodiversity that depended on the ecosystems. Therefore, land use change, depending on the resultant land uses, had an immense influence on the adaptation potentials of the wider ecosystem and its dependent biota.

In addition to the direct consequences of land use changes, examination of the global value chains of the commodities also shows some grave concerns of high-level emissions associated with the supply chain- processing, transporting and utilization and consumption inefficiencies (Mbow et al 2019). The best example comes from the high level of bio-waste produced from such commodities from the early stages of the supply chain- production, harvesting and distribution, eventually resulting in further emissions affecting global climate. Nonetheless, despite the absence of robust data on the wastage and consumption inefficiencies and their associations with greenhouse gas emissions along the supply chain, the latest global efforts by processing companies such as Nestle, Mars, etc., indicate an increasing level of awareness of users in reducing bio-waste. Also, as the major producers of the commodity crops, smallholder farmers are taking actions (e.g., diversified agroforestry cocoa, coffee and oil palm) that are environmentally friendly.

The impacts are anticipated to decline gradually depending on the underlying incentives, provisions and market access they maintain. Various incentive schemes (e.g., premium prices, market access, etc.) are put in place by international agencies, national governments, and local actors to encourage environmentally friendly production schemes. Main processing companies are also committing (though yet to be broadly operationalized) to limit the inefficiencies in the processing processes to curb the high levels of GHG emissions they generate.

For the large part, most of the narratives around climate change and tree commodities was confined to the mitigation agenda. However, commodities do also have direct and/or indirect effects on climate change adaptation efforts. The effects on adaptation are highly relevant at production levels, particularly in commodity growing landscapes. Two streams of adaptation are key in this context – adaptation of the production system and adaptation of the communities earning a living from commodity systems. The adaptative capacity of communities is affected by the natural, physical, social, human, and financial capitals that the community relies on when climate change effects occur. Hence, there is a strong need to understand how climate change affects these capitals that influence the community's adaptation to climate change effects.

With many countries focusing on tree commodities as the main export commodities, it is important to understand how the expansion efforts and the climate objectives align. This chapter aims is to underline the influences of commodity production in Africa on climate change and vice versa, and propose options to address the negative outcomes resulting from commodity expansion. The scope of analysis is limited to the major tree commodities (i.e., cocoa, coffee and oil palm) in Africa. The chapter does not look at advanced industrial value addition levels happening beyond the countries of raw material production.

2. Influence pathways of tree commodities on climate change

Tree commodities influence climate change through the various stages of production, processing and consumption. At the production stage, the influence often comes through land use - land cover conversion during farm establishment or expansion. Thus, the significant volume of GHG emissions (mitigation) and adaptation related effects occur at this stage. The other set of activities where impacts occur is at the food processing, handling and packaging stages, creating waste, hence affecting GHG emissions and adaptation efforts. Figure 19.1 shows the influence pathways through which commodity crops affect climate change mitigation and adaptation.

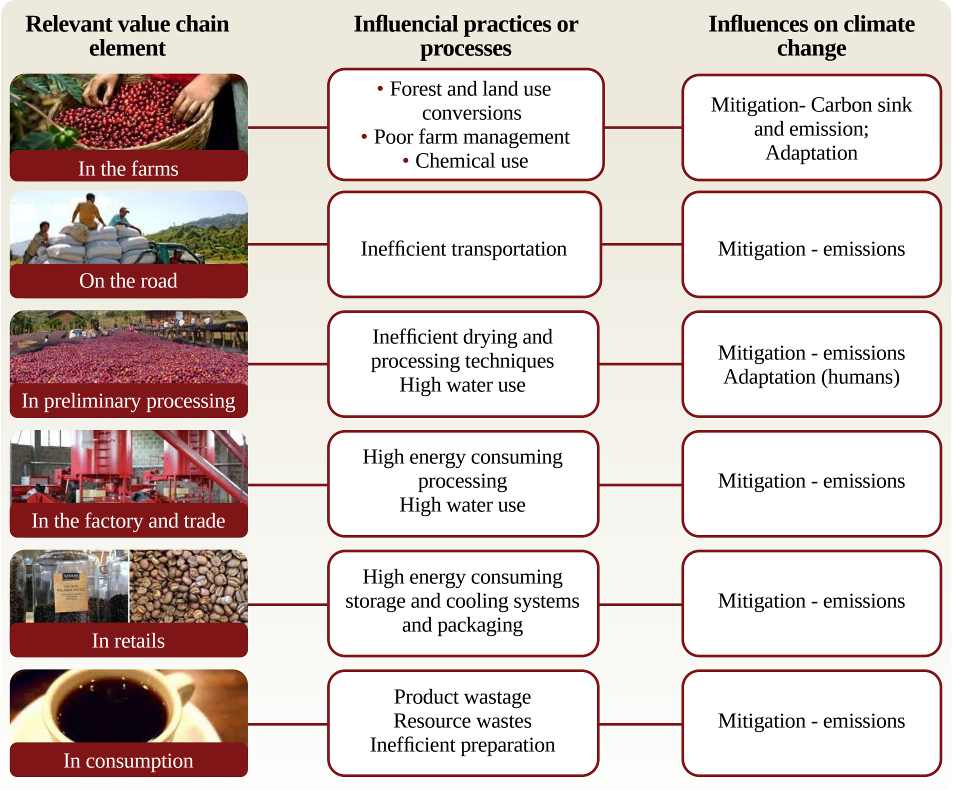

Figure 19.1: *Influence pathways mapping for coffee as a case study commodity*

As per the methods provided by UNFCCC to estimate such impacts, two basic approaches – land based and commodity-based are described. Box 19.1 presents details about the two approaches.

Box 19.1

The footprint approach to emissions accounting and associated attributes

Currently, there are two basic approaches to counting and accounting for "anthropogenic interference with the climate system" based on net emissions of GHGs. The first is based on 'land', and the second has 'traded commodities' as a basic concept. Where both are used, there are problems of double-counting and accounting gaps to be managed. The ***land-based approach*** uses countries (nation states) as the basic accounting units, closely linked to decision making within UN bodies such as UNFCCC. Land areas add up nicely to the total terrestrial domain, with only minor disputes remaining over the exact location of international boundaries. Import/export data have conventionally been compiled at national scales and facilitate country level accounting of net greenhouse gas emissions. Responsibility for cross-border transport (such as bunker fuels used for shipping and airplane fuels) is, however, more difficult to attribute and has been left out of

Box 19.1

international agreements on emission reduction. Furthermore, the path dependency of international negotiations has meant that country-level classifications (developing vs developed) imply that internal inequities within each country are ignored. However, the 'poor' in 'rich' countries may have less anthropogenic interference with the climate system than the 'rich' in 'poor' countries.

The ***commodities*-based** approach takes human consumption and the global trade in commodities that support it as the basis for emission accounting. It identifies national 'footprints' as based on a weighted sum of population size multiplied with lifestyles, lifestyles relating to the combination of consumption volumes across all currently existing commodities, and a typical emission intensity associated with each unit of any of the commodities. It leads to 'deforestation free' or 'carbon neutral' claims of commodity production chains, without clarity of how 'additional' the measures need to 'compensate' for 'inevitable' emissions due to activities along the chain. This ***commodities*** approach to accounting has no problem in accounting for international transport as part of the 'footprints' and can integrate over emissions in production and consumption countries without major difficulties. It can readily differentiate between lifestyles and alternate modes of production of comparable products. A 'footprint' approach has been popularized by NGO's and matches with the sense of individual responsibility that interacts with the usually much slower shifts in national policies. This approach, however, also has its share of challenges in providing comprehensive accounting of anthropogenic interference with the climate system. As many land uses are 'multifunctional' and contribute to multiple commodity flows, an attribution system is needed. Where land use change is a multi-phased process, sharing of responsibility across commodity flows becomes more complicated, as a typical sequence of logging for high-value timber, overlogging for pulp-and-paper industry and conversion to oil palm, coffee or cocoa production shows. Another example is the 'deforestation-free' conversion to coffee gardens in Vietnam of swiddens that otherwise would have recovered as secondary forests.

The aggregate emission from tree commodities can be summarized in the two equations below.

① Net emission intensity per unit product = $\frac{\sum(\text{LCUCe, FMe, TPe, WEe, OFe})}{\text{Product volume}}$

② Product emission volume = $\text{Product demand volume} \times \text{emission intensity per unit}$

Where LCUCe - Commodity driven land cover and land use change emission, FMe - Farm management practices related emissions, TPe - Transport and processing related emission, WEe -Waste and end-user related emission, and OFe - Other factors related emissions are summed for (subsets) of a global value chain. Figure 19.2 describes the specific typologies of emission sources and actors at various scales.

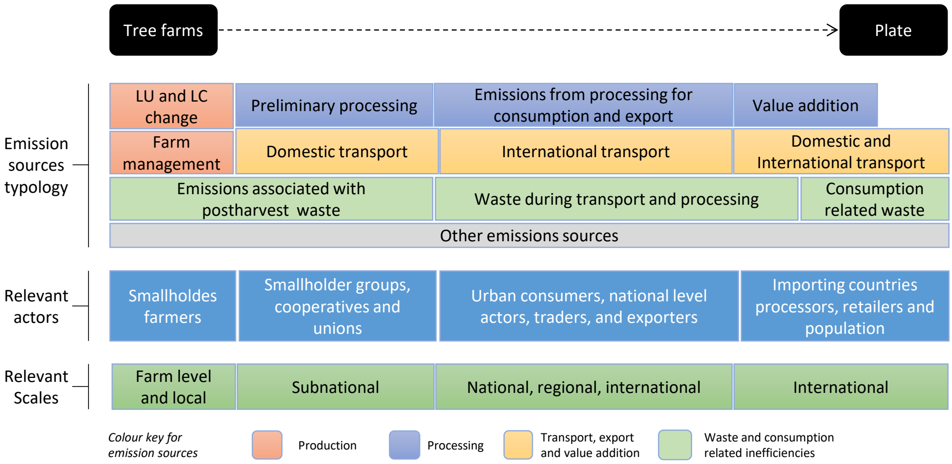

Figure 19.2: *Typologies of emission sources, actors and relevant scales in emissions from tree commodities.*

Note: LU and LC stand for land use change and land cover changes, respectively. The different colors for emission sources typology indicate different sources. Different blocks with the same color represent the same source with different attributes.

The understanding of this is crucial to tackle emission reduction through the contributions of those who are the likely sources. For a detailed example of the impact of nitrogen fertilizer use on both greenhouse gas emissions and yield, with a curvilinear effect on the 'footprint' of, in this case palm oil, see van Noordwijk et al (2017).

3. Tree commodities and climate change mitigation

The mitigation influences of tree commodity are often visible as farms expand, displacing forests. Meyfroidt et al (2014), in their work on expansions of commodity crops, found that most of the expansion and new lands for commodities were created by clearing forestlands. For instance, cocoa farms in Ghana (Takyi et al 2019; Ruf et al 2015) and oil palm plantations expansion in Cameroon (Ordway et al 2017) are based on clearing pristine forests. As a result, agricultural expansion, either at smallholder farmers scale or for commercial plantations, is among the major drivers of deforestation in Africa's tree commodity producing countries.

The mode in which commodities are grown significantly affects the extent of climate change mitigation benefits or influence what they contribute to. As described in the studies cited in this chapter, there is ample evidence that when commodity crops are grown in combination with other native shade trees, the potential to retain high carbon stock in the landscapes is higher than in monocrop systems. This also plays a crucial role in mimicking a natural system with high diversity and hence contributing to carbon sequestration and delivery of other ecosystem services. The subsequent sections delve into different attributes through which tree commodities directly influence climate change mitigation.

3.1. Impact through the biomass carbon loss or gain

Biomass loss or gain is the main mechanism by which tree commodity related activities either positively or negatively influence greenhouse gases emissions, as exemplified in the differences in carbon stock between forest and tree commodity production systems (Table 19.1). As expected, the conversions from natural forests to any commodity systems result in significant carbon stock losses, resulting in increased emissions. However, once the commodity systems are established, the impacts could be reduced if management actions are taken.

Table 19.1: *Changes in carbon stocks resulting from different land use and land cover conversions*

Change pathways		Changes in biomass carbon	Net change	Loss or gain
Biomass carbon in coffee systems in Togo	Forest land ↦ Fullsun coffee	197 tC/ha -> 23 tC/ha	-174	Loss
	Fullsun coffee ↦ Coffee with Albizia shade	23 tC/ha -> 82 tC/ha	+59	Gain
	Forest land ↦ Coffee with Albizia shade	197 tC/ha -> 82 tC/ha	-115	Loss
*Biomass carbon in coffee systems in Ethiopia**	Forest land ↦ Full-sun coffee	413 tC/ha -> 219 tC/ha	-194	Loss
	Forest land ↦ Heavy shade coffee	413 tC/ha -> 387 tC/ha	+26	Gain
	Forest land ↦ Light shade coffee	413 tC/ha -> 258 tC/ha	-155	Loss
	Full-sun coffee ↦ Heavy shade coffee	219 tC/ha -> 387 tC/ha	+168	Gain
	Full-sun coffee ↦ Light shade coffee	219 tC/ha -> 258 tC/ha	+39	Gain
	Full-sun coffee ↦ Traditional coffee agroforestry	413 tC/ha -> 138 tC/ha	-275	Loss
Biomass carbon in cocoa systems in Ghana	Primary forest ↦ Heavy shade cocoa	224.1 tC/ha -> 155.1 tC/ha	-69	Loss
	Primary forest ↦ Light shade cocoa	224.1 tC/ha -> 71.9 tC/ha	-152.2	Loss
	Light shade cocoa ↦ Heavy shade cocoa	71.9 tC/ha -> 155.1 tC/ha	+83.2	Gain
	Primary forest ↦ Full sun cocoa	224.1 tC/ha -> 17.8 tC/ha	-206.3	Loss
*Carbon in cocoa systems in South Cameroon**	Primary forest ↦ Old cocoa agroforest	305 tC/ha -> 184 tC/ha	-121	Loss
	Secondary forest ↦ Old cocoa agroforest	251 tC/ha -> 184 tC/ha	-67	Loss
	Forest fallow ↦ Old cocoa agroforest	180 tC/ha -> 184 tC/ha	+4	Gain
	Crop field ↦ Old cocoa agroforest	67 tC/ha -> 184 tC/ha	+117	Gain

Note: *Denotes stated values are inclusive of soil carbon up to the depth of 30 cm. For Togo, Dossa et al 2008; Folega et al 2020; For Ethiopia, De Beenhouwer et al 2016; For Ghana, Asase et al 2008; Mohammed et al 2016; For Cameroon, Njomgang et al 2011

3.2. Impact through soil carbon loss or gain

The mode of development of commodity farms also affects the mitigation impacts and contributions due to changes in soil carbon. A summary of the impacts of various coffee production systems in Uganda (Tumwebaze and Byakagaba 2016) is presented below. For carbon stock in forestlands, a middle point of the average values reported by Twongyirwe et al (2013) as 54.6 to 82.6 (middle point of 68.6) tC/ha was used.

Arabica coffee

Forest land ↦ Full sun coffee	68.6 tC/ha -> 50.99 tC/ha [-17.61]
Fullsun coffee ↦ Coffee with fruit trees	50.99 tC/ha -> 54.01 tC/ha [+3.02]
Fullsun coffee ↦ Coffee with fruit and other trees	50.99 tC/ha -> 54.54 tC/ha [+3.55]
Forest land ↦ Coffee with fruit and other trees	68.6 tC/ha -> 54.54 tC/ha [-14.06]

Robusta coffee

Forest land ↦ Full sun robusta coffee	68.6 tC/ha -> 51.78 tC/ha [-16.82]
Fullsun coffee ↦ Coffee with fruit trees	51.78 tC/ha -> 49.64 tC/ha [-2.14]
Fullsun coffee ↦ Coffee with fruit and other trees	51.78 tC/ha -> 57.56 tC/ha [-5.78]
Forest land ↦ Coffee with fruit and other trees	68.6 tC/ha -> 57.56 tC/ha [-11.04]

3.3. Impacts through farm and value chains management

Besides the farm establishment modes, the processes in the supply chains from farm management, harvesting, processing to transporting influence the mitigation impacts. To estimate this, there is a need to understand the product carbon footprint or yield-scaled emissions (Ortiz-Gonzalo et al 2017), which calculates emissions based on the extent of yield that a farmer manages or produces. Kenya coffee production is among the widely studied in this regard. About 70% of the coffee in Kenya is produced by farmers managing different farm sizes, often averaging around a hectare or less.

The product carbon footprint of coffee in Kenya is at least around 0.08 tons of CO_2 per ton of coffee berry produced (Ortiz-Gonzalo et al 2017) at the farm level. The authors found the minimum CO_2/ha/yr to be 6.53 tons varying with the degree of fertilization. At the processing level, which involves activities such as washing, drying and cleaning and transportation to stores, Maina et al (2014) estimated that a ton of coffee parchment produces an equivalent of 2.4-2.64 tons of CO_2e (with an average value at 2.55 tons of CO_2e). The high level of emissions associated with coffee was also highlighted in other studies. For instance, Reay (2019) stated that the carbon footprint of coffee ranges from around 70 grams per cup for instant one to as much as 150 grams per cup for filter coffee.

The best way to manage such a high level of emissions across the supply chains is to improve the farm management techniques and use of energy and resource-efficient processing techniques. For instance, Ortiz-Gonzalo et al (2018) found that fertilized coffee farms had a high emission level compared to unfertilized farms– 7.55 tC/ha vs 4.87 tC/ha in Thara site in Kenya. This suggests that using farm manure and other local organic fertilizers could potentially reduce the coffee farms' carbon footprint.

3.4. Emissions as a result of wastes along the supply chain

Along the tree commodities supply chain, the bulk of the waste occurs nearly in all stages of production, harvesting, processing and consumption. Due to increasing demand and thus increasing production, large amounts of residues are generated along the value chain. For instance, coffee represents the world's most widely traded agricultural commodity, with an estimated total production of 10.3 million tonnes in 2018/2019 alone (www.ico.org). About 40% of a fresh coffee berry weight is pulp or husk- a waste largely remaining on landscapes near production sites. Further, during production and consumption of expresso or hydro-soluble coffee, an estimated 90% of the brewed coffee ends up as waste in the form of spent coffee grounds (SCGs) (Afriliana et al 2020). For cocoa, on-farm processing alone leaves about 80% of the fruit as residual biomass, including cocoa pod husks, cocoa bean shells and cocoa sweatings (Vasquez et al 2019). For oil palm, production of 1 tonne of crude palm oil requires 5 tonnes of Fresh Fruit Bunches (FFB), and processing of 1 tone FFB generates 230 kg Empty Fruit Bunches (EFB) and 650 kg palm oil mill effluent as residues (Stichnothe and Schuchardt 2010). These wastes usually are dumped either as general waste in the producer's landscape or landfilled or processed at municipal composting facilities with other organic wastes in consumer countries. Therefore, the environmental and carbon footprints of these wastes are enormous, with large quantities of solid and liquid wastes generated globally.

The impacts of waste in tree commodity value chains also occur due to inefficient production systems (e.g., low efficiency machinery) and postharvest losses due to improper storage and waste from careless consumption by the end users. It is also crucial to recall the environmental wastes associated with packaging materials such as plastics. All such ones add up to the negative externalities of tree commodity value chains.

Nevertheless, with increasing environmental awareness, strict policy legislation and technological breakthrough, wastes are now perceived as sources of energy and other value-added products. Coffee wastes, cacao and palm oil residues are becoming increasingly popular as feedstock, for composting for organic farming, bioenergy such as pellets, biogas and biodiesels, processes that can potentially play a role in reducing emissions from these wastes.

4. How do tree commodities systems and adaptation to climate change relate?

There is a growing realization that communities whose livelihood depends on the proceeds of tree commodities need to be aware of the climate change impacts, plan on how to adapt and take the necessary actions when needed. To understand the adaptation impacts of tree commodities and/or how climate change affects the commodities, we explored the sensitivity and adaptive capacity of the production systems, inclusive of the human population that depends on them.

4.1. Sensitivity of tree commodity systems to climate change impacts

Commodity crops, like any other agricultural crops, are being affected by climate change and variability. Coffee will be significantly affected by climate change, as studies suggest (Davis et al 2012; Jassogne et al 2013). For example, Davis et al (2012) found that indigenous arabica coffee in Ethiopia is to experience about 38-90% area suitability decline by 2080 due to climate effects. This will significantly affect the wild coffee populations and hence making the production system very sensitive to climate change effects. With the predicted decline in a suitable area, the sensitivity of coffee systems will likely increase sharply. However, not all is that bad, as Ovalle-Rivera et al (2015) revealed. The authors, using global models, found that suitable areas for coffee growing are likely to increase in high altitude parts while shrinking in low lying areas in many coffee growing African countries (particularly Ethiopia and Kenya). This increase in suitability is a narrow window of opportunity for coffee growers. However, areas found suitable may already be faced with other competing land uses due to the significant land scarcity challenges.

Cocoa is facing similar challenges, just like coffee. In the West Africa Cocoa belt, Schroth et al (2016) found that areas with above 50% suitability for cocoa are projected to decrease almost by half by 2050 if the predicted climatic conditions are to take effect. Läderach et al (2013), using suitability analysis methods, found that of the 294 spatial points selected from the current cocoa growing areas in Ghana and Côte d'Ivoire, close to 90% showed declining suitability by 2050. Therefore, the sensitivity of cocoa is high, thereby increasing the sensitivity of the households depending on it.

Box 19.2

The roots of climate change adaptation research in agroforestry

Research on climate change adaptation has deeper roots in existing research traditions than that on climate change mitigation. A recent review (van Noordwijk et al 2021) traced the start of climate change adaptation research on agroforestry and tropical tree crops to the research tradition started by Peter Huxley at ICRAF in the 1980s. It distinguishes four adaptation approaches:

a. Reversal of negative trends in diverse tree cover as generic portfolio risk management strategy,

b. Targeted, strategic, shift in resource capture (e.g. light, water) to adjust to the changing conditions (e.g. lower or more variable rainfall, higher temperatures),

c. Vegetation-based influences on rainfall patterns, or

d. Adaptive, tactical management of tree-crop interactions based on weather forecasts for the (next) growing season.

Only approach D is commonly considered for agriculture based on annual crops. The review considers seven questions that are highly relevant for any tree commodity production systems.

1. How can farmers adapt to global climate change through introducing, or better managing, trees on farms and in agricultural landscapes?
2. How are site-level impacts of global climate change relevant for tree growth influenced by topography and ‘upwind’ vegetation?
3. What change in tree phenology, growth and production can be expected for a given variability and/or trend in local climate?
4. How does tree cover, managed on-farm, influence microclimate at the crop level relative to weather station data and the climate models calibrated to such data?
5. How does belowground resource capture by trees and crops (including fodder grasses) interact with modified resource availability under projected climate-change regimes?
6. What are the options for farmers to manage agroforestry practices in the context of expected climate change?
7. How do social and economic changes associated with the changing climate and response to it affect the adoptability of agroforestry?

On each question, current concepts and methods have allowed considerable progress.

Disease and pest prevalence are other attributes of cocoa and coffee farming that expose the system to a high sensitivity level. With the growing effects of climate change, coffee berry borer (*Hypothenemus hampei*) is likely to worsen in arabica producing East Africa countries, affecting coffee productivity (Jaramillo et al 2011). Kutywayo et al (2013) also reported increasing ranges for the African coffee white stem borer (*Monochamus leuconotus*), which is unique to Zimbabwe due to precipitation changes resulting from climate change effects. Wessel and Quist-Wessel (2015), in fact, stated that the major challenge with cocoa productivity in the future is the prevalence and aggressiveness of pests and diseases due to changing environmental factors. For cocoa, though the most prominent productivity threat is the cocoa swollen shoot virus disease, the relations between climate change and this disease are not yet well established. However, such a disease that significantly affects cocoa production (Andres et al 2018) will increase the system's sensitivity to climate change effects due to increased disease pressure on the system. Overall, there is a consensus that there will be an increase in pests and diseases damage on commodity crops growing the sensitivity of the commodity dependent livelihoods.

4.2. Influences of tree commodity systems on adaptive capacity

To understand the influence of tree commodities systems on adaptive capacity, we examined impacts or contributions for the four capitals following the approach used by Rahn et al (2014).

4.2.1. Tree commodities and natural capital

To understand the influences on adaptative capacity of tree commodities, we chose four indicators – biodiversity conservation, pollination, ecological succession, and pollution. Tree commodity crops affect biodiversity in several ways. The level of influence varies depending on land used for commodity farms creation and the management actions deployed. However, most of the influences discussed below are largely negative.

Biodiversity conservation is significantly affected by tree commodity farms expansion. With most commodity farms starting with forest conversions, primarily due to the search for fertile lands, the influences on biodiversity are immense, e.g. the threat to the wild coffee gene pool in Ethiopia due to clearing of wild coffee forests. When commodity farms are established or expanded by clearing forest plots (Asase et al 2018), it disrupts ecological vegetation succession. The climax species are often replaced by commodity species (either cocoa or coffee) hence creating a modified vegetation form. This affects the natural capital as it degrades ecosystem services. It also affects the biodiversity as commodity farm management usually requires chemical or inorganic products inputs (Ortiz-Gonzalo et al 2017; Denkyirah et al 2016; Potts et al 2016; Priess et al 2007). Cocoa heavily depends on insects for pollination. Toledo-Hernández et al (2017), reviewing researches on pollinators, confirmed that failure to manage pollinators may lead to a significant decline in cocoa yield, thereby affecting the livelihood of millions of cocoa dependent households. This affects the adaptive capacity of the farming communities.

The use of agro-chemicals may end up in the soil and water resources (Asogwa and Dongo 2009; Akinnifesi et al 2006), hence causing pollution. Pollution affects the health of households, thus forcing them to spend their income on medical bills. Furthermore, the translocation of the chemicals into edible plants also poses a significant health risk (Aiyesanmi and Idowu 2012) which increases the vulnerability of the communities living in the proximity.

Commodity production systems are physical resources (such as water, energy, soil, etc.) intensive. This extractive use threatens the adaptative capacity in the production areas as it creates competition for other resources in the landscapes. For example, coffee uses water heavily during cleaning, washing and preliminary processing. Even at the field level production stage, the production of a ton of cocoa and coffee beans is at 19,745 and 15,249 cubic meters, respectively. Figure 19.3 below shows the green water footprint of various cocoa and coffee products. The green water footprint is the amount of water used for the products under rainfed conditions only. Though local variabilities exist, it is notable that commodity farms decrease water volume in the landscapes.

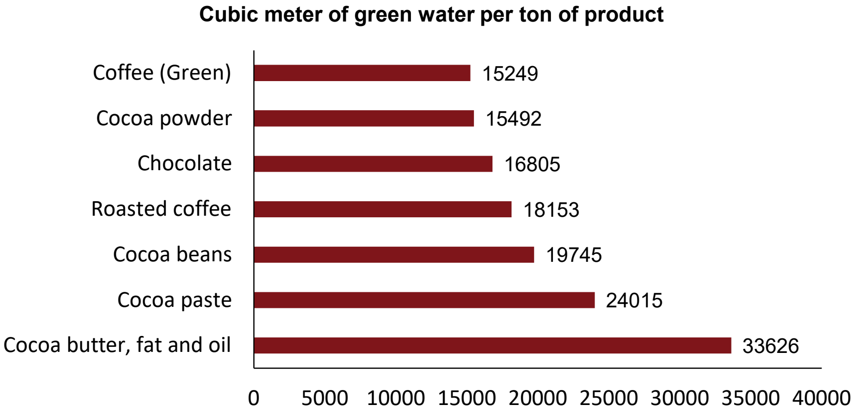

Figure 19.3: *Water footprint of commodity crops coffee and cocoa. Source: Authors compilation from Mekonnen and Hoekstra (2011).*

On the other hand, commodity farms also positively influence natural capital especially depending on where the production system starts. If the production system adopts heavy shade schemes, impacts on biodiversity will be minimal as the diversified vegetation act as refugia for fauna and flora and as pathways of connectivity (Tadesse et al 2014). When commodity farms are established on bare lands, the trees serve as important habitats for animals (Asase et al 2018; Gove et al 2008). In Ghana, Asase et al (2008) found the following trends: Bird richness - Shaded cocoa > Forest > Fullsun cocoa; Plant and buttery fly richness: Forest > Shaded cocoa > Fullsun cocoa. Hence, the degree of positive influence largely varies from what reference point we are looking at.

4.2.2. Tree commodities and social, human and financial capitals

Table 19.2 summarizes how tree commodities affect the three capitals, which is largely positive and thereby contributing positively to the adaptive capacity.

Table 19.2: *Influences of tree commodities on financial, social and human capitals of commodity producers*

Indicators	Description of how tree commodities could contribute or influence adaptive capacity
Income diversification	Tree commodities employ millions of smallholder farmers and other actors along the value chains. The commodities diversify and increase household income (Rahn et al 2014). Households who have such income sources can access assets that can help them to be more resilient. The resilience benefits also attained through the diverse income sources are achievable in heavy shade systems, particularly in coffee and cocoa systems (Obiri et al 2007; Abdulai et al 2018; Ruf 2011). This diversification also averts the risks associated with single commodity reliance and cushions the households.
Access to specialty markets	Coffee and cocoa farmers are in the process of accessing specialty markets/ premium prices that pay more than the normal prices if the commodities qualify to the required standards (Mitiku et al 2017).
Access to credits	Through their unions and cooperatives, most smallholder farmers access credit, though still has a long way to go (Ruben and Heras 2012; Mojo et al 2017; Mojo et al 2015).
Access to information and education	Access to formal and informal education through training and awareness creation events were seen as an important indicator for this. Compared to other farmers, commodity farmers have a better chance of accessing education either formally or informally.
Access to social support	Cocoa and coffee producers are among the most organized groups of smallholders in Africa, and hence members get better social support through such structures, which boosts their adaptive capacity. Moreover, such producer groups also get infrastructural support (e.g., clean water supply, energy sourcing, schools, health facilities, markets, etc.) from companies and corporations that rely on commodity value chains.

4.3. What opportunities are there for tree commodity systems to contribute to climate objectives?

What can we do to reduce the climate change impacts of tree commodities? Table 19.3 summarizes some potential measures that could be taken to avert the negative impacts of commodity production systems on climate change mitigation and adaptation.

Table 19.3: *Intervention options to improve the climate change impacts of tree commodities*

Options	Specification	Relevant examples	Influence pathways	Some potential policy and regulatory tools
Practice selection	1. Environment friendly intervention choices	Adopt shaded cocoa and coffee systems rather than full sun cocoa and coffee. Jassogne et al (2013) stated that shade could reduce temperature by up to 20ºC. Adoption of Integrated Pest Management than use of chemical pesticides and herbicides; Composting and mulching than chemical fertilizers	Largely mitigation with significant adaptation benefits	Environmental Impact Assessment Forest Stewardship Council certification
	2. Climate (smart) friendly intervention choices	Intensification rather than expansion into forests Less mechanized options (reducing emissions from equipment)	Both mitigation and adaptation	REDD+ FSC certification Payment for ecosystem services
	3. Biodiversity friendly intervention choices	Practice designs that allow corridors for animal movements Pollinator and insect friendly options	More adaptation benefits and some mitigation benefits	Rainforest Alliance Certification; Aichi target
Resource use efficiency	1. Choice of lands with less competition	Use of marginal and degraded lands for tree crops than clearing forests	Mitigation	National or local land use policy
	2. Efficient resource utilization	Use of biodigester and solar power for energy	Mitigation	Energy saving certificates
Processing	1. Waste management	Coffee and cocoa waste for energy generation and biofertilizer Wastewater treatment in palm oil processing	Mitigation	
	2. Renewable energy	Processing plants using renewable energy	Mitigation with some adaptation	Renewable energy certificates
	3. Reuse, Reduce, Recycle	Biodegradable packaging, reusable bottling, etc. Minimize food waste through managed consumption	Mostly mitigation with some adaptation	Consumer behavior programmes

Options	Specification	Relevant examples	Influence pathways	Some potential policy and regulatory tools
Safeguarding	Insurance	Cooperatives and unions could safeguard farmers through weather indexed insurance (Sibiko et al 2018) hence reducing deforestation.	More adaptation benefits	Weather index-based insurance
	Premium prices	Access to premium prices gives the farmers additional income, which boosts the resilience and avoids emissions.	More adaptation benefits	Premium prices regulation

There could be many actions to be taken to reduce the impacts of commodities on climate change mitigation and adaptation. But the magnitude of effects really depends on what measures we adopt and how the actions are followed and implemented sustainably with contexts considered.

5. Conclusion

We explored how tree commodities and climate change relate both from the negative impacts and arising opportunities to address the impacts. Our scope was on three tree commodities -coffee, cocoa and oil palm. In general, the main summary ideas from the study are that tree commodities affect climate change and vice versa. The impacts manifest at different levels along the value chain from the farm level production to the final consumption by an end user. The main pathways of influence include: 1) emissions associated with land use and land cover conversions which are both through biomass and soil carbon losses or gains; 2) emissions as a result of postharvest issues; 3) emissions during processing and value addition; 4) wastes generated as a result of the waste; 5) boost in adaptative capacity due to structural improvement such as the formation of cooperatives and unions and also access to credit schemes. Addressing these challenges needs articulated planning and deployment of interventions that can induce efficiency, environmentally friendly production systems and thoughtful consumption.

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