Coffee-Banana Intercropping: Implementation guidance for policymakers and investors

Overview of practice

Coffee-Banana Itercropping is a climate-smart agricultural practice based on indigenous knowledge. It increases farmer incomes, improves resilience to climatic impacts, and sequesters higher amounts of carbon as opposed to monocropping systems. The practice also has positive effects for rural women and household nutrition.

GACSA
GLOBAL ALLIANCE FOR CLIMATE-SMART AGRICULTURE

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KEY MESSAGES

1 Coffee-Banana Intercropping (CBI) addresses all 3 pillars of CSA in a multifaceted way.

2 CBI in both Arabica and Robusta generates 50% more revenue than either coffee or banana monocrop.

3 Farmers' risk is reduced by practising CBI, making them more resilient to climate change impacts.

4 Transformational changes are needed in the attitude towards CBI, to support scaling up of the practice.

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Overview of practice

Arabica *(Coffea arabica)* and Robusta *(Coffea canephora)*, the two main types of coffee, offer the promise of a better life for 20-25 million farming families, 70% of whom are smallholder producers (Eakin et al., 2009). Coffee is a major export crop and an important source of foreign revenue in most tropical and subtropical regions, including the Great Lakes Region of Eastern and Central Africa. These same farmers also depend on bananas *(Musa spp.)* for food security and additional income throughout the year. Yet, the prevalence of seasonal food insecurity in many coffee growing communities suggests a lack of resources for smallholder coffee farmers to feed themselves and their families (Caswell et al., 2012). The intersection between coffee and food security amidst climate change represents a formidable step towards delivery of viable livelihood and improved conditions for smallholder farmers (Caswell et al., 2012).

Climate change is indisputably having negative effects on global crop yields and threatening food security. The key issues facing the coffee sector, including declining productivity, price volatility and terms of trade, have been compounded by increased temperature change. Recent evidence shows that climate change is having substantial impact on the areas suitable for cultivation of Arabica coffee in the major growing regions, including the East African Highlands region (Craparo et al., 2015; Ovalle-Rivera et al., 2015). In Uganda, for example, the National Planning Authority (NPA) considered a scenario in which coffee production could be entirely wiped out in less than 100 years (NPA, 2010). Consequences for national income and livelihoods for millions of smallholder farmers in the region are dramatic, with losses estimated at USD 100 million in revenue per year (Rijsberman, 2015).

This calls for immediate action through increased investment in climate change adaptation strategies in coffee-based systems, something that has been stressed over the past years. Coffee intercropping with shade trees is recognized among the promising adaptation practices capable of compensating for higher canopy temperatures by 2°C to 3°C (Ovalle-Rivera et al., 2015). Apparently, the extensive time lag (5-10 years) for the establishment of shade trees is a major barrier to substantial adoption by many smallholders. Conversely, bananas normally attain their full canopy cover within 6-12 months, and hence intercropping with banana is the most promising climate change adaptation approaches for coffee today.

Coffee-Banana Intercropping (CBI) is not a novel approach per se, it is a traditional practice developed by smallholder farmers over decades (Ekong, 2015), as a coping strategy to maximize their crop production amidst population pressure and declining arable land size. CBI is very diverse in nature and widely practiced in the East African highlands, and across the humid tropics, including Latin-America, Asia and West Africa. Both crops can be planted at the same time. Alternatively, coffee can be introduced in existing banana plantations but banana population may need to be thinned to provide sufficient space for the coffee trees. Similarly, banana can be planted in an existing coffee plantation but the coffee trees may need to be pruned initially to create room for the banana plants during their establishment.

Official recommendations from public extension and research bodies differ significantly, with optimum banana densities being highly variable within and between locations. Until recently, many governments including those of Rwanda and Burundi, had banned farmers from intercropping coffee with banana, in the mistaken belief that intercropping would reduce yields and incomes. However, the recent efforts of CGIAR’s researchers and partners have helped transform this negative outlook about intercropping coffee with banana. The practice is now recognised as climate-smart because of its beneficial triple-wins of increasing food security and income, climate change adaptation, and mitigation of greenhouse gas (GHG) emissions.

Several on-farm research and controlled on-station experiments conducted in Rwanda, Burundi, Uganda and the Democratic Republic of Congo have revealed that CBI (i) increases total revenue per unit area by over 50% when compared to either monocropped banana or coffee, (ii) improves coffee quality, although it does not significantly affect coffee yields, (iii) helps the coffee crop better overcome drought periods, (iv) diversifies farmer's food and cash revenues and (v) reduces greenhouse gas (GHG) emissions by increasing above- and below-ground carbon stocks and increasing total production per unit energy invested.

Benefits of CBI

Research conducted in East and Central Africa by the International Institute of Tropical Agriculture (IITA) and partners has proven that CBI offers smallholders with a unique opportunity for multiple benefits. These include improved soil fertility through provision of in situ mulch, sustainable intensification of small plots, income risk management and food security, improved production and quality of coffee, increased resilience to drought and extreme weather events, reduced pest and disease pressure, and natural resource integrity.

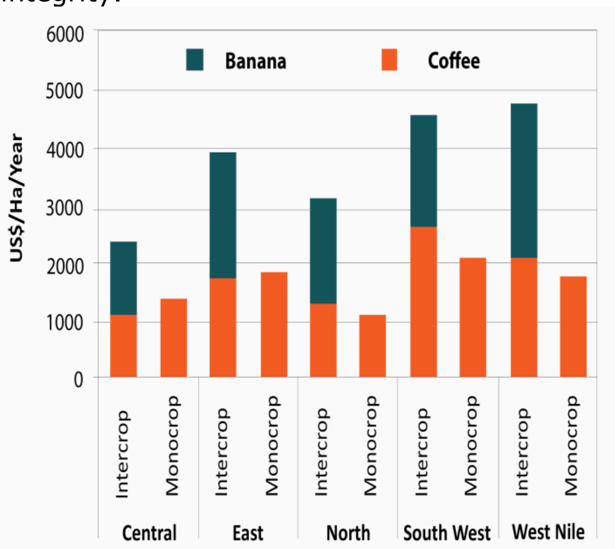

FIGURE 1 Example of Coffee-Banana Intercropping revenues as compared to coffee monocropping plots from large on-farm studies (n=357) in Uganda. Central and North are Robusta coffee growing regions; East, South West, West Nile are Arabica coffee growing regions.

Increased incomes

Coffee intercropping with banana is particularly beneficial in newly established coffee farms, where the long juvenile period (3-5 years) delays initial returns on investment. Notably, bananas can be harvested a year after establishment. Evidence shows that with average banana harvests of 12.5 tons per hectare per year, farmers can offset cash flow constraints worth about USD 10,000 in the years that coffee is not yet productive (van Asten et al., 2012). Several on-farm studies reveal a higher yield equivalent per unit of land when banana or coffee are intercropped compared to a monocrop under the same management level (i.e. land equivalent ratio (LER)). The LER of 1.5 means that farmers who practice CBI will only require 1.5 units instead of 2 units of land to produce the same quantities of coffee and bananas under monocropping. Moreover, coffee yield does not significantly differ between intercropped and monocropped (van Asten et al., 2008). These observations are consistent in many countries of the Great Lakes Region (i.e. Uganda, Burundi, Rwanda and DR Congo) (Nibasumba, 2013; van Asten et al., 2012). CBI in both Arabica and Robusta generates 50% more revenue than either coffee or banana monocrop (Figure 1). This implies that while coffee provides the cash boom twice a year, bananas ensure a continuous flow of income throughout the year (van Asten et al., 2011). This way, CBI provides smallholder with double-wins (i.e. income and food security) amidst increased population pressure and diminishing farm size.

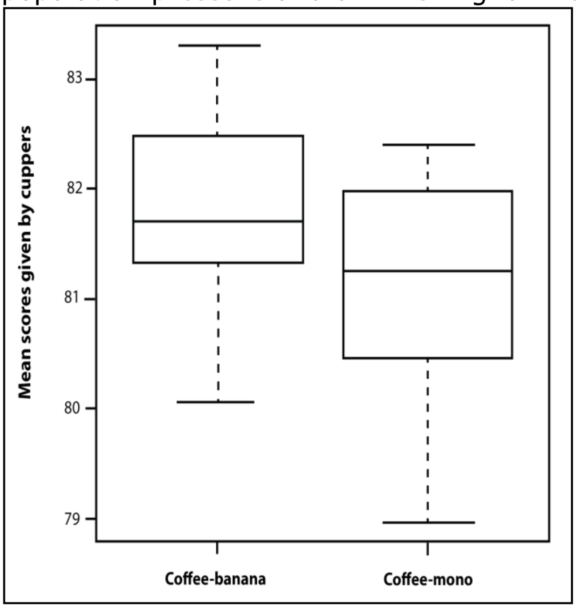

FIGURE 2 Mean Arabica cupping scores (blind-tested) for banana-shaded and monocropped coffee in West Nile, Uganda. Classification of scores: 90-100 = Outstanding; 85-89.99 = Excellent; 80-84.99 = Very good; < 80 = Below specialty (Mukasa et al., 2013).

Improved food security

Bananas within CBI constitute the food security component, and are a great opportunity to diversify coffee production systems. Although banana yields per unit area reduces by up to 50% when intercropped with coffee, the supplementary banana harvest can bolster food security even during the dry season and contribute to coffee-growing regions. Women perform essential role as primary caretakers in household food security. CBI particularly offers a chance for women who traditionally do not own land, to make good use of limited space occupied by coffee, and to contribute towards ending household under-nutrition among children through production of bananas rich in vital vitamins A, B and D. Furthermore, including banana in the coffee system spreads the risk in the event if one crop fails, farmers can still get a harvest from the other.

Natural resource integrity

Characteristically, CBI is not conventionally weeded but rather in situ mulching is used to control weeds to avoid injury of the roots particularly for bananas a surface feeder. Use of external mulch in coffee plots is expensive and labour intensive, thus not feasible in the context of smallholders. Integrating coffee and banana in the same field decreases the amount of labour required to transfer mulch from one field to another, and from other external sources. Notably, in situ mulch from banana system has a higher biomass turnover, which helps to recycle organic matter and nutrients, and suppress weeds. CBI also has the advantage of maintaining permanent ground cover, which minimizes land degradation and pollution, improves soil-structure interaction of roots between crops, and promotes ecosystem services (e.g. soil and water and biodiversity conservation).

Increased resilience to drought and extreme weather events

Drought is a major yield loss factor in rainfed cropping systems. Coffee is sensitive to changes in climate (i.e. increased temperature and erratic rainfall patterns). Notably, a slight change in temperature at a critical stage of coffee can compromise growth and eventually yield. Intercropping coffee with bananas potentially contributes to climate change adaptation through enhancement of the microclimate for coffee growing. The complementary advantages of bananas in CBI include provision of shade, protection against weather shocks such as drought and hailstones, and reduced competition for water. Contrary to some shade trees, bananas are quite sensitive to drought (van Asten et al. 2011). However, they are relatively more efficient at regulating

BOX 1: Productivity and profitability of Arabica coffee intercrop on the slopes of Mt. Elgon region in Uganda

Arabica coffee and banana are the primary cash and food crops in much of Mount Elgon region in Uganda. High population growth rate (3.4% per annum) provides ideal conditions for smallholders to grow coffee and bananas in an intercrop system to optimize productivity per unit area of limited land.

Recent efforts to unravel the economic benefits of coffee-banana intercropping in the Mt. Elgon region have shown that coffee yield does not significantly differ between intercrop and monocrop. Moreover, smallholders also enjoy stable food supply from the harvest of banana. Marginal rates of return of investment are higher for intercrops compared with mono-cropped coffee. Altogether the annual yield value of both coffee and banana is significantly higher for intercrops compared to monocrops (Figure 3).

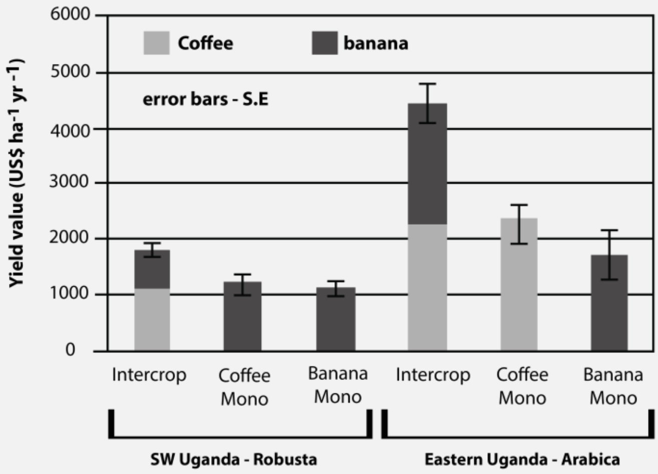

FIGURE 3 Annual yield value of intercropped and mono-cropped coffee and banana in farmer fields in Mt Elgon and South West Uganda.

The considerable gains in productivity and profitability of the coffee system in the Mt Elgon region have confirmed that farmers can enjoy a cash boom from coffee and banana growing together, once or twice a year. Besides, banana is a continuous source of nutritious food throughout the year.

Source: van Asten et al., 2011; van Asten et al., 2012 stomata closure and transpiration, which allows banana to remain highly hydrated under drought stress (Kissel et al., 2015). Consequently, the banana plant competes less with the coffee plant for water than some other shade trees.

Enhanced coffee production and quality

The quality of coffee and bananas are mutually enhanced through above- and below-ground complementarity. Above ground moderation by shading reduces the temperature in the coffee canopy by over 2 °C (Beer et al., 1998). Shading triggers differences in physiological behaviour of the coffee plants, such as improved photosynthesis and increased leaf area index, resulting in better performance than it is possible in direct sunlight (Bote and Struik, 2011). Coffee grown under shade generally produces heavier and larger cherries due to reduction of overbearing, and buffering against biennial fluctuations in coffee yields (Bote and Struik, 2011; Vaast et al., 2006), something that has even been observed in banana-shaded coffee systems in Burundi (Nibasumba, 2013) and Uganda (Mukasa et al., 2013) (Figure 2). Besides, shade cover indirectly influences coffee quality, in terms of biochemical composition, including the contents of caffeine, oil and chlorogenic acid. Hence, the taste of finished products is therefore better, and can earn farmers a higher price. Growers can ensure highest premium price by maintaining i) appropriate growing conditions, ii) good agronomic practices, and iii) immediate post-harvest handling and processing.

Reduced pest and disease incidence

Climate change raises serious plant protection issues and phytosanitary risks to coffee, particularly with regard to the distribution, success, spread and impact of invasive species of plants, pests and pathogens (Wang et al., 2015). In Uganda, for example, climate change has increased the incidence of pests and diseases such as leaf miners, mealy bugs and leaf rust. Increased biodiversity in coffee systems plays a strategic role in significantly reducing the impact of coffee pests and diseases through i) spatial disruption of pest and pathogen dynamics, ii) conservation and build-up of natural enemies against disease vectors, iii) general and specific soil suppressiveness, and iv) deterrence and allelopathy (Ratnadass et al., 2012). Key advantage of the integration of coffee-banana systems is that bananas are not secondary hosts of pests and diseases of coffee, as is the case with certain agroforestry trees. Generally, banana-shaded coffee experiences 50% lower incidence of coffee leaf rust (*Hemileia vastatrix*) and black coffee twig borer (*Xylosandrus compactus*) compared to tree-shaded systems.

Reduction of greenhouse gas emissions

Besides suffering from the effects of climate change, coffee production has also made significant contribution to greenhouse gas (GHG) emissions in the recent past. Most of GHG emissions are directly driven by the use of resources (i.e. land, fertilizers, fossil fuels, pesticides). Land use systems that increase the soil organic matter (SOM) pool and stabilize soil organic carbon (SOC) are globally proposed to increase the production resource use efficiency and compensate for GHG emissions (Oelbermann et al., 2004). Climate-smart approaches like the integration of coffee with bananas and trees have enormous potential to sequester atmospheric carbon in trees and soil while maintaining sustainable productivity (Albrecht and Kandji, 2003). Evidence shows that the average combined carbon stocks in shaded coffee plants increased from 10.5 Mg ha^{-1} in unshaded monocultures to 42.5 Mg ha^{-1} in traditional polycultures, with intermediate values in commercial polycultures (30.2 Mg ha^{-1}) and shaded monocultures (14.3 Mg ha^{-1}) (van Rikxoort et al., 2014). Similarly, Zake et al. (2015) observed that CBI systems contained 1.5 times higher soil carbon stocks and 26% larger total carbon pools compared to banana monocultures. From the above data, it can be noted that CBI contributes towards (i) increased above ground carbon stocks, (ii) accumulated mulch layer on soil surface i.e. significantly higher total soil organic matter and total nitrogen, and consequently (iii) increase soil carbon content. Besides, the increased overall productivity of the system (land equivalent ratio >1.5) reduces the carbon footprint of the system because the total emissions from agricultural inputs (originating from fertilizer, pesticides and fuels) can be spread over a larger agriculture produce.

CBI in indirect adaptation to price fluctuations

The profitability of coffee is not only driven by the yield quantity but also the intrinsic quality of the beans. The latter being directly responsible for increased market demand and significant price differentials for distinct flavour profiles (Mukasa et al., 2013). Recent studies reveal that predicted future climate change will reduce areas suitable for coffee production, and impact on the world coffee market prices, especially for gourmet coffees with denomination of origin status (Haggar and Schepp, 2013). Coffee intercropping with banana and a variety of shade trees positively affects soil nutrient status and production microclimate, which are strongly correlated with coffee quality. The practice renders ecosystem benefits like biodiversity and soil and water conservation. It also indirectly contributes to climate change adaptation through reduction of the carbon footprint at farm level. CBI buffers against biennial fluctuations in productivity that may arise from altered air temperature, wind speeds and increased relative humidity (Carmago et al., 2008). For example, in Kenya, shading has been adopted to avoid reductions in night temperatures at high elevations (Carr, 2001). This enables growers to maintain the highest quality and stable harvest patterns, which guarantees premium prices in the future. This is particularly important for countries and companies that are heavily dependent on coffee and would wish to tap into the lucrative specialty coffee market.

Challenges to adoption of CBI

Evidence reveals that coffee growers in densely populated regions are more likely to intercrop coffee with shade trees, bananas and vegetables due to scarcity of arable land. Despite this, uptake of coffee intercropping is not that straightforward for all coffee farmers to intercrop with bananas permanently. A combination of causes contributes to poor farmer uptake and implementation of Coffee-Banana Intercropping.

Seasonal food insecurity in coffee producing communities

Rural agricultural families in coffee communities are particularly vulnerable to seasonal irregularity of available food and income (Eakin, 2009). For example, about half of the households in Mexico, Nicaragua and Guatemala experience at least one up to eight months of seasonal food insecurity each year. These smallholder farmers often face the dilemma of maintaining the balance between coffee, which provides income, and food crops, which provide staple food (Bacon, 2005; Morris et al., 2013). The vast majority produce coffee already under multiple resource challenges, and must tactfully divide land, time and resources towards sustained crop production, for income and household food consumption (Steinberg and Taylor, 2009). Moreover, limited flexibility in making adjustments toward more productive or profitable options has critical implications for the sustainability of the coffee industry.

High levels of initial capital investment

Because coffee is perennial, it requires high levels of initial investment (i.e. labour and capital), with a 10 to 15-year time horizon (Panyhusen and Pierrot, 2014). Many subsistence coffee farmers like to obtain a direct and immediate return for their investment, however, the extended time period before realization of economic benefits discourages many poor farmers from adopting coffee intercropping. This being compounded by the fact that smallholder farmers inhabit a fragile space defined by vulnerability to a volatile international price structures (Caswell et al., 2012). Aside from the delayed returns on investment, farmers are also reluctant to adopt intercropping due to unpredictable weather patterns, and increased incidence of droughts and floods.

Lack of site-specific recommendations

Observed variants of CBI (i.e. variable spacing and plant density) on farmers' fields raises questions about the adequacy to match productivity, profitability and sustainability targets. Most of the information available to farmers originated from the FAO Coffee Guidelines that are difficult to duplicate everywhere. Moreover, existing research findings are difficult to compare across the board of farmer sites. There is a strong need to review past research and recommendations, to allow for more site-specific and flexible CBI recommendations that can help enhance profitability and sustainability of the intercrop system. Coffee farmers need special training on how to strike a balance within the intercrop system since both crops require careful management of the soil and crop leaf canopies. In addition, structures, procedures and process for effective research communication to end-users should be established.

Mining of soil nutrient stocks

Soil fertility is an important factor controlling net primary productivity (Seastedt et al., 1991). Like banana, coffee is a heavy feeder requiring large amounts of nitrogen (N), phosphorous (P), and potassium (K). For example, nutrient uptake in a plantation yielding 10 t/ha/year fresh banana and 0.5 t/ha/year green beans of coffee, is about 90 kg N, 10 kg P and 190 kg K per ha (Wairegi et al., 2014). Both coffee and banana have a shallow rooting system with most of the feeder roots found within 20 cm of the soil surface (Wairegi et al., 2014). The relatively high demand for K requires particular attention. The rate of nutrient mining is generally much higher than the rate of replenishment (Zake, 2010). Both banana and coffee yields can only be sustained by the addition of manure, compost and/or mineral fertilizers (Wairegi et al., 2014). The continued lack of replenishment of nutrient mined ultimately jeopardizes the sustainability of the coffee-banana system. Maintaining yields calls for detailed assessment of limiting nutrients and the adoption of integrated soil fertility management (ISFM) practices for long-term productivity and profitability of the system.

Conflicting interests of coffee sector actors

The effects and consequences of climate change ought to be tackled sector wide. Working with multi-actors has potential to address important sector challenges and create more self-sustaining forms of capacity (Acquaye-Baddoo et al., 2010). However, harnessing multi-stakeholder commitment within the coffee sector is marred by diverging interests, power and conflicts among those at the centre of strategies for change. This by no doubt poses a severe challenge to our current concepts of sustainable coffee production (Baker, 2010).

Gender inequality and imbalance in plantation ownership

Gender issues in agricultural production have been well documented; however, very little is known about the role of gender and coffee-banana intercropping for household food security. Women farmers, for example, contribute a vast proportion of labour in coffee farming (i.e. planting, growing and harvesting) although their role on coffee plantations is often underappreciated. The majority of women farmers are affected by restrictions on ownership of plantations and unequal opportunities to break into coffee production. Therefore, it is recommended that policies as well as technological and institutional interventions be developed that allow women to benefit fully from intercropping, and hence contribute to food security.

Government ambitions and targets

Many government extension and advisory services in East and Central Africa have not yet officially adopted coffee intercropping, to the extent of promoting monocropping as a form of agricultural modernization necessary to achieve the African Green Revolution. Apparently, these are colonial-era recommendations, enforced at a time when the key emphasis was increasing coffee exports, without consideration for long-term sustainability of production system. In Rwanda, for example, farmers have to date been particularly encouraged to consolidate fragments of land parcels and grow coffee as a monocrop (van Asten et al., 2011). Lately however, there has been significant shift in attitude from the strict monocropping regulation of coffee towards consideration of the benefits of intercropping to relieve pressure on land, ensure food security, but also protect coffee from increased temperatures and erratic weather patterns (Ekong, 2015).

Unregulated field of climate change adaptation

The diffused nature of the coffee sector with multiple actors and unregulated climate change adaptation and mitigation agricultural activities has particularly slowed down the uptake of intercropping in coffee (Ekong, 2015). Creation of a coffee sector multi-stakeholder platform will be instrumental in harmonizing activities and contributing to shared visions with the effective collaboration of implementing agencies including donors, the private sector, NGOs, research, and extension. Such a working group will also help to ensure effective uptake of CBI at policy and implementation level. Even though policy formulation around coffee intercropping may take some time, there appears to be good reason for optimism about its uptake (Ekong, 2015).

CBI on the farm

CBI is ideal for more effective resource use in land-constrained farms. A prerequisite for a sustainable CBI at plot level is good crop management. Therefore, farmers are advised to use the correct spacing and plant densities to manage resource competition and improve the cumulative yield of banana and coffee crops. Unfortunately, plant spacing recommendations only exist for monocropped Arabica, Robusta and banana (Table 1). However, recent research conducted by the International Institute for Tropical Agriculture (IITA) and its partners shows that the best CBI performance is associated with 600-800 banana mats per hectare to 2000-2400 Arabica coffee trees per hectare and 1000-1200 Robusta coffee trees per hectare (Table 1).

Table 1 Suggested plant spacing and plant densities for Coffee-Banana Intercropping

System	Crop	Spacing		Density (Plants/hectare)
		Between rows	Within rows	
Monocrop	Arabica	3	1.5	2222
	Robusta	3	3	1111
	Banana	3	3	1111
Intercrop	Arabica	3	1.5	2222
	Banana	3	4.5	740
	Robusta	3	3	1111
	Banana	3, 6*	3	740

*Double rows, 3 m between the two rows, 6 m between double rows

When coffee and banana are planted simultaneously in a new field, it is also recommended that annual crops are grown in between them for one to two years to provide some income before the bananas and coffee are ready for harvesting (Wairegi et al., 2014). In contrast, when introducing either coffee or banana to existing plantations, farmers need to make relevant adjustments to the existing system. Notably, mature coffee trees need to be pruned initially to create room for the banana plants. Similarly, banana population must be thinned down from 1111 to 740 banana mats per hectare to create space for coffee trees (Table 1; Figure 4).

The above generated information has helped to demystify earlier perceptions held by certain governments and smallholders that intercropping of coffee with banana could be counterproductive for their coffee yields (Jassogne et al., 2013). Subsequently, CBI is now being promoted in coffee growing areas to mitigate impact of high temperature and longer dry periods, which would result in depressed coffee yields and quality.

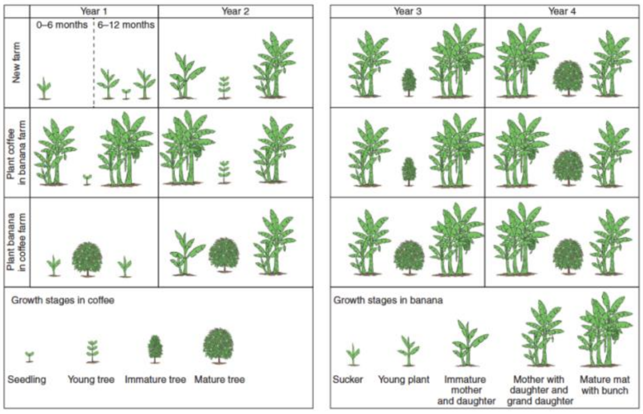

FIGURE 4 Stages in the development of banana-coffee systems from planting to harvest

Where can CBI be practiced?

CBI is particularly interesting for areas where access to land is limited, but access to labour is not a key constraint. The benefits of CBI are determined by the ability to manage competition for nutrients, water and light between coffee and banana. Choosing banana varieties that are tall enough to exceed the coffee canopy is important to avoid excessive light competition for bananas. For the coffee, short/dwarf varieties match best under the banana canopy. This is particularly relevant for Robusta, where trees are usually taller, and root systems are superficial and dense, which creates competition for light, water and nutrients with bananas. Therefore, if young bananas are to be planted into an existing Robusta plantation, the coffee densities must be reduced to about 1100 trees per hectare to reduce competition. Coffee canopy size can also be adapted through correct timing, frequency and sequencing of pruning. When left unmanaged, coffee will ultimately outcompete bananas. Conversely, under good management, coffee benefits from the shade and mulch from bananas. For this reason, Professor J.Y.K. Zake (Soil Scientist from Uganda) concludes: “take care of your bananas, and your bananas will take care of your coffee,” as bananas seem to be the weaker link in the system.

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