TEMPLATE COFFEE CLIMATE-SMART CREDIT PRODUCT

F3 Life

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1. Executive Summary

Introduction

The purpose of this document is to establish a generalised "climate-smart credit product" for small scale coffee growers (SSGs). A climate-smart credit product is a loan to a farmer, where the terms of the loan agreement require that the farmer implement a specified set of climate-smart and/or sustainable land management (CSA) practices on their farm, and that information about compliance with CSA loan terms informs borrower credit risks scores.

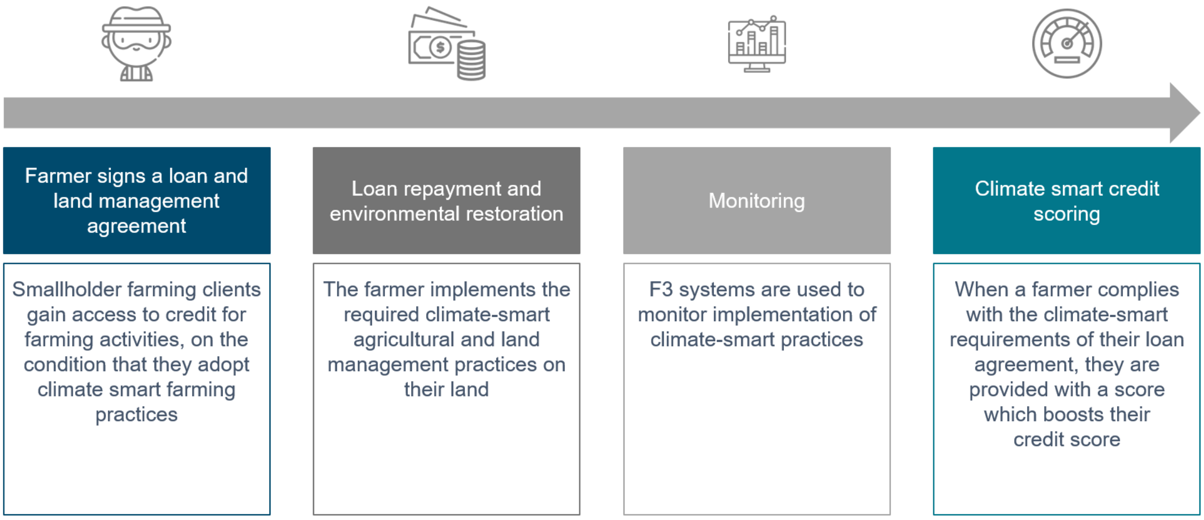


Figure 1: Climate-Smart Lending Process

Growing conditions for coffee vary according to agro-ecological context. Therefore, the climate-smart credit product requirements presented in this document are generalised, i.e. not tailored to a specific geographical area or agro-ecological context, but which can be adjusted simply according to the context in which it is deployed.

The financial and environmental justification and impact models related to use of the climate-smart credit product, also presented in this document, are similarly generalised. When precise crop and land management requirements are modified according to context, the financial, environmental and agricultural impact models will also be adjusted accordingly.

This document therefore sets out the template climate-smart coffee product and related models which can be easily adapted for use with specific application.

The purpose of this document is not to propose interest rates and appropriate loan tenor for loans for small scale coffee growers, which will be set by the financial institutions which use the F3 Life system. However, where a lender wishes to establish a loan product for coffee growers, the agricultural economic analysis in this document would serve as the basis (only) for the loan product to be developed.

Climate risks to coffee production

Impact studies of climate change on coffee production are largely focused on Latin America and East Africa, with less focus on other major coffee regions in Asia. Available studies are diverse and point largely to the chief risks posed by climate change to coffee production, namely: (i) increased growing season temperatures; (ii) inter and intra-seasonal droughts; (iii) shortening of the growing season; (iv) unpredictable seasons; and (v) increased rainfall intensity. Serious reductions of coffee production are predicted globally due to climate change. The greatest risk is that declining yield associated with climate change will result in extensification of production and associated clearing and development of forest areas to meet growing coffee demand.

Despite the categorisation of these risks, there is limited empirical evidence of the uptake, cost, benefits, and effectiveness of different adaptation measures (as well as the risk of maladaptation) in different countries and regions. This is not unusual in the agronomic literature. As such, climate-smart land management strategies are those which are known to reduce the agronomic stress on coffee caused by the likely impacts of climate change listed at (i) to (v) above.

Climate resilient / sustainable crop and land management measures for coffee production

Certain established, proven and de-risked sustainable crop and land management practices are increasingly being advocated and used for improving coffee yields. These measures create agronomic benefit for production, and for this reason are also appropriate in mitigating the impacts of climate change on coffee production. Measures proposed in this report are designed to be implemented over successive loan cycles, starting with new coffee establishment and being maintained as the coffee matures and reaches optimum economic yield levels. From the time seedlings are planted, it takes three years before the first coffee cherries are harvested. Thereafter yields will increase reaching mature economic yield level from the sixth year onwards. Seven levels of loans are proposed based on the area of land under coffee. A number of CSA practices have been identified falling into five broad categories. These include: (i) planting new varieties, (ii) integrated soil fertility management, (iii) soil and water conservation measures, (iv) agro-forestry, and (v) integrated pest and disease management, as indicated in Table 1, with local agro-ecological conditions dictating appropriate modification.

The areas of land are 0.03 ha, 0.06 ha, 0.25 ha, 0.50 ha, 0.75 ha and one hectare. The smallest 0.03 ha or 1/32nd ha is intended a learner level allowing the grower to test out the technologies on a small scale before progressively increasing the area grown under CSA. This is intended to encourage the adoption of new practices as experience is gained. Three basic scenarios are envisaged.

Firstly, where the grower has already established drought tolerant and pest resistant varieties and the coffee is already bearing cherry. In such circumstances the other nine practices would be a requirement of any loan. Secondly, planting new or rehabilitating existing coffee with improved varieties including the other CSA practices. Thirdly, planting new coffee varieties in an intercropping system with bananas, in circumstances where the bananas may be a food or marketable crop.

Benefits of climate-smart credit product CSA crop and land-management requirements

There are a number of CSA practices proposed across five broad areas ((i) use of improved varieties, (ii) integrated soil fertility management, (iii) soil and water conservation, (iv) agroforestry, and (v) integrated pest management. These measures are designed to (a) increase yields, (b) reduce input and other costs, (c) mitigate the impact of climate change-related stressors, and (d) improve on-farm carbon sequestration as well as deliver other environmental benefits. These are shown in Figure 2.

(a) CSA-related yield increases

Yields will increase over time as new drought and pest tolerant varieties mature and start yielding coffee cherry, soil organic matter builds, soil health is restored and soil conservation measures become effective with planted trees providing shade, moderating temperatures and providing mulch material and aiding the fight against pets and diseases. Yield improvements, derived from research and/or practical experience in East Africa and Latin America, indicate that yields could double from a base of less than 300-700 kg per ha as a result of the CSA practices. Their impact will be greatest where yield levels have or are declining due to poor soil health, soil erosion, drier and warmer

		0.03ha	0.06ha	0.13ha	0.25ha	0.5ha	0.75ha	1ha
Contractual Requirements	Banana Suckers	63 suckers	250 suckers	500 suckers	750 suckers	1,000 suckers	1,200 suckers	1,600 suckers
	Plant Trees	16 trees	63 trees	125 trees	188 trees	150 trees	200 trees	250 trees
	Rainwater Harvesting Structures	0	0	0	1	2	3	4
	Cover Crops	0.03ha	0.06	0.13ha	0.25ha	0.5ha	0.75ha	1ha
	Mulching	0.03ha	0.06	0.13ha	0.25ha	0.5ha	0.75ha	1ha
	Contour Terracing	13m	25m	50m	100m	200m	300m	400m
	Manure / Compost	0.03ha	0.06ha	0.13ha	0.25ha	0.5ha	0.75ha	1ha
		Loan 1	**Loan 2**	**Loan 3**	**Loan 4**	**Loan 5**	**Loan 6**	**Loan 7**
Non-Contractual Requirements	Improved Varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties
	Integrated Pest Management	Training	Training	Training	Training	Training	Training	Training

Figure 2: Climate-smart credit product for small scale coffee grower conditions, often on steeper slopes with poor soil conservation practices and under rainfed conditions.

(b) CSA-related cost reductions

Research indicates that considerable cost savings can be made by adopting CSA practices, mainly for inorganic fertiliser, a 20-100% reduction; and pesticide applications, a 20-100% reduction. The larger reductions are for speciality coffees where organic certification is required and the use of inorganic fertiliser and pesticides is not permitted. There is considerable scientific argument about the pros and cons of this with indications[1] that some use of inorganic fertiliser and pesticides are necessary to attain sustainable yields[2].

(c) CSA-related risk mitigation

Agricultural research has not yet meaningfully quantified the benefits of CSA in terms of mitigating coffee losses associated with climate-change related weather events. However, near total losses can be expected as a result of either lower (more frost) or higher temperatures (more pests and diseases) and declining soil fertility as growers cut costs when faced with declining profitability. Agronomy suggests CSA benefits exist and whilst we intend to add to this report and the associated models as new research is produced, in order to be conservative, we allow for estimates to be included by way of sensitivity analysis.

Agronomic basis of coffee CSA and land-management requirements

Proposed CSA measures achieve their objectives by: (i) planting improved varieties; (ii) improving soil fertility through reducing the use of inorganic in favour of organic fertilisers; (iii) reducing or eliminating soil erosion by means of contour terraces reinforced by planting grass on them; (iii) planting trees for shade , temperature control and soil erosion prevention; (iv) reducing the use of agrochemicals (as a cost reduction measure); and (v) protecting land alongside streams and riverbanks and areas of high biodiversity.

Precise estimates, together with an explanation of their agronomic basis are explained more fully in the body of this report.

Coffee farmer climate-smart lending gross margin and cost-benefit analysis

As part of our climate-smart credit product design process, we undertake a gross margin and cost benefit analysis from the perspective of the implementing farmer. This is to ascertain that (i) the proposed practices are net beneficial for the farmer to adopt, and (ii) because perceived profitability has been recognised as a key factor in explaining farmers' decisions to adopt or not adopt sustainable land management (SLM) technologies.

Recent studies show that sustainable land practices required under the terms of climate-smart credit products generate considerable benefits for farmers. Using conservative estimates, we project the following gross margins, returns to labour and benefit cost ratios associated with deploying the climate-smart credit product (Table 1):

[1] VAN DER VOSSEN H. A. M.,2005. A Critical Analysis of the Agronomic and Economic Sustainability of Organic Coffee Production. Expl Agric., volume 41, pp. 449–473, Cambridge University Press.
[2] Markus Giger , Hanspeter Liniger, Caspar Sauter, Gudrun Schwilch,. 2015. Economic Benefits and Costs of Sustainable Land Management Technologies: An Analysis of WOCAT's Global Data. Land Degrad. Develop. 29: 962–974 (2018). Published online 7 October 2015 in Wiley Online Library DOI: 10.1002/ldr.2429

Table 1: Climate-smart lending cost benefit ratios

Scenario	Yield per ha at coffee bush maturity (kg per ha)	Gross margin (USD per ha)	Labour required at coffee bush maturity (days per ha)	Returns to labour at coffee bush maturity (USD per ha)	Returns to labour at coffee bush maturity (USD per day)	Benefit/cost ratio
Base Case	700	266	64	426	7	-
Existing coffee plus CSA	1,400	1,099	120	1,398	12	4.2
New coffee plus CSA	1,400	1,416	137	1,258	9	2.2
New coffee plus CSA plus bananas	1,400	1,866	147	2,038	14	3.4
					Discount rate	**10%**

This clearly indicates an increase in overall productivity for the three scenarios over the base case. Replacement of existing coffee bushes remains an important decision for growers due the time taken for new bushes to reach peak yields as demonstrated by the lower benefit cost ratio shown in scenario 2.

The analysis presented is a generalised analysis for coffee production under the terms of a climate-smart credit product. It confirms that under the circumstances and assumptions in this study, a coffee climate-smart credit product should be beneficial to a small scale coffee grower. However, the template sustainable land-management requirements should be adjusted according to context specific agro-climatic and market conditions.

Coffee “lender financial impact model”

A further component of the design of a climate-smart credit product is to build an impact model for the agri-lender offering the climate-smart credit product. The purpose of this exercise is to provide preliminary validation that business-as-usual agricultural loans are less profitable than climate-smart loans which incorporate requirements for climate-smart agricultural and land management practices into loan terms. From assumptions generalised from scientific and agricultural research, we believe that climate-smart lending is likely to have an appreciable effect on the cash position of the agri-lender.

	Loan 1	Loan 2	Loan 3	Loan 4	Loan 5	Loan 6	Loan 7
Yield loss scenario	30%	30%	30%	30%	30%	30%	30%
Number of clients	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Loan book size (US$)	4,998,000	3,931,200	3,931,200	3,931,200	3,931,200	3,931,200	3,931,200
Portfolio loss with no climate-smart lending	**(950,857)**	**(1,600,000)**	**(1,600,000)**	**(1,600,000)**	**(1,600,000)**	**(1,600,000)**	**(1,600,000)**
Portfolio loss with climate-smart lending	**(1,148,350)**	**(793,520)**	**(705,744)**	**(633,927)**	**(574,080)**	**(523,440)**	**(480,034)**
Savings due to CSA practices	(197,493)	806,480	894,256	966,073	1,025,920	1,076,560	1,119,966
Cost of capital w/o climate-smart lending	20%	20%	20%	20%	20%	20%	20%
Cost of capital w climate-smart lending	8%	8%	8%	8%	8%	8%	8%
Annual interest savings (US$)	599,760.00	471,744.00	471,744.00	471,744.00	471,744.00	471,744.00	471,744.00
Cash position improvement with climate-smart-lending (US$)	**402,267**	**1,278,224**	**1,366,000**	**1,437,817**	**1,497,664**	**1,548,304**	**1,591,710**

Table 2: Climate-smart lending lender cash positions

Coffee “environmental cost-benefit analysis”

The final component of the design of a climate-smart credit product is an environmental cost benefit analysis which demonstrates that the terms of a climate-smart credit product creates valuable environmental benefits. We have completed the creation of this template, and run it with some preliminary data to show the benefits of implementing the CSA measures of the climate-smart credit product create a benefit with net present value of USD 30 over 7 years. This is somewhat smaller than expected but we would expect it to increase when run with site specific data.

Contents

2. An introduction to coffee and climate risks to production

2.1. Introduction

Coffee[3] (*Coffea L.*) is one of the world's most widely consumed beverages, supporting a multibillion-dollar industry spanning a lengthy value chain from farmer to consumer. As coffee production is largely in the hands of smallholder farmers, the livelihood value is immense, with an estimated 100 million coffee farmers worldwide. The global coffee trade relies on two species, firstly Arabica (*Coffea arabica*) comprising c. 60% of traded coffee and secondly Robusta (*Coffea coffeephora*), the remaining 40%. Liberica coffee (*Coffea liberica*), a third beverage species, is sometimes used as a grafting rootstock for both Arabica and Robusta but is insignificant in terms of global trade. Arabica coffee grows better at higher altitudes, while Robusta coffee is better suited to warmer, more humid lowland environments.

Coffee is grown commercially and exported by more than 60 developing countries with the major consumers being developed countries, in particular the USA, EU and Japan. Globally, it is the second most traded commodity to oil and plays a key role in the balance of trade between developed and developing countries, providing the latter with an important source of export earnings to pay for imports[4]. Most coffee-growing countries fall into the lower- and middle-income nations of the world, but with at least 20 being classified as least developed.

Coffee growing and its related activities provide a major source of employment in all producing countries providing direct full-time employment for 25 million people worldwide. Taking into account related industrial and service activities (processing, marketing, roasting, and transportation) the figure rises to 100 million people, including their families. World coffee green bean production from both Arabica and Robusta types was 9.5 million tonnes in 2017/18, up from 6.5 million tonnes in 2001/02 and 5.8 million tonnes in 1990/91, an increase of 47% since 1990/91.

The largest ten producers by total yield in 2017 were Brazil producing 29% of the world's coffee, Vietnam-17%, Colombia-8%, Indonesia-7%, Honduras-5%, Ethiopia-5%, Peru-4%, India-3%, and Guatemala-3%.   The ten largest by area were Brazil growing 17% of the total, Indonesia-12%, Cote d'Ivoire-9%, Colombia-7%, Ethiopia-6%, Mexico-6%, Viet Nam-6%, Honduras-5%, and India-4%[5]. Further detail on all producer areas and yields of coffee is provided in Annex 1.

98% of coffee exports come from 15 countries (Table 2) with Brazil and Vietnam contributing nearly 50%[6].

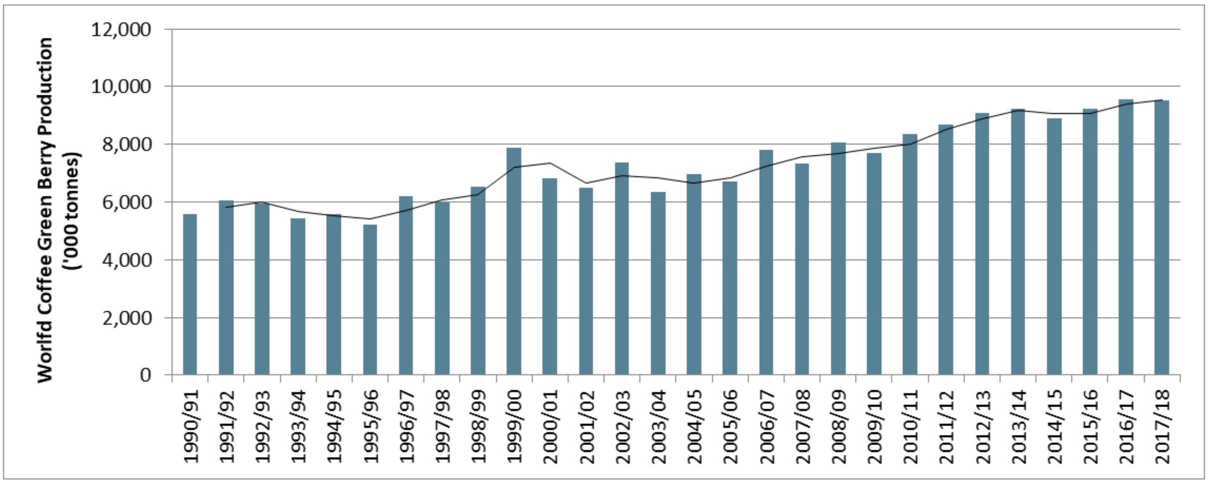
[3] Aaron P. Davis1,*, Helen Chadburn1, Justin Moat1,2, Robert O'Sullivan1,3, Serene Hargreaves1 and Eimear Nic Lughadha1, 2019. High extinction risk for wild coffee species and implications for coffee sector sustainability. Science Advances 16 Jan 2019:, Vol. 5, no. 1, eaav3473. DOI: 10.1126/sciadv.aav3473.

[4] ICO, 2018. Global Coffee trade. International Coffee Organisation Downloaded from http://advances.sciencemag.org/ on January 18, 2019 http://www.ico.org/new_historical.asp?section=Statistics accessed 5th January 2019

[5] FAOSTAT, 2018. Statistical data base. Food and Agriculture Organisation of the United Nations, Rome, Italy. http://www.fao.org/faostat/en/#data/PP/ accessed 30th December 2018

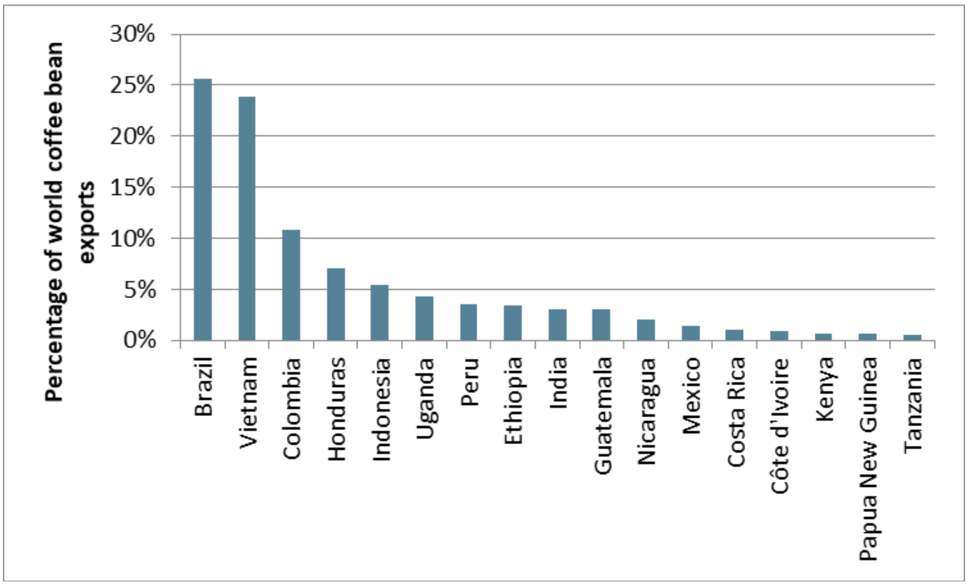
[6] ICO, 2018. Global Coffee trade. International Coffee Organisation. http://www.ico.org/sustaindev_e.asp

Table 3: World coffee green bean production (1990/91 to 2017/18) [7]



98% of coffee exports come from 15 countries with Brazil and Vietnam contributing nearly 50%

Table 4: Percentage of world coffee exports by the main country exporters8



Production in the three major growing regions by area and yield is shown in Table 5with average yields being greatest in Asia and lowest in sub Saharan Africa. Although the average was 0.73 tonnes per ha, this ranged from 0.03 tonnes per ha to nearly four tonnes per ha as detailed in Annex 1.

[7] ICO, 2018. Global Coffee trade. International Coffee Organisation. http://www.ico.org/sustaindev_e.asp
[8] ibid

Table 5: Coffee production by Region, area and yield[9]

Region	By Area	By yield	Av yield t/ha
Asia	25%	32%	0.98
Central/Latin America	48%	55%	0.7
Sub Saharan Africa	27%	13%	0.59
	100%	**100%**	**0.73**

The top ten producers, by area, in Sub Saharan Africa in 2017 were Cote d'Ivoire-9%, Ethiopia-6%, Uganda-4%, Tanzania-2%, Kenya-1%, Cameroon-1%, Madagascar-1%, Democratic Republic of the Congo-1%, Togo-1%, Angola-0.3%.

2.2. Climate risks to coffee production

Although weather variability has always been a major factor in the fluctuations of coffee yield and quality, climate change now poses a serious threat to the long-term sustainability of coffee as a global commodity crop[10]. Threats posed include: changing rainfall patterns both between and within seasons including; droughts; an increase in extreme weather events including hail storms, high intensity rainfall, floods and landslides as well as increased and more variable temperatures. As a result growers are likely to experience declining productivity and reduced income. Small scale growers (SSGs) will experience increased vulnerability through food insecurity caused by reduced yields not only of coffee but also of other primarily food crops on which they may depend.

Coffee eco-systems are highly vulnerable to rising temperatures and unstable and extreme weather conditions and at the same time limited knowledge about effective adaptation approaches is presently reaching farmers.

Specific risks[11] include:

- **Declining yields** caused by higher temperatures, unseasonal or reduced rain during flowering or fruit setting. Unseasonal rainfall during harvest will also complicate the sun drying of coffee adversely affecting quality and therefore price.
- **Increased soil erosion** due to higher and more intense rainfall and stronger winds leading to both reduced soil capacity to hold water and declining soil fertility. This is of particular importance in drier areas, particularly when coupled with rising temperatures.
- **Reduced soil moisture** due to increased evaporation will make the coffee bush further susceptible to drought conditions. Lack of water during the critical stages of fruit development also brings about a high risk of black beans, small beans and other defects, as well as increased incidence of pests such as coffee berry borer.
- **Increased susceptibility to diseases, pests and drought,** as temperatures rise and extreme weather grows more frequent. Incidence of coffee berry borer, leaf miner, nematodes, coffee rust and others may increase as temperatures rise. The consequent need for control will make production both more complicated and expensive. This means yield and quality will both fall.

The coffee berry borer (*Hypothenemus hampei*), the most important pest of coffee worldwide, has already benefited from the temperature rise in East Africa resulting in increased damage to coffee

[9] Ibid
[10] Ibid
[11] International Trade Centre (ITC), 2011. Possible Effects of Climate Change on Coffee Production. The Coffee Exporter's Guide. – [3rd ed.], Geneva: ITC, 2011. xvi, 247 p.

crops and expansion in its distribution range have been reported. This is forecast to worsen in the current Arabica producing areas of Ethiopia, the Ugandan part of the Lake Victoria and Mt. Elgon regions, Mt. Kenya and the Kenyan side of Mt. Elgon, and most of Rwanda and Burundi[12].

In Latin America, coffee rust disease caused by the fungus, *Hemileia vastatrix* seriously affected a number of countries: Colombia, 2008-2011; Central America and Mexico, 2012–13; and Peru and Ecuador in 2013. The main drivers have been both economic and meteorological, with disease outbreaks resulting from low profitability, either low prices or high input costs resulting in suboptimal coffee management and hence increased plant vulnerability. However, a contributing factor in more recent Colombian and Central American epidemics has been higher minimum and lower maximum temperatures. This is considered as a warning for the future, as the disease was enhanced by weather conditions consistent with climate change[13].

Lower yields and poorer quality coffee will impact on SSG livelihoods. Severe weather shocks, especially when combined with poverty, may force farmers out of coffee altogether and contribute to human migration. In zones favourable for growing coffee in Latin America, a production drop by nearly 90 percent is possible by 2050, with high-quality Arabica coffee being most at risk. Arabica, being less able to withstand slight fluctuations in temperature, humidity or sunlight is more at risk than Robusta. Areas currently better suited for Arabica are predicted to migrate upwards in elevation as growers seek more suitable agro-climatic conditions.[14]

Several adaptation and mitigation strategies for coffee growers are being proposed in response to the challenges facing the sector. These include farmer capacity-building, developing drought and disease-resistant varieties, improved farming practices notably: enhancing soil fertility, improving disease and pest control and better post-harvest processing. In more extreme cases, the solution may be to diversify out of coffee or shift production to more suitable areas. However, it should be noted that coffee, as an evergreen bush, can be an important contributor to carbon sequestration and soil stabilisation. Grown under the right circumstance it can permit the preservation of much of the original biodiversity in planted areas as well as being an important contributor to grower livelihoods.

At the same time wild coffee species are critical for development for new varieties and, thus, for the sustainability of global coffee production. Unfortunately, wild coffee species are extinction sensitive, especially in this era of accelerated climatic change. A recent study[15] found that at least 60% of all coffee species are threatened with extinction.

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[12] Juliana Jaramillo Eric Muchugu , Fernando E. Vega, Aaron Davis,Christian Borgemeister, and Adenirin Chabi-Olay, 2011. Some Like It Hot: The Influence and Implications of Climate Change on Coffee Berry Borer (Hypothenemus hampei) and Coffee Production in East Africa. Published- September 14, 2011. https://doi.org/10.1371/journal.pone.0024528

[13] Jacques Avelino, Marco Cristancho, Selena Georgiou, Pablo Imbach, Lorena Aguilar, Gustavo Bornemann, Peter Läderach, Francisco Anzueto, Allan J. Hruska, Carmen Morales. 2015. The coffee rust crises in Colombia and Central America (2008–2013): impacts, plausible causes and proposed solutions. Food Security, April 2015, Volume 7, Issue 2, pp 303–321.

[14] ibid

[15] Aaron P. Davis1,*, Helen Chadburn1, Justin Moat1,2, Robert O'Sullivan1,3, Serene Hargreaves1 and Eimear Nic Lughadha1, 2019. High extinction risk for wild coffee species and implications for coffee sector sustainability. Science Advances 16 Jan 2019:, Vol. 5, no. 1, eaav3473. DOI: 10.1126/sciadv.aav3473 Downloaded from http://advances.sciencemag.org/ on January 18, 2019.

3. CSA COFFEE AND LAND MANAGEMENT REQUIREMENTS

The purpose of this section is to propose a climate-resilient and sustainable land management system appropriate for implementation by smallholder coffee producers, based on climate-smart and sustainable land-management practices. This section provides: (i) context, (ii) the recommended CSA measures, and (iii) implementation detail.

3.1. Coffee production[16]

The following section is an overview of the agro-climatic and production factors relevant to coffee. This is provided as a general background for the non-specialist reader, in order to better understand the context for climate-smart coffee production practices.

Coffee is a tropical plant which grows between the latitudes of 25 degrees N and 25 degrees S of the equator, requiring specific agro-climatic conditions for commercial cultivation. Temperature, rainfall, sunlight, wind and soils are important, with requirements varying between the different varieties grown. It is a tree or bush, which can survive for up to 70 years with the first flowers appearing during the third year and production becoming profitable from the fourth or fifth year onwards. Two species of coffee dominate world trade - Arabica representing about 60% of production and Robusta the remaining 40%.

Agro-climatic conditions: Ideal average temperatures range from 15-24C for Arabica coffee and 24-30C for Robusta, which is better adapted to warmer, drier conditions, but cannot tolerate temperatures much below 15C, while Arabica can for short periods. Both types are easily damaged by frost, particularly a danger in southern Brazil and closer to the Equator at altitudes over 2,000 metres. Robusta can be grown between sea level and about 800 metres, while Arabica does best at higher altitude and is often grown in hilly areas. As altitude relates to temperature, Arabica can be grown at lower levels further from the Equator, until limited by frost. Both types require an annual rainfall of 1,500-3,000 mm depending on soil type, humidity and cloud cover. The pattern of rain and dry periods is important for growth, budding and flowering. All coffee needs good drainage, but can grow on soils of different depths, pH and mineral content, given suitable soil fertility status. In drier areas the crop can benefit from irrigation.

Coffee productivity[17] is often limited by the age of the bushes, use of old or traditional varieties, poor management practices and neglected soil fertility management, exacerbated by climate change. Although improving existing coffee will lead to improved yields, establishment of new coffee with improved varieties will ensure more uniform and better yields on a more sustainable basis, more especially when existing coffee is heavily infested with pests or diseases. Growers should endeavour to plant more than a single variety as a risk management strategy, in case one develops susceptibility to a pest, disease or environmental stress.

Propagation: Coffee can be propagated by seed, vegetatively using clonal cuttings, grafting or tissue culture. Planting new varieties will lead to higher yields, better quality with resistance or tolerance to drought and pests and diseases[18]. Planting material should always be obtained from reliable registered seed producers or nurseries with cuttings taken from selected mother plants with the desired characteristics.

[16] FAO, 2018. http://www.fao.org/docrep/003/x6939e/X6939e06.htm
[17] FiBL, 2017. African Organic Agriculture Training Manual. A Resource Manual for Trainers. Module 09 Crops: Unit 13 Coffee Research Institute of Organic Agriculture, Switzerland, www.fibl.org.
[18] Silas Brasileiro, 2017. Brazilian Coffee Production: Overcoming the Challenges of Sustainability. 7th Consultative Forum on Coffee Sector Finance, 27 September2017. Conselho Nacional Do Café. www.cncafe.com.br

Coffee seedlings raised from cuttings will bear fruits 24-36 months after transplanting, whereas plants grown from seed bear fruit commonly only after 36 months. Propagation by grafting or tissue culture requires specially trained personnel and consequently is less easily available to SSGs.

Field production: Both Arabica and Robusta require constant application of nutrients for both quality and quantity with nutrients removed from the soil, through harvested biomass, must be replenished from external sources. Poor soil fertility often limits production in most cases, with N, P, K and Mg being the nutrients most commonly limiting. Arguments about fertiliser are often strongly polarised with claims that the best way to increase yields is to use large quantities of inorganic fertiliser and that promotion of the use of organic fertilisers will condemn farmers to continuing low yields. Opponents of this view regard inorganic fertilisers as harmful and can trap farmers in high-cost production systems. Although there can be truth in both arguments, exclusive use of inorganic fertiliser is often associated with long-term yield decline. Ideally soil samples should be taken and analysed at a reputable laboratory. However, where this is not available a blanket recommendation is often given.

Coffee is attacked by a wide range of diseases and pests, with protection being required. Most of the important coffee diseases are caused by fungus, including, coffee wilt disease, coffee leaf rust, coffee berry disease, coffee bark disease and brown eye spot. Effective management starts with the choice of suitable varieties for local conditions. Good management practices will enhance the ability of the coffee to tolerate and limit infection. Both nursery and field plants are often protected by spraying with a fungicide.

Harvesting: Coffee berries ripen over several months, going from green-yellow-red and finally almost black, the ideal time picking time being when the berries are red.

Berries are ready for harvesting 8-9 months after flowering and can be harvested by

- Handpicking, the most labour intensive but giving the best results. Ripe cherries are picked by throughout the year as many times as necessary.
- Stripping by removing everything on the branch by hand: ripe cherries, flowers, unripe cherries, and black, over-ripe ones. This method produces poor results, but is nevertheless practised in some countries, leaving leaves and green cherries intact on the tree.
- Using mechanical vibrators fixed to the tree trunks, which cause the ripe fruit to fall to the ground, or tractors with rotating brushes, which can damage the trees by stripping off the flowers and leaves as well.

Sorting and cleaning: Harvested cherries are sorted and cleaned to separate unripe, overripe and damaged cherries and remove dirt, soil, twigs and leaves.

Primary processing: Ripe cherries go through a number of operations aimed at extracting the beans from their covering of pulp, mucilage, parchment and film to improve their appearance. Removing beans from the cherry can be done either by a dry or wet method the latter beings more expensive, but the resulting coffee is usually of better quality. When the process is complete, unroasted beans are sold as green coffee beans. This can be by either a dry or a wet method.

Dry Method: The dry method is the oldest, simplest and requires little machinery. It is used for much of the Arabica produced in Brazil, most of the coffees produced in Ethiopia, Haiti and Paraguay, as well as for some Arabicas in India and Ecuador. Almost all Robustas are processed by this method. However, it is not practical in rainy regions, where the humidity is high or where it rains frequently during harvesting. It involves drying the whole cherry, sorting and cleaning, drying and then hulling.

Cherries are spread to dry in the sun on large concrete or brick patios or on mats raised to waist height wire mesh tables. As the cherries dry, they are raked or turned by hand to ensure even drying. This may take up to four weeks before reaching an optimum 11% moisture content. Machine drying can be used to speed the process. Dried cherries are then stored in bags or special silos, until they are sent for hulling, sorting, grading and bagging. During hulling the outer layers of the dried cherry are removed by the hulling machine.

Wet Method: The wet method is used for most Arabica coffees other than the cases mentioned earlier, and rarely for Robusta. It requires specific equipment and substantial quantities of water. The coffee produced is usually of better quality and commands higher prices. Three basic steps are involved - sorting and cleaning, pulping, fermenting, drying and hulling.

- Sorting and cleaning is undertaken soon after harvesting, usually by washing the cherries in tanks filled with flowing water. Screens may be used to improve the separation between the ripe and unripe, large and small, cherries.
- Pulping involves removal of the pulp of the fruit being separated from the beans before drying. It is undertaken soon after harvest to avoid any deterioration of the fruit. Because pulping is done by mechanical means, it normally leaves some residual flesh and a sticky mucilage adhering to the parchment surrounding the beans.
- Fermentation of newly pulped beans in large fermentation tanks allows the mucilage to be broken down by natural enzymes and then washed away. For most coffees fermentation takes 24-36 hours, depending on temperature, thickness of the mucilage layer and concentration of the enzymes. When the fermentation is complete, the coffee is thoroughly washed with clean water in tanks or in special washing machines.
- Drying to reduce the moisture to 11%, undertaken either in the sun or in a mechanical dryer, or a combination of the two. Sun drying takes from 8 to 10 days, depending upon temperature and humidity. The process requires carefully control to achieve satisfactory and economic drying without damage to quality. After drying, the wet-processed coffee, or parchment coffee, is stored until hulling.

Hulling, secondary processing, grading and storage: This is undertaken to remove the parchment common to both wet and dry-processed coffee. After which the coffee is cleaned and dried, sorted and graded by size, shape and colour to uniform density to meet international standards. The coffee is then sold.

Blending and roasting: This usually undertaken in importing countries, often because domestic consumption is very low. For instance, in Uganda less than 5% of total annual production is consumed locally.

3.2. Coffee value chain

The coffee value chain involves thousands of companies around the world, including agri-input manufacturer and supply organisations, producers, primary processors, graders, auction houses, traders, secondary processors, wholesalers, and retailers through to coffee shops and restaurants.

The role of small scale growers (SSGs) is often restricted to the start of the chain, when they deliver coffee beans for either wet or dry primary processing. Large farms, estates and cooperatives often undertake this themselves, or state-owned institutions may have been established for this purpose. Most value is added from point of sale either to auction houses or intermediaries or bulkers through to secondary processing and marketing activities, which have the capacity to invest in the capital-intensive technologies needed to further process coffee green beans. A typical coffee value chain is shown in Table 6, with Government often the Ministry of Agriculture or a state body being responsible for policy and the regulatory requirements for creating an enabling environment.

Table 6: Typical coffee value chain

Improved varieties, land management & agronomic practices	Agri-Input acquisition & production advice	Coffee bean production & initial processing (Arabica & Robusta)	Transport and green bean marketing	Processing (Domestic & international)	Marketing and consumption
− Researchers	**Production advice** − Extension agents (Govt & NGO) − Grower Associations − Cooperatives − Other farmers **Machinery and implements suppliers** **Coffee seed production** − Research stations − Seed producers − Farmers **Fertilisers / pesticides** − Agri-input producers − Agro-dealers − Coops **Production credit** − Buyer credit − Micro-finance institutions, NGOs, Coops − Banks, Agri-banks	**Bean production** − Large Scale Farmers − Small scale growers − Community companies − Cooperatives **Initial processing (wet or dry)** − Farmers − Cooperatives − Traders / bulkers − Processing companies − State enterprises	**Transport** − Transporters − Farmers' cooperative − Intermediaries / Bulkers **Bean marketing** − Graders − Auction houses − Buyers, local & international − National sellers **Exporters** − International traders	**Roasting companies** − Roasting − Cooling − Blending − Grinding − Packaging	− Wholesalers − Supermarkets − Small retailers − Coffee shops − Bars and restaurants − Consumers

3.3. SSG Coffee Production

SSGs are usually regarded as those growing typically a few trees up to five ha of coffee with or more often without irrigation. However, most smallholder farmers in regions where coffee is grown work with less than 2 ha of land, especially in SSA. For instance, in Uganda the average coffee farm or garden is 0.18 ha[19]. SSGs often grow a number of different crops, with coffee being the most important cash crop. Other crops are often for home consumption. Other SSG models include farmer groups, cooperatives or community owned companies producing larger areas of coffee typically 30-100 ha, possibly with an employed manager. Farmers in a group or cooperative can share machinery for pulping and milling, as well as storage space.

Marketing: Many coffee companies have well established supply chains directly linked to farmer groups or cooperatives. Under such schemes, some companies manage the entire system from advisory services, procurement, processing to final marketing and in some cases certification. In addition to such schemes, independent farmers and groups also contribute a significant amount of coffee. Most coffee is exported to coffee consuming countries where speciality or certified coffee may be in high demand. Certification comes with costs, which will be profitable if there is a market that demands certified coffee. To reduce certification costs, individual farmers may either join an existing certification scheme or organise themselves into a new group, especially during postharvest handling.

[19]UCDA, undated. Coffee Fact Sheet Uganda Coffee Development Authority, Coffee House, Plot 35 Jinja Road, 7267,Kampala, Uganda. https://ugandacoffee.go.ug/fact-sheet

Typical costs associated with key stages of the value chain are production, processing, and marketing, before roasting marketing and consumption have estimated as follows[20].

- **Production (74%)**
- Plant production in the nursery and planting (25%)
- Maintenance of coffee bushes including fertiliser, weeding, disease and pest control (45%)
- Harvesting (15%)
- Transport to a washing or depulping centre (10%)
- **Wet processing 13%**
- Depulping, washing and fermentation (48%)
- Drying and sorting of parchment (28%)
- Maintenance of infrastructure (12%)
- Storage and transport to dry mill (12%)
- **Dry milling and marketing (10%)**
- Deparching, grading and polishing (60%)
- Hand sorting of green coffee (33%)
- Warehousing and transport to dry mill
- Sales costs include marketing auction, storage, communication, quality control and regulation, port and shipping fees and documentation (7%)

Coffee grower selling prices are usually quoted as green coffee sales costs

International coffee organisations: The International Coffee Organization[21] (ICO) is the main intergovernmental organisation for coffee, bringing together exporting and importing Governments to tackle challenges facing the world coffee sector through international cooperation. The ICO was established under the auspices of the United Nations to administer an International Coffee Agreement. The ICO's mission is to strengthen the global coffee sector and promote its expansion in a market-based environment for the betterment of all participants in the coffee sector. It does this through encouraging sustainable development and poverty reduction in producing countries through projects in coffee producing countries. Particularly important are food safety practices throughout the coffee chain, addressing both the concerns of producing countries in building capacity, and consumer health concerns of regulatory bodies. For instance action against pests and diseases are important to protect the economies of producing countries and the livelihoods of farming populations and to protect quality. Food safety practices and consumer health concerns are addressed through establishing basic quality standards to prevent the presence of contaminants in shipments and to make it attractive to both retailers and consumers. Phytosanitary issues are regularly reviewed including moisture levels, grading and pesticide residue levels in green coffee.

World Coffee Research (WCR)[22] is a non-profit research and development organisation with participation from 30 coffee industry groups including many Importers, exporters and processors. WCR recognises that the livelihoods of coffee farmers and the businesses that rely on these farmers

[20] https://worldcoffeeresearch.org/
[21] http://www.ico.org/profiles_e.asp
[22] https://worldcoffeeresearch.org/

to grow high quality coffee are urgently threatened by climate change, low yields, diseases and pests. As such it funds research to meet these challenges.

3.4. Climate smart agriculture practices for Small Scale Growers

Climate-smart agriculture (CSA) contributes to the achievement of sustainable development goals[23], through integrating three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is an approach that requires site-specific assessments to identify suitable agricultural production technologies and practices.

Table 9 following summarises the main climate change threats to sustainable coffee production, the impact it is likely to have and suitable mitigation strategies. These include the need to establish: (i) new varieties adapted to drier conditions with resistance to pests and diseases, (ii) integrated soil fertility management (ISFM), through use of composts and manures, mulches and cover crops integrated where necessary with the use of inorganic fertilisers, (iii) soil and water conservation (SWC) measures using contour barriers or terracing especially on steeper slopes combined with rainwater harvesting techniques and improved irrigation, when available, (iv) agroforestry involving the planting of trees and hedges to mitigate sun, wind and water damage, improve soil fertility, and intercropping with bananas or other crops where appropriate, (v) integrated pest and disease management, through improved scouting and biological control methods and (vi) protection of areas of high biodiversity.

Table 7: Climate change threats, impact and mitigation strategies

Climate change threats	Impact	Mitigation strategies
– Changing rainfall patterns between and within seasons – Increase in droughts between and within seasons – Increase in extreme weather events (hail storms, high intensity rainfall, floods, and landslides – Increased and more variable temperatures	– Reduced quality and yields – Increased soil erosion and soil fertility loss – Reduced soil moisture availability – Arrival or increase in pests and diseases not previously experienced – Sun damage decreasing quality – Increased risk of damage by frosts – Declining suitability for growing coffee and consequential move to more suitable areas – Biodiversity loss	– New varieties – Integrated soil fertility management – Soil and water conservation – Agroforestry – Integrated pest management – Protection of areas of high biodiversity

An initiative for coffee and climate was launched in 2010 to address the challenges that changing climatic conditions pose to the coffee value chain[24]. This focused its efforts on testing, consolidating and promoting the best climate adaptation and mitigation techniques for smallholder coffee farmers. These are being documented as a toolbox[25], launched initially in 2013 and relaunched in 2018 with updated information and tool descriptions. Selected practices are based on their relation to climate resilience, base of evidence and feasibility to implement. Many have been field tested and/or reviewed by a board of scientists and coffee experts. These mitigation practices supplemented with further information from referenced sources are identified in Table 8 and detailed in the sections that follow.

[23] FAO, 2013. Climate Smart Agriculture Sourcebook. ISBN 978-92-5-107720-7 (print), E-ISBN 978-92-5-107721-4 (PDF). www.fao.org/climatechange/climatesmart
[24] Hanns R. Neumann Foundation, Am Sandtorpark 420457 Hamburg, Germany https://www.hrnstiftung.org/about-us/
[25] Coffee and Climate toolbox. http://toolbox.coffeeandclimate.org/

Table 8: CSA practices for coffee production

CSA practice	
Developing new varieties	– Improved varietal selection for drought and disease resistance – Grafting Arabica onto Robusta root stock – Using deeper polybags for seedling growth – Adding mycorrhizae to soil used for seedlings
Improving soil fertility	– Integrated soil fertility management (ISFM) – Use of composts and manures in addition to or replacing inorganic fertilizers – Mulches and cover crops – coordinated with inorganic fertiliser use as required
Soil and water conservation	– Terracing/contouring, drainage and trapping/storing run-off rain water in a coordinated system of micro-watershed management – Growing grass on terraces and cover crops between coffee bushes – Mulching to reduce evaporation, avoid erosion and improve soil fertility – More effective irrigation and water resources management
Agroforestry	– Appropriate coffee field spacing – Planting trees and hedges to mitigate wind damage, increased solar brilliance, reduce temperature variations, reduce soil erosion and retain soil moisture and improve soil fertility – Introduce coffee-banana systems where appropriate
Integrated pest and disease management	– Improved scouting of pests and diseases – Use of multiple pest and disease management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment
Protecting areas of high biodiversity	– The protection of water resources, where springs are protected to maintain the flow of water during the dry season, preservation of local biodiversity facilitating a greater movement of both fauna and flora; and creating or protecting ecological corridors
Processing	– Reduce water usage with eco-friendly pulpers – Improve wastewater management and disposal – Make effective use of all compostable materials – Use solar energy, i.e. sun drying where feasible – Use renewable energy sources for mechanical drying – Make better use of dry milling by-products (fuel, charcoal briquettes, board)

3.5. Developing new varieties

- **Varietal Selection for drought and disease resistance:** Although coffee varieties were not bred specifically for their resilience to specific climate hazards, research studies have shown that coffee varieties can display a range of responses to drought and disease. Research is increasingly focusing on these traits and with new varieties becoming available, growers should seek to plant those recommended for their location. Coffee can be propagated by seed, vegetatively using clonal cuttings, grafting or tissue culture. Planting new hybrid varieties can lead to higher yields, better quality with tolerance to drought and resistance to pests and diseases[26]. Planting material should always be obtained from reliable / registered seed producers or nurseries with cuttings obtained from selected mother plants with the desired characteristics. Growers should plant different varieties in case one develops susceptibility to a pest, disease or environmental stress, as a risk management strategy to ensure the whole farm is not affected. Coffee seedlings raised from cuttings will bear fruits 24-36 months after transplanting, whereas plants grown from seed bear fruit commonly only after 36 months. Propagation by grafting or tissue culture requires specially trained personnel and consequently is less easily available by SSGs.
- **Grafting Arabica Scion onto Robusta Rootstock:** Some Robusta varieties have deeper and more vigorous roots than Arabica varieties. By grafting the latter onto the former, resistance to drought for Arabica may be enhanced. With a skilled operative, each graft costs about USD 0.03.
- **Use of deeper polybags to grow seedlings:** Polybags are used to grow seedlings for typically 6-8 months prior to planting out. They vary in size but are rarely more than 20 cm deep. In conditions where rain is scarce or unreliable, using deeper polybags (25 cm) has resulted in seedlings with more developed root systems that are better able to survive an extreme drought event once planted in the field. The commercial price of producing seedlings in deeper polybags is USD 0.30 compared with the conventional seedling of USD 0.12.
- **Adding mycorrhizae to soil used for seedlings:** Supporting good root structure in seedlings is increasingly relevant as replanting of new varieties becomes more common. Adding mycorrhizae to the soil used for seedlings in the polybags for both coffee and shade trees can improve root nutrition. Mycorrhizal fungi feeds on the substances that the roots exude, and in return produces nutrients that help the plant grow. This is especially relevant for degraded soils, particularly those affected by drought, where natural mycorrhizae may be missing or scarce. Also, where mycorrhizae are well established, the amount of fertilizer applied may be able to be reduced. Where available, dosage cost is typically a few US cents per plant.

3.6. Improving soil fertility

- **Integrated soil fertility management (ISFM):** Both Arabica and Robusta require constant application of nutrients for both quality and quantity. ISFM requires an increase in soil organic matter content with organic nutrient being sourced from legumes, green manure cover crops, crop residues, mulches, manure and urine, composts and household waste. At the same time it is recognised that in intensive cropping systems, recycling and re-using nutrients from organic sources, may be insufficient to sustain high crop yields, especially where micronutrient deficiencies are common. Nutrients removed from the soil, through harvested biomass, must be replenished from external sources. Thus, in many situations the use of inorganic fertiliser is an essential component of ISFM. In this situation, targeted minimal use of inorganic fertiliser will be necessary to obtain high yields. Hence, ISFM requires an assessment of each situation in agronomic, socio-economic and ecological terms to determine the appropriate mix of

[26] Silas Brasileiro, 2017. Brazilian Coffee Production: Overcoming the Challenges of Sustainability. 7th Consultative Forum on Coffee Sector Finance, 27 September2017. Conselho Nacional Do Café. www.cncafe.com.br

nutrients27. For instance, the Uganda Coffee Development Authority[28] (UCDA) recommend an annual application of a compound fertiliser, 562 kg per ha for Robusta and 750 kg per ha for Arabica as well as 10 kg of manure per tree every other year. Typical recommended fertiliser rates[29] for Arabica and Robusta in Sub Saharan Africa (SSA) show increasing requirement up to the third year, but reducing thereafter (Table 11).

Table 9: Recommended fertiliser application rates for coffee in SSA (kg per ha)

Coffee type	Year	Urea	Triple Super Phosphate (TSP)	Muriate of Potash (MOP)	Total
Arabica	Y1	125	38	100	263
	Y2	250	75	200	525
	Y3	375	113	300	788
	Y4	400	115	600	1115
	Y5	250	60	400	710
Robusta	Y1	250	75	200	525
	Y2	500	150	400	1050
	Y3	750	225	600	1575
	Y4	550	150	850	1550
	Y5	300	100	500	900

It should be noted that conservation agriculture (CA) practices do not directly apply to coffee since it is a perennial crop. However, since most coffee smallholders also grow other crops, CA, which includes many practices used in ISFM, can be encouraged to make their other cropping systems more climate resilient.

- **Mulching:** For the first 2-3 years it is important to protect soils from extreme temperatures until the trees grow to a size where roots are more established and self-shading limits high soil temperatures. However, it can be challenging to provide a thick layer of mulch that lasts through a long dry season. Some farmers bring in material from outside the farm but this can be costly. However both cover crops and grasses can be grown in situ. Brachiaria which has vigorous root systems can help to penetrate compacted soils, increase rainwater infiltration and increase soil organic matter when their roots break down. They can be planted on terraces / contours, cut and then used for mulching.

- **Cover crops:** This refers to a wide range of plants that can be sown to cover bare ground to reduce the rate of soil erosion and nutrient leaching. In the case of coffee, this is to cover the soil between coffee rows. On many coffee farms, management practices involve rigorous weeding between rows to reduce competition for soil nutrients. However, the resulting bare soil tends to lead to high rates of soil erosion and, where shade is not dense, high soil temperatures. Use of cover crops quickly reduces soil erosion to very low levels. Use of leguminous ones will add nitrogen to the soil to the benefit of the coffee plant. Cover crops that can be grown include Mucuna, Cajanus, lablab and Crotalaria Juncea, all of which can be grown and then cut to mulch the ground adjacent to the rows of coffee. This also helps in weed control. However careful management is required to ensure that growth of the cover crop is not too vigorous to compete with the coffee. If well managed, cover crops can achieve multiple wins - reduced erosion, lowered soil temperatures and evaporation and increased infiltration and soil organic matter.

[27] Conway, 2012.
[28] UCDA, undated. Coffee Fact Sheet Uganda Coffee Development Authority, Coffee House, Plot 35 Jinja Road, Kampala, Uganda. https://ugandacoffee.go.ug/fact-sheet
[29] Wairegi, L.W.I., van Asten, P.J.A., Giller, K.E. & Fairhurst, T. (2016) Banana–coffee system cropping guide. Africa Soil Health Consortium, Nairobi.

After initial costs of planting, on-going maintenance costs are similar or lower than those of weeding operations. Field tests suggest that yields improve under cover crops hence it is expected that any extra costs will be more than compensated.

3.7. Soil and water conservation

- Contour barriers/terraces in a system of micro-watershed management: Soil and water conservation forms an essential component of coffee production, especially on steeper slopes, where coffee is often grown. Creating barriers – with vegetation, earth or manmade drop structures on steep slopes can slow down water flow and both help to reduce erosion and improve infiltration. Alternatives include:

  - Stone and/or vegetative barriers placed or planted across slopes to reduce flow velocity across open ground. This can lead to the establishment of terraces. Typically, they should be 25 metres apart, but closer on steep slopes and wider apart on gentler ones.

  - Shallow, broad and vegetated channels designed to store or convey runoff. They can also be designed to promote infiltration where soil and groundwater conditions allow.

  - Banks of vegetation such as *Brachiaria*, vetiver or lemongrass across steep slopes will also tend to slow water flow and reduce erosion and likelihood of flooding. These will also work to increase infiltration and reduce runoff. The grass will help in collecting soil and organic matter aiding the formation of terrace-like structures. They can also be used for mulching the coffee.

  - Where gullies have already formed, further erosion can be slowed by lining them with stones, which will absorb the impact of falling water and reduce flow velocity.

  - Rainwater harvesting building barriers such as drop structures and check dams placed in streams on steep slopes will reduce water velocity. Ideally, these would then channel the excess water into holding ponds or infiltration zones where the water can seep into ground to recharge ground water. Other ways to control rainwater in order to reduce run-off and encourage infiltration include small in-field soil depressions or rainwater basins (typically 0.6m x 0.6m x 0.3m deep). These create depressions or undulations within the field itself so that the water is held temporarily to give the water time to infiltrate into the soil where it helps to recharge moisture in the lower horizons of the soil which can subsequently be taken up by the plants. These basins can be constructed around the coffee stem, so that the tree grows in a basin. Alternatively micro-basins can be made between the coffee rows to minimize damage to coffee roots.

    If well executed, these methods can be developed into a water management system that can address both problems of too much and too little water. Ideally it requires adjoining farmers to coordinate the planning of their layouts by means of a micro-watershed plan.

    Many of these SWC measures have a high labour requirement in the early stages, but considerably less for planting vegetative barriers.

  - **Saving Irrigation Water:** Insufficient rainfall is a challenge for coffee production, especially in drier areas. Those farmers receiving free supplies of water often apply too much, but through training water use can be reduced, whilst maintaining or increasing yield through better irrigation scheduling. This can save a significant amount of labour and fuel to apply the water.

  - **Coffee Field Spacing:** Climate change requires rethinking tree spacing configurations to provide adequate mulching material to protect coffee roots and surrounding soil through long hot dry seasons. Wider between-row spacing should be considered when replanting.

Since young trees (< 2 years) are exposed to a long dry season tree mortality can be high, it becomes important that shade trees are planted in advance of coffee seedlings.

3.8. Agroforestry

For windbreaks, shade and erosion protection: High winds can physically damage branches especially when they are laden with ripening berries, or create cool wet conditions that can chill the leaves and encourage pest attack. They can also provide wood, mulching material, fruit or fodder and firewood. Normally they are formed from one or two rows of trees.

Species commonly used[30] include**:** *Albizia coriaria, Grevillea robusta, Casuarina spp., Cordia africana Erythrina, Pinus patula* and Mesiopsis eminii , and *Leucaena leucocephala*. The best species to plant will depend on suitability for the location, soil type, height, and other desired uses apart from wind protection. On small plots it may be sufficient to position them at one or more borders. In larger fields banks within the field will be required. Considerations of the appropriate trees to us include:

- Trees with umbrella shaped canopies provide better shade, protecting against excessive temperatures and heat stress that can cause flower and fruit abortion.
- Deep rooted shade trees recover soil nutrients from deeper soil horizons and transport them to their leaves. When the leaves fall and rot, they provide organic matter or manure which is released to the coffee. This organic matter improves the soil texture and water retention thus availing the much needed water to the coffee. Besides, deep rooted trees don't compete with the coffee for water and other nutrients.
- Leguminous shade trees capture nitrogen from the atmosphere making it available to the coffee.
- Some trees will repel dangerous pests.

It can take many years to develop a good windbreak, so temporary windbreaks are often grown, especially to protect young coffee trees. Temporary trees or bush species can be progressively removed as the coffee trees grow. Species commonly used for temporary windbreaks include: *Cajanus cajan, Crotalaria* spp, *Flemingia contesta, Sesbania* and *Tephrosia spp.*

Costs: Low – purchase of seedlings/saplings and a few days labour, but young trees may grow slowly or suffer high mortality. A tall bank of trees may cause enough shade to cause some reduction in flowering. Too much protection in areas that normally have very low wind speeds, can lead to high humidity which may favour the development of fungal diseases.

3.9. Coffee- Banana inter- cropping system[31].

Bananas and coffee can grow well together. However, optimizing conditions for both crops requires careful management in order to avoid excessive competition for light, water and nutrients between the two crops. The banana provides shade for coffee, beneficial for reducing stresses caused by extreme temperatures and strong winds. The banana also provides mulch and the soil cover that benefits both crops. The mulch improves root development in both banana and coffee, and improves availability of potassium in the topsoil, due to the large biomass turnover. The permanent canopy and root systems of banana reduce soil losses due to erosion and surface wash by reducing the impact of rainfall on the topsoil. Best conditions are deep, well-drained fertile soil with good water holding capacity, with pH above 5 and rainfall more than 900 mm/year. Deeper soils (more than 3 m) that allow coffee plants to develop a taproot and both crops to develop a more extensive root system are preferred in areas affected by seasonal drought. On less favourable soils, bananas

[30] FARFÁN V., F. (2014). Agroforestería y Sistemas Agroforestales con Café. Manizales, Caldas (Colombia), 342 p
[31] Wairegi, L.W.I., van Asten, P.J.A.,Giller, K.E. & Fairhurst, T., 2016. Banana–coffee system cropping guide. Africa Soil Health Consortium, Nairobi.

can be grown at higher densities (greater than 740 plants/ha) without affecting coffee yields, when the banana plants will be smaller and less competitive for light, nutrients and water.

3.10. Other intercrops

Depending on location, climatic conditions and growth stage of the coffee plants, coffee can also be grown together with other crops. In young fields there is enough space for growing short term crops such as beans, maize or cassava as well as long-term crops like bananas, cocoa and vanilla. As well as providing extra income, these crops will provide the shade to the young coffee seedlings. As with coffee-banana intercropping systems alternatives have not received much attention from researchers.

3.11. Integrated pest and disease management

Managing pests and diseases in coffee requires regular scouting of the coffee fields to identify infections early. This gives time to intervene before much damage is done. The use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment can reduce costs substantially.

Coffee is attacked by a range of pests, including the coffee berry borer (*Hypothenemus hampei*) and the white coffee stem borer (*Monochamus leuconotus*), green scales, mealy bugs and nematodes. The most important is, coffee berry borer, where adult females bore holes into the coffee berry and deposit their eggs. Upon hatching, the larvae feed on the coffee seeds inside the berry, reducing yield and quality. It can be controlled through (a) encouraging natural enemies, by introducing shade trees and cover crops, which provide the habitat for the pest's natural enemies, including parasitoids, ants, birds and thrips, nematodes, and fungal entomopathogens. (b) regular removal and destruction of infected branches and leaves, and (c) prompt harvesting and collection of fallen beans from beneath trees. Also, restricting the movement of organic material such as mulch from one area to another reduces development of pests. Nursery seedlings can also be protected by covering them under nets or spraying with purchased or natural sprays such as black jack, *Tephrosia* or neem extracts.

Most of the important coffee diseases are caused by fungus, including, coffee wilt disease[32], coffee leaf rust, coffee berry disease[33], coffee bark disease and brown eye spot. Effective management starts with the choice of suitable varieties for local conditions. At the same time good management practices will enhance the ability of the coffee to tolerate and limit infection. This includes soil fertility improvement, pruning and de-suckering to increase airflow and reduce the humidity around the plant, ensuring infected plants or parts are removed and destroyed with materials and equipment not being moved from infested fields to healthy ones. Both nursery and field plants can be protected by spraying with a fungicide. Alternatively, a lime sulphur can be used creating a physical barrier to prevent rust spore germination and penetration into the leaf tissue. The treatment will not halt an aggressive outbreak but may prevent or slow disease development. It is less expensive than fungicides. A typical fungicide will cost around 40 USD/ha, whereas lime sulphur costs about 10 USD/ha) but may be less effective.

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[32] Also known as 'fusarium wilt' or 'tracheomycosis,' this is the most destructive coffee disease and can lead to 100% yield losses. It affects both Arabica and Robusta. It is a vascular wilt disease caused by the fungus Fusarium xylarioides. The first signs of the disease include yellowing, folding and inward curling of the leaves. The leaves then dry up and become brown and eventually drop off, leaving affected trees completely leafless. The disease spreads when infected trees are dragged through the garden for use as firewood, fencing, or left in the field. It also spreads through contaminated tools, human beings or soil that gets into contact with healthy plants. Its control requires strict quarantine measures, involving restrictions on the movement of coffee materials (seedlings, beans, husks, etc.) from affected areas, destroying all infected and adjacent plants preferably by burning them at the site without moving them. Field tools that have been used on infected trees should be sterilized by flaming fire over the metal part before using them on other fields.

[33] This is caused by Colletotrichum kahawae is a major constraint for mainly Arabica coffee. The disease is specific to green or immature berries and can lead to 20-30 % harvest losses. It causes sunken lesions, which spread to cover the berry and the inside bean may also be affected. Older coffee will have higher disease pressure due to the build-up of primary inocula in the bark. In addition, field crop hygiene by removing infected beans is also helpful

3.12. Minimising postharvest losses

The final quality of coffee depends a lot on how well the coffee has been picked, processed, dried, packed and stored. In order to minimize contamination until safe storage, it is therefore important to carefully harvest and safely handle the harvested coffee through primary processing activities.

3.13. Protecting areas of high bio-diversity

Permanent protected areas (PPAs) such as those established in Brazil are natural areas, where direct economic exploitation is not allowed. They offer several benefits, including (a) the protection of water resources, where springs are protected to maintain the flow of water during the dry season; (b) preservation of local biodiversity facilitating a greater movement of both fauna and flora; and (c) creating or protecting ecological corridors. In Brazil, PPAs provide for 50 m of protection for a spring; 30 meters for watercourses of less than 10 meters wide; 50 m for watercourses 10 to 50 meters wide; 100 metres for watercourses from 50 to 200 meters wide; 200 metres for watercourses 200 to 600 meters wide; and 500 metres for watercourses more than 600 meters wide.

4. THE CLIMATE SMART COFFEE CREDIT PRODUCT

The purpose of this section is to identify how climate-smart land-management measurements will be progressively built out over progressive loan cycles as requirements of those loans.

The integrated approach required for SSGs to derive optimum benefit from the CSA coffee practices dictate that loans advanced should be dictated by the size of the area to be planted or rehabilitated, starting with an area of 0.06 ha, this being equivalent to 1/32nd of one hectare measuring 12 m x 25 m. This would be regarded as a "Learner Level", where all CSA practices could be tried, tested and learnt from, before proceeding to larger areas. These would be progressively increased from 0.03 ha to 0.06 ha, 0.25 ha, 0.5 ha, 0.75 ha and then one ha, as indicated on the next page. Not only would this support the learning process of the individual grower concerned, but would also be available for demonstration, learning and, if necessary, modification by nearby farmers. The process lends itself to both new coffee establishment as well as rehabilitation of old coffee areas.

On the basis of the foregoing analysis ,a number of CSA practices have been identified (shown overleaf), eight of which are visually verifiable using the climate-smart credit scoring tools. The remaining two requirements are not visually verifiable but are nevertheless considered good practice and this constitutes the climate-smart credit product for coffee growers.

Table 10: Practices required under the coffee climate-smart credit product

CSA Practice		per ha	Units ha	CSA input requirements Loan 1 0.03	Loan 2 0.06	Loan 3 0.13	Loan 4 0.25	Loan 5 0.5	Loan 6 0.75	Loan 7 1
New varieties	1 Plant improved varieties	1600	seedlings	50	100	200	400	800	1,200	1,600
Integrated soil fertility mamangment	2 Practice compost making and application to coffee (3 kg per tree) in addition to recommended inorganic fetiliser rates	3	kg/seedling	150	300	600	1,200	2,400	3,600	4,800
Soil and water conservation	3 Construct contours and terraces	400	metres	13	25	50	100	200	300	400
	4 Plant grass on contours/terraces	400	metres	13	25	50	100	200	300	400
	5 Plant cover crops between rows of coffee	200	sq. metres	6	13	25	50	100	150	200
	6 Cut grass and mulch around coffee trees	400	sq. metres	13	25	50	100	200	300	400
	7 Establish rainwater harvesting structure linked to contours/terraces	4	No.	-	-	-	1	2	3	4
Agroforestry	8 Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	250	seedlings per ha	8	16	31	63	125	188	250
	9 Intercrop with bananas where appropriate	1000	suckers	31	63	125	250	500	750	1,000
Integrated pest and disease management	10 Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	-	-	-	-	-	-	-	-	-

		0.03ha	0.06ha	0.13ha	0.25ha	0.5ha	0.75ha	1ha
Contractual Requirements	Banana Suckers	63 suckers	250 suckers	500 suckers	750 suckers	1,000 suckers	1,200 suckers	1,600 suckers
	Plant Trees	16 trees	63 trees	125 trees	188 trees	150 trees	200 trees	250 trees
	Rainwater Harvesting Structures	0	0	0	1	2	3	4
	Cover Crops	0.03ha	0.06	0.13ha	0.25ha	0.5ha	0.75ha	1ha
	Mulching	0.03ha	0.06	0.13ha	0.25ha	0.5ha	0.75ha	1ha
	Contour Terracing	13m	25m	50m	100m	200m	300m	400m
	Manure / Compost	0.03ha	0.06ha	0.13ha	0.25ha	0.5ha	0.75ha	1ha
		Loan 1	**Loan 2**	**Loan 3**	**Loan 4**	**Loan 5**	**Loan 6**	**Loan 7**
Non-Contractual Requirements	Improved Varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties
	Integrated Pest Management	Training	Training	Training	Training	Training	Training	Training

Figure 3: Climate-smart credit product for coffee small holders

5. YIELD AND MITIGATION BENEFITS

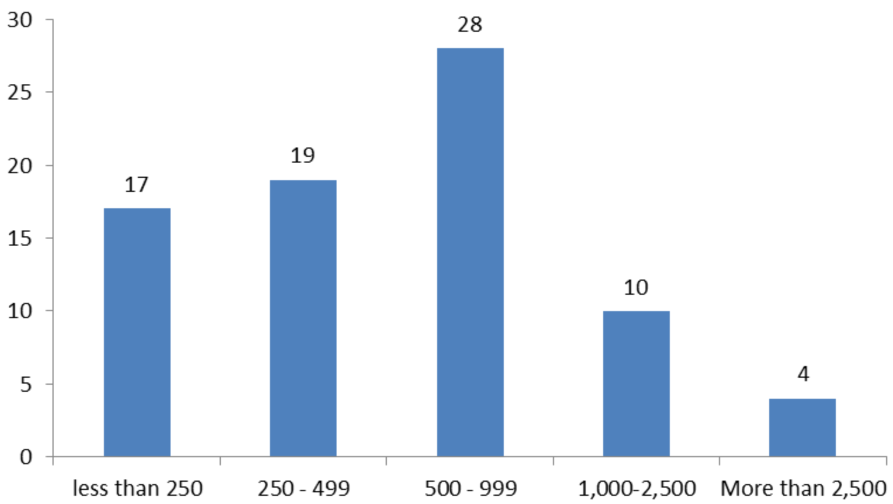
5.1. Introduction

This section explains the yield and climate mitigation benefits of the proposed climate-smart credit product land-use requirements. We also provide some context, as this informs the impact analysis in following sections with regards to base level yield and price with reference to countries of interest.

5.2. Present Yield Levels

FAO statistics[34] for 2017 showed that of the 78 countries producing coffee, 12 were responsible for growing over 85% of the total area (Table 13). The total area of Arabica and Robusta grown was 10,840,132 ha producing 9,212,168 tonnes of coffee at an average yield of 730 kg/ha, although there was a wide range of yield levels as shown in Table 13.

Table 11: Range of coffee yields (kg ha-1) (no. of countries) (Arabica and Robusta, rainfed and irrigated)



As can be expected those countries achieving the highest yields often have more favourable growing conditions, with better soils with large areas under irrigation, but importantly are supported by access to well-resourced research and advisory systems often funded by levies on growers. The areas of coffee grown, yields achieved and world ranking in terms of area grown and yield ha^{-1} are shown for various countries in Table 14.

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34 FAO, 2018 FAOSTAT. http://www.fao.org/faostat/en/#data/QC

Table 12: Area of coffee, yields and rank in terms of area grown and yields, 2016[35]

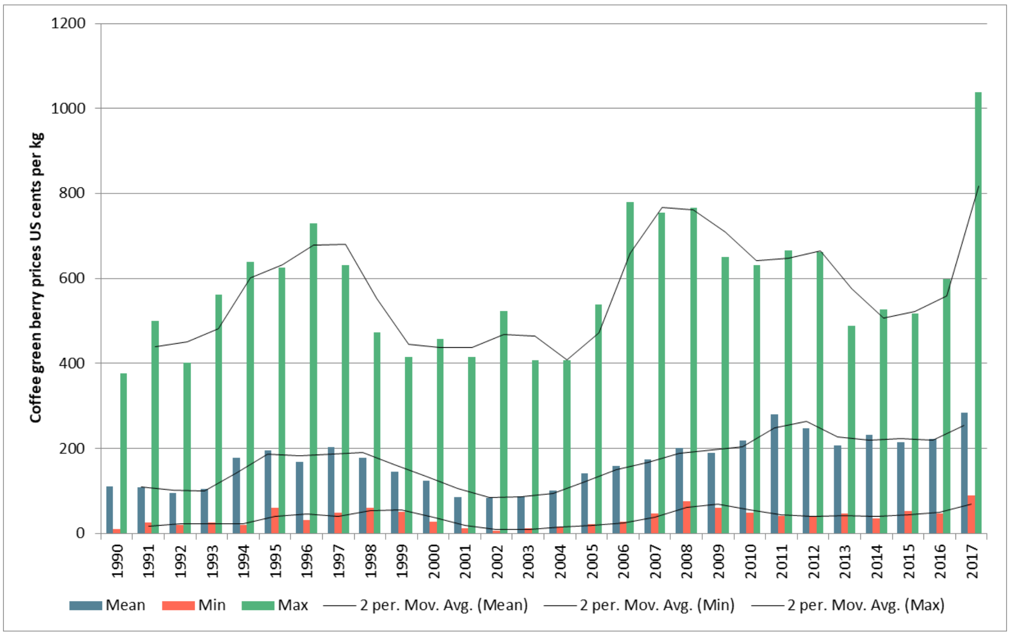
Country	Area	% of area	Rank area grown	Tonnes	Rank total yield	% of yield	t/ha	Rank yield per ha
Brazil	1,800,398	17%	1	2,680,515	1	16%	1.49	2
Colombia	798,358	7%	4	754,376	3	4%	0.94	3
Cote d'Ivoire	925,442	9%	3	103,514	12	1%	0.11	12
Ethiopia	694,332	6%	5	471,247	6	3%	0.68	8
Guatemala	278,232	3%	12	245,441	9	1%	0.88	5
Honduras	505,115	5%	8	475,042	5	3%	0.94	4
India	449,357	4%	9	312,000	8	2%	0.69	7
Indonesia	1,253,796	12%	2	668,677	4	4%	0.53	10
Mexico	638,603	6%	6	153,794	11	1%	0.24	11
Peru	423,545	4%	10	346,466	7	2%	0.82	6
Uganda	385,296	4%	11	209,325	10	1%	0.54	9
Viet Nam	605,178	6%	7	1,542,398	2	9%	2.55	1
Total	8,757,652	81%		7,962,795		46%	0.87 (mean)	

5.3. Coffee Prices

The price of coffee shows high variability both between countries and between years, with lows being in the years 2000-05 and then peaking in 2006-09, before dropping and then increasing in 2017[36]. Over a 27-year period the highest prices have been consistently been much greater than mean and lowest prices indicating the importance of both weather conditions and the need to obtain high grades for green beans (Table 13).

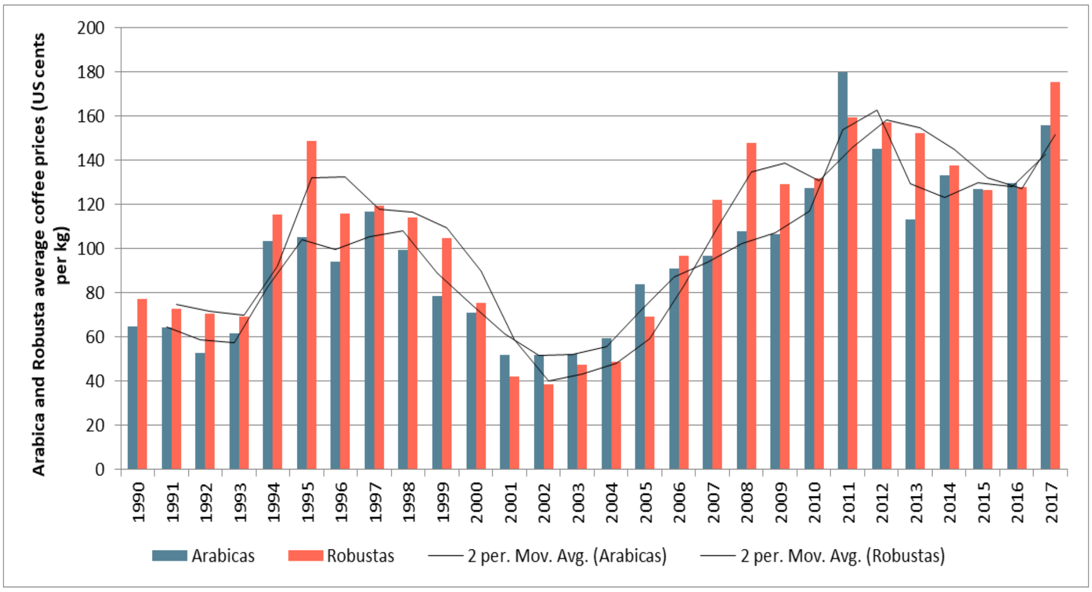
[35] ibid
[36] International Coffee Organization

Table 13: Mean, maximum and minimum coffee prices (US cents per kg) (Arabica and Robusta) (1990- 2017)



The average price of Robusta closely mirrors that of Arabica (Table 14), despite generally being regarded as higher quality.

Table 14: Average Arabica and Robusta coffee prices (US cents per kg) (1990- 2017)



The variation is shown for a number of countries in the table below, for which data is available. The highs and lows for the major producers are shown in the table below.

Table 15: Major country coffee producer price ranges, 2001, 2008,2017[37] (US cents per kg)

	2002		2008		2017	
Country	**Arabica**	**Robusta**	**Arabica**	**Robusta**	**Arabica**	**Robusta**
Brazil	68	44	240	201	243	216
Colombia	116	-	251	-	277	-
Ecuador	60	-	319	-	-	-
Ethiopia	59	-	158	-	186	-
Côte d'Ivoire	-	20	-	114	-	129
Guatemala	109	-	244	-	295	-
Honduras	82	-	199	-	200	-
India	87	49	268	211	299	209
Indonesia	-	32	-	-	-	-
Kenya	149	-	-	-	-	-
Mexico	99	-	233	-	-	-
Peru	65	9	-	78	-	-
Tanzania	57	-	139	-	-	-
Uganda	61	28	161	156	169	141
Vietnam	-	40	-	196	-	-
Mean	**84**	**32**	**221**	**160**	**238**	**174**
max	149	49	319	211	299	216
min	57	9	139	78	169	129

Farm gate prices vary considerably ranging from 60%-70% of the world market prices[38]. In Uganda farmers are paid 75% of the FOB export price.

5.4. The Impact of Sustainable Land-Management and Climate-Smart Practices

Qualitative impact of resilience, risk, mitigation and productivity

Key features of the CSA approaches to sustainable coffee production are given below.

- **Reducing or eliminating soil erosion**, extending the number of times that coffee can be cut, hence replanting less frequently using minimal or no-till production systems
- **Improving soil fertility** through crop rotation with legumes, green fertilization by planting green manure cover crops such as *Crotalaria juncea*, using coffee crop residues after harvesting as a mulch or ground cover
- **Further reducing the use of inorganic fertiliser** through utilisation of coffee processing waste products.
- **Reducing the use of agrochemicals** through biological control, introducing natural enemies to fight pests and advanced genetic enhancement programs.
- **Protecting and recover land alongside streams and riverbanks**, thus improving biodiversity.

[37] ibid

[38] Van Der Vossen H A M, 2005. A Critical Analysis of the Agronomic and Economic Sustainability of Organic Coffee Production. Expl Agric. (2005), volume 41, pp. 449–473 C . Cambridge University Press. United Kingdom

The impact[39,40] of these practices, lies in four broad areas varying according to agro-climatic and market conditions. These are cumulative, but dependent on the deployment as integrated packages.

- **Improving the resilience of natural resource use.** This includes increasing farm level biodiversity; increasing groundwater availability, reducing soil erosion, increasing availability of plant nutrients from the soil, increasing infiltration of water into the soil, increasing soil microbial diversity, improving soil aggregation and increasing soil water holding capacity.
- **Reducing the risks associated with climate change**. These include increased temperatures, droughts both between and within growing seasons, shortened growing seasons, increased rainfall intensity and more unpredictable seasons.
- **Mitigating the effects of some of the causes of climate change**. These include encouraging changes in land use, reducing emissions from inputs used in coffee production, sequestering carbon both in the soil and in increased biomass, and N_20 emissions through reducing fuel use.
- **Increasing productivity.** These include increased yields with less yield variability and a reduction in input costs, but sometimes an increase in labour requirement. Consequently incomes will be increased.

[39] Bell P, Namoi N, Lamanna C, Corner-Dollof C, Girvetz E, Thierfelder C, Rosenstock TS. 2018. *A Practical Guide to Climate-Smart Agricultural Technologies in Africa.* CCAFS Working Paper no. 224. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org

[40] B Campbell, 2107. *Climate Smart Agriculture What is it?* Rural 21 4:14-16. CGIAR Research program on Climate Change, Agriculture and Food Security (CCAFS)

Detail of the impact of each of these components are shown qualitatively (- no effect, + some effect, ++ intermediate effect and +++ large effect) in Table 18 with resilience and productivity further demonstrated in Table 19. This emphasises the importance of higher agro-climatic potential and good markets in achieving higher productivity.

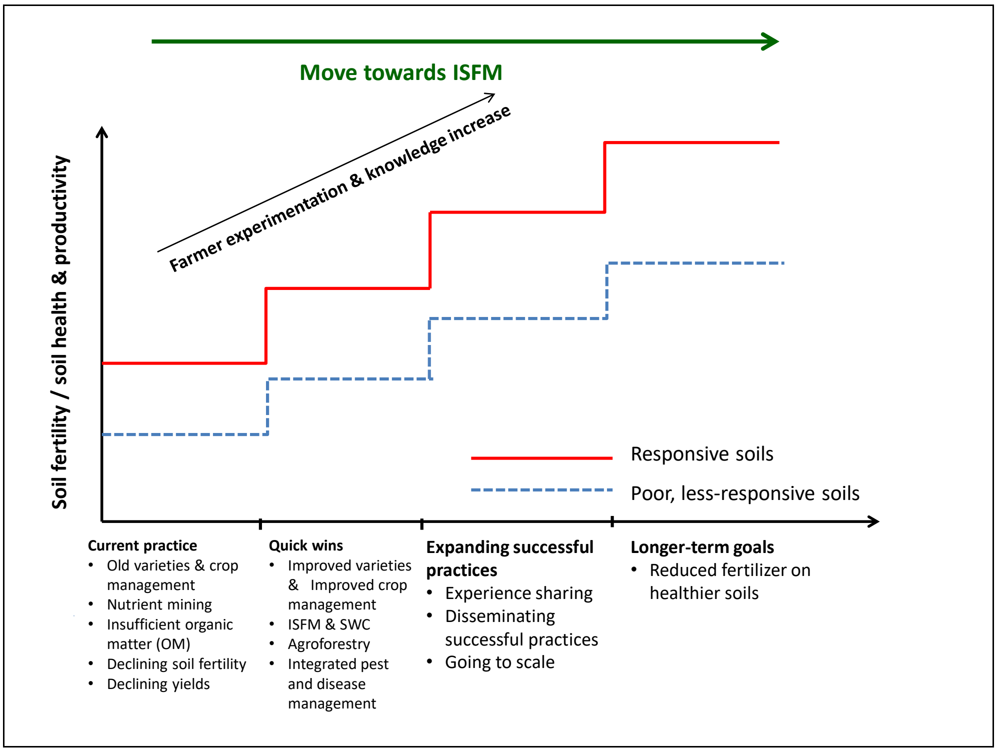
Table 16: Towards climate smart sustained coffee production[41]

Climate smart agricultural practice		Yield	Yield variability	Labour	Income
Improved Coffee varieties	1 Plant improved varieties - more tolerant of temperature and drought as well as pests and diseases	+++	+++	-	+++
Integrated soil fertility management	2 Make compost and apply 5 kg to each coffee plant annually	+++	+++	-	+++
Soil and water conservation	3 Construct contours and terraces*	+++	+++	+++	+++
	4 Plant grass on contours/terraces*	+++	+++	+++	+++
	5 Cut grass and mulch around coffee trees	+++	+++	+++	+++
	6 Plant cover crops	++	++	++	++
	7 Establish rainwater harvesting structure linked to contours/terraces**	+++	+++	+++	+++
Agro-forestry	8 Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	+++	+++	+++	+++
	9 Intercrop with bananas where appropriate	++	++	-	+++
Integrated pest and disease management	10 Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	+++	+++	++	++

** greatest on steeper slopes*
*** especially on areas without irrigation*

- *no effect*
+ *small effect*
++ *intermediate effect*
+++ *large effect*

Table 17: Towards self-sustaining integrated soil fertility management42



[41] Adapted from Vanlauwe B, Desceemaeker K, Giller K et al, 2015. Integrated soil fertility management in SSA: Unravelling local adaptation. Soil, 1, 491-508.

5.5. Yields Increases through adoption of CSA coffee practices

The following section explains yield response to drought or excessive rain with an explanation of the agronomic mechanism by which yield is increased or yield loss is mitigated.

Estimates of the yield increases through use of the proposed CSA coffee production practices are difficult to quantify individually as greatest benefit will occur with an integration of their use alongside these and other good agronomic practices, and these are the scenarios under which yield improvements are tested, ie altogether rather than in isolation. Although they will be location specific dependent on agro-climatic conditions, increased yields (table below) can be achieved alongside a reduction in the costs particularly inorganic fertiliser and chemical applications to control diseases and pests, although an increased labour requirement can be expected.

Yields will increase over time as soil organic matter builds, soil health is restored, and soil conservation measures become effective. Progressive yield increases, based on research and practical experience in a number of countries, can occur from a base of 600 kg ha^{-1} by more than 100% or more up to and exceeding 1500 kg ha^{-1}. Under well managed irrigation, yield levels would be substantially higher. The impact will be greatest where soil health is poor and yield levels are already declining, often on steeper slopes with poor soil conservation practices and under rainfed conditions. Unfortunately, mistakes made during establishment of the coffee can mean that attainable yields are not reached, and yield gaps are likely to persist throughout the life of the crop. This requires careful establishment of the system.

Common causes of yield gaps include the use of inferior planting materials and incorrect plant spacing as well as failure in application of the CSA farming practices.

Table 18: Quantification of the impact of CSA practice on yield levels over time

Climate smart agricultural practice		% yield increase	Agronomic reasons for benefit
New varieties	1 Plant improved varieties -	25%	Great genetic potential with resistance /tolerance to drought as well as pests and diseases
Integrated soil fertility management	2 Make compost and apply 5 kg to each coffee plant annually together with balanced inorganic fertilisers	15%	Improving soil organic amtter content increases soil moistue holding capacity, improves soil health allowing a reduction in time of the need for inorganic fertiliser
Soil and water conservation	3 Construct contour barriers and/or terraces	30%	Reduced soil erosionand consequential increse in soil fertility
	4 Plant grass on contours/terraces		Stabilisation of contour banks and use as mulch material
	5 Cut grass and mulch around coffee trees		Protect the soil against raindrop action, soil erosion and reduce soil temperature
	6 Plant cover crops, where appropriate		as above, but also saves laboutr and herbicide requirment for weed control
	7 Establish rainwater harvesting structure linked to contours/terraces		Harvest and store rain water to increase soil moisture availability for the crop
Agroforestry	8 Establish trees between the coffee bushes	20%	The provision of shade, windbreaks, mulching, and erosion control
	9 Intercrop with bananas where appropriate		Bananascan provide similar benfits to other tree species as well as an additional crop
Integrated pest and disease management	10 Use of multiple pest and disease management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	10%	Biological control will help reduce the costs of using purchased pesticides
Total		100%	

Notes: *Although % increases are attributed to each CSA practice, integration/coordination of all practices at the same time is required to derive full impact*
Yields will increase over a period of time from a base of 600 kg ha-1as the soil organic matter builds, soil health is improved and soil conservation measures become effective.

Variation can be expected dependent on agro-climatic conditions, market opportunity and, most importantly, farmer capacity – which emphasises the need for farmer training.

5.6. Cost Increases and Reductions through Use of CSA Coffee Practices

Research indicates that considerable cost savings can be made by adopting CSA practices, mainly by applying less inorganic fertiliser, a 20-100% reduction, as soil health improves through application of manures, composts and mulching materials; and pesticide applications, a 20-100% reduction as integrated pest management methods are utilised. The larger reductions are for speciality coffees where organic certification is required and the use of inorganic fertiliser and pesticides is not permitted. There is considerable scientific argument about the pros and cons of this with indications[43] that some use of inorganic fertiliser and pesticides are necessary to attain sustainable yields.

[43] VAN DER VOSSEN H. A. M.,2005. A Critical Analysis of the Agronomic and Economic Sustainability of Organic Coffee Production. Expl Agric., volume 41, pp. 449–473, Cambridge University Press.

[43] Markus Giger , Hanspeter Liniger, Caspar Sauter, Gudrun Schwilch,. 2015. Economic Benefits and Costs of Sustainable Land Management Technologies: An Analysis of WOCAT's Global Data. Land Degrad. Develop. 29: 962–974 (2018). Published online 7 October 2015 in Wiley Online Library DOI: 10.1002/ldr.2429

Table 19: Quantification of the impact of CSA practice on coffee input costs

					CSA input requirements per unit								CSA input requirements (USD)						
				Units	Loan 1	Loan 2	Loan 3	Loan 4	Loan 5	Loan 6	Loan 7	USD/	Loan 1	Loan 2	Loan 3	Loan 4	Loan 5	Loan 6	Loan 7
CSA Practice			**per ha**	**ha**	**0.03**	**0.06**	**0.13**	**0.25**	**0.5**	**0.75**	**1**	**unit**	**0.03**	**0.06**	**0.13**	**0.25**	**0.5**	**0.75**	**1**
New varieties	1	Plant improved varieties	1600	seedlings	50	100	200	400	800	1,200	1,600	**0.2**	**10**	**20**	**40**	**80**	**160**	**240**	**320**
Integrated soil fertility mamangment	2	Practice compost making and application to coffee (3 kg per tree) in addition to recommended inorganic fetiliser rates	3	kg/seedling	150	300	600	1,200	2,400	3,600	4,800	0	0	0	0	0	0	0	0
Soil and water conservation	3	Construct contours and terraces	400	metres	13	25	50	100	200	300	400	0	0	0	0	0	0	0	0
	4	Plant grass on contours/terraces	400	metres	13	25	50	100	200	300	400	0.20	2	4	8	16	32	48	64
	5	Plant cover crops between rows of coffee	200	sq. metres	6	13	25	50	100	150	200	0.05	0.3	1	1	3	5	8	10
	6	Cut grass and mulch around coffee trees	400	sq. metres	13	25	50	100	200	300	400	0	0	0	0	0	0	0	0
	7	Establish rainwater harvesting structure linked to contours/terraces	4	No.	-	-	-	1	2	3	4	0	0	0	0	0	0	0	0
Agroforestry	8	Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	250	seedlings per ha	8	16	31	63	125	188	250	0.5	5	10	20	40	80	120	160
	9	Intercrop with bananas where appropriate	1000	suckers	31	63	125	250	500	750	1,000	0.5	160	160	160	160	160	160	160
Integrated pest and disease management	10	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
												Total	177	195	229	299	437	576	714

Table 20: Quantification of the impact of CSA practice on coffee labour requirements

				Labour requirement (days)								Labour costs (USD)						
				Loan 1	**Loan 2**	**Loan 3**	**Loan 4**	**Loan 5**	**Loan 6**	**Loan 7**		**Loan 1**	**Loan 2**	**Loan 3**	**Loan 4**	**Loan 5**	**Loan 6**	**Loan 7**
CSA Practice			**Days per ha**	**0.03**	**0.06**	**0.13**	**0.25**	**0.50**	**0.75**	**1.00**	**USD/day**	**0.03**	**0.06**	**0.13**	**0.25**	**0.50**	**0.75**	**1.00**
New varieties	1	Plant improved varieties	**10**	**0.3**	0.6	1.3	2.5	5.0	7.5	10.0	2.5	0.8	1.6	3.3	6.3	12.5	18.8	25.0
Integrated soil fertility mamangment	2	Practice compost making and application to coffee (3 kg per tree) in addition to recommended inorganic fetiliser rates	5	0.2	0.3	0.6	1.3	2.5	3.8	5.0	2.5	0.4	0.8	1.6	3.1	6.3	9.4	12.5
Soil and water conservation	3	Construct contours and terraces	20	0.6	1.3	2.5	5.0	10.0	15.0	20.0	2.5	1.6	3.1	6.3	12.5	25.0	37.5	50.0
	4	Plant grass on contours/terraces	1	0.0	0.1	0.1	0.3	0.5	0.8	1.0	2.5	0.08	0.2	0.3	0.6	1.3	1.9	2.5
	5	Plant cover crops between rows of coffee	1	0.0	0.1	0.1	0.3	0.5	0.8	1.0	2.5	0.1	0.2	0.3	0.6	1.3	1.9	2.5
	6	Cut grass and mulch around coffee trees	20	0.6	1.3	2.5	5.0	10.0	15.0	20.0	2.5	1.6	3.1	6.3	12.5	25.0	37.5	50.0
	7	Establish rainwater harvesting structure linked to contours/terraces	1	0.0	0.1	0.1	0.3	0.5	0.8	1.0	2.5	0.1	0.2	0.3	0.6	1.3	1.9	2.5
Agroforestry	8	Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	20	0.6	1.3	2.5	5.0	10.0	15.0	20.0	2.5	1.6	3.1	6.3	12.5	25.0	37.5	50.0
	10	Intercrop with bananas where appropriate	50	1.6	3.1	6.3	12.5	25.0	37.5	50.0	2.5	3.9	7.8	15.6	31.3	62.5	93.8	125.0
Integrated pest and disease management	11	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total				4	8	16	32	64	96	128	Total	10	20	40	80	160	240	320

5.7. Mitigation of Crop Loss in the Event of Weather Shock

The risks to coffee associated with climate change and associated weather shocks are: (i) increased droughts both between and within growing seasons and consequently shortened growing seasons; (ii) increased rainfall intensity; (iii) increased temperatures and more unpredictable seasons. The increased occurrence of such events means that coffee yields are likely to become more unpredictable and could reduced. Unfortunately, no robust data is available detailing possible yield losses due to adverse weather, although in extreme circumstances 100% losses are likely to be experienced.

The main reasons why coffee growers have been able to maintain high yields and quality include a combination of good agronomic and CSA practices, including: (i) introduction of new varieties and variety variation, minimising in-field competition through appropriate row spacing pf coffee and trees, (ii) maintaining and improving soil fertility, (iii) sound soil and surface water conservation practices, (iv) introducing agro-forestry practices (v) sound weed and pest control, and (vi) sound record keeping.

The CSA lending practices embody these practices and give emphasis to increasing uses of organic biomass in a system of Integrated Soil Fertility Management and sound soil conservation measures, designed to reduce the risks associated with climate change.

6. AGRO-CLIMATIC AND MARKET PARAMETERS WITHIN WHICH CSA LENDING CAN BE DEPLOYED

6.1. Introduction

This section provides a brief and concise identification of the quantitative and qualitative parameters in which the credit product can be deployed, which will be dependent on the conditions in which the crop can be profitably grown and sold

6.2. Agro-climatic conditions

Section 2.2 sets out the conditions where coffee flourishes. Ideal average temperatures range from 15-24C for Arabica coffee and 24-30C for Robusta, which is better adapted to warmer, drier conditions, but cannot tolerate temperatures much below 15C, while Arabica can for short periods. Both types are easily damaged by frost, particularly a danger in southern Brazil and closer to the Equator at altitudes over 2000 metres. Robusta can be grown between sea level and about 800 metres, while Arabica does best at higher altitude and is often grown in hilly areas. As altitude relates to temperature, Arabica can be grown at lower levels further from the Equator, until limited by frost. Both types require an annual rainfall of 1,500-3,000 mm depending on soil type, humidity and cloud cover. The pattern of rain and dry periods is important for growth, budding and flowering. All coffee needs good drainage, but can grow on soils of different depths, pH and mineral content, given suitable soil fertility status. In drier areas the crop can benefit from irrigation.

CSA lending products can be used in any of the suitable environments especially where coffee yields may have declined due to poor management practices and soil degradation. CSA products are specifically intended to build soil fertility through ISFM practices supported by soil and water conservation and agroforestry practices.

6.3. Market parameters

Coffee is one of the world's most widely consumed beverages, supporting a multibillion-dollar industry spanning a lengthy value chain from farmer to consumer. As coffee production is largely in the hands of smallholder farmers, the livelihood value is immense, with an estimated 100 million coffee farmers worldwide. Coffee growing and its related activities provide a major source of employment in all producing countries providing direct full-time employment for 25 million people worldwide.

The crop is grown commercially and exported by more than 60 developing countries. Globally, it is the second most traded commodity to oil and plays a key role in the balance of trade between developed and developing countries, providing the latter with an important source of export earnings to pay for imports[44]. Most coffee-growing countries fall into lower- and middle-income nations of the world, but with at least 20 being classified as least developed.

SSGs are usually regarded as those growing typically a few trees up to five ha of coffee with or more often without irrigation, although the vast majority of smallholder farmers in regions where coffee is grown work with less than 2 ha of land, more especially in SSA.

Many coffee companies have well established supply chains directly linked to farmer groups or cooperatives. Under such schemes, some companies manage the entire system from advisory services, procurement, processing to final marketing and in some cases certification. In addition,

[44] ICO, 2018. Global Coffee trade. International Coffee Organisation Downloaded from http://advances.sciencemag.org/ on January 18, 2019 http://www.ico.org/new_historical.asp?section=Statistics accessed 5th January 2019

independent farmers and groups also contribute a significant amount of coffee. Certification comes with costs, which will be profitable if there is a market that demands certified coffee. To reduce certification costs, individual farmers may either join an existing certification scheme or organise themselves into a new group, especially during postharvest handling.

CSA lending for SSGs can be deployed in most coffee growing areas, where SSGs predominate.

7. FARMER COST-BENEFIT ANALYSIS

7.1. Introduction

The purpose of this section is to present the findings of a generalised cost benefit analysis for coffee production under the terms of a climate-smart credit product. The purpose of this is to (i) demonstrate that the terms of a climate-smart credit product will be beneficial for a small scale coffee grower, and (ii) to provide a cost benefit analysis model template for creation of climate-smart credit products in specific contexts.

7.2. Why undertake cost benefit analysis?

Ecologically sustainable coffee production is possible by applying best practices of agronomy, crop protection and post-harvest processing[45]. These include soil conservation measures with or without shade trees, applying organic and inorganic fertilizers to maintain optimum soil quality and crop nutrient levels, planting of disease resistant varieties and applying IPM to reduce crop losses due to biotic stress factors, and the use of novel processing equipment. However, full commitment of all stakeholders in the coffee cector is required in helping to ensure economic and social sustainability of coffee production.

Perceived profitability has been recognised as a key factor in explaining farmers' decisions to adopt or not adopt sustainable land management (SLM) technologies[46]. It was concluded that a wide range of existing SLM practices generate considerable benefits not only for land users, but for other stakeholders as well. However high initial investment costs associated with some practices may constitute a barrier to their adoption; and short-term incentives for land users can help to promote these practices where appropriate.

Results from a recent study[47] of coffee production of 27 case studies showed wide variation in yields, incomes, costs and profitability (Table 23).

Table 21: Yields, Income, Costs and Profitability of 27 case studies

	Yield kg per ha	Income USD per kg	Income per ha	Cost USD per ha	Cost USD per kg	Net Income USD per ha	Benefit: Cost ratio
Mean	992	2.48	2,432	2,240	2.45	296	2.04
Median	950	2.45	2,333	2,039	2.46	466	1.2
Min	288	1.07	507	44	1.76	-2,837	0.40
Max	2150	4.75	5,653	5,715	2.63	2,396	13.68

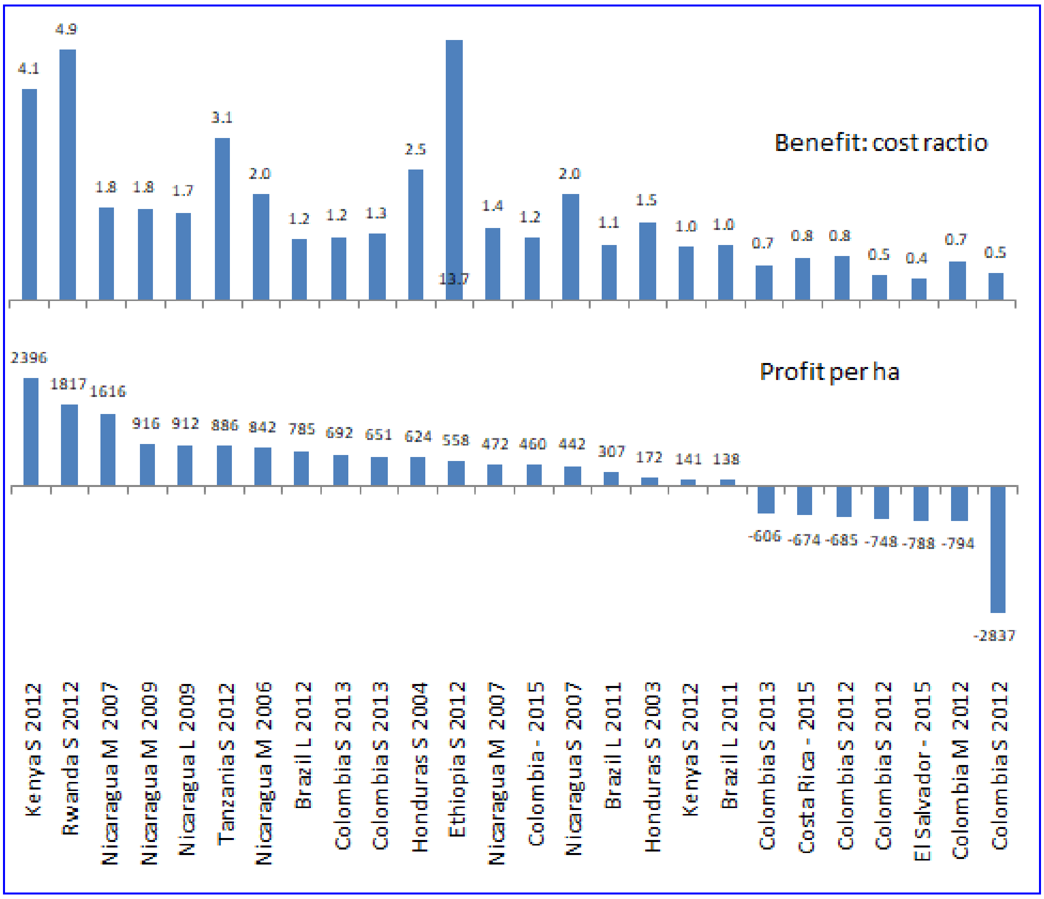
[45] Van Der Vossen H. A. M., 2005. A Critical Analysis of the Agronomic and Economic Sustainability of Organic Coffee Production. Expl Agric. (2005), volume 41, pp. 449–473. Cambridge University Press

[46] Markus Giger, Hanspeter Liniger, Caspar Sauter, Gudrun Schwilch, 2015. Economic benefits and costs of sustainable land management technologies: an analysis of WOCAT's global data. Land Degrad. Develop. 29: 962–974 (2018). Published online 7 October 2015 in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/ldr.2429

[47] Christophe Montagnon, 2017. Coffee Production Costs and Farm Profitability: Strategic Literature Review, Specialty Coffee Association. RD2 Vision. October 2017

Further analysis showed that the benefit to cost ratio showed little relation to the level of profitability. This is demonstrated across the studies analysed (below). For example, the Rwanda-2012 study showed a high benefit to cost ratio (4.9:1) with a lower level of profit (USD 1,817 per ha) in comparison with the Kenya-2012 study (benefit to cost ratio 4.1:1 and profit of USD 2,396 per ha). The study concludes that investing less than $2000/ha is likely to make profit, whereas investing more than $2000/ha require high yields and/or high prices to achieve profitability.

Table 22: Benefit cost ratios and profitability of coffee production case studies



The ICO[48] reported that more research is needed to understand the economic viability of coffee production world-wide with data availability currently hampering research. This reinforces the need for each situation to be carefully analysed, accounting for agro-climatic, economic and social conditions.

[48] International Coffee Council, 2015. Assessing the economic sustainability of coffee growing

7.3. Cost benefit analysis assumptions

Many factors in a farmer cost benefit analysis vary according to location, agro-ecological and economic context. Farmer adoption of new practices will also depend on farmer perceptions of the advantages and disadvantages of proposed new practices. Those variables used to inform this template analysis are summarised in the tables below, with a coffee farm gate price of US$1.50 per kg for coffee cherry, this being 70% of the green bean price together with an opportunity price for labour of US$ 2.50 per day.

Table 23: Base case variables affecting the CSA coffee production practices

Base practices Outputs	Year	Unit	#
Base coffee yields (mature tree)	Y6 on	kg/ha	700

Coffee farm-gate price (70% of export-FOB-Free / truck price)		USD/kg	1.5

Base case Inputs		Unit	No.	Cost (USD)
Coffee Seedlings	Y1	No./ha	1600	0.2
Fertiliser				
Urea (AN)	Y1	kg/ha	230	0.6
	Y2-	kg/ha	300	0.6
Triple Super Phosphate (TAP)	Y1	kg/ha	60	0.6
	Y2-	kg/ha	80	0.6
Muriate of Potash (MOP)	Y1	kg/ha	400	0.6
	Y2-	kg/ha	500	0.6
Herbicides	Y3-	cost per tree	1600	0.02
Fungicides	Y3-	cost per tree	1600	0.02
Pesticides	Y3-	cost per tree	1600	0.02
Processing costs (contracted out)	Y3-	USD per kg	-	0.02

Labour			
Land preparation	Y1	days/ha	20
Planting seedlings	Y1	days/ha	20
Apply inputs	Y1-	days/ha	8
Canopy management (prune and desucker)	Y1-	days/ha	8
Hand weeding and rogueing	Y1-	days/ha	20
Harvesting and loading	Y3-	days/100 kg	4
Labour cost		US$/day	2.5

Table 24: Base case variables affecting the CSA coffee production practices

CSA practice Outputs	Year	Unit	New plant
Mature tree (improved variety)	Y6 on	% increase on base yield	100%
% of mature tree for new coffee planting	Y1 & Y2	% mature tree	0%
	Y3	% mature tree	25%
	Y4	% mature tree	50%
	Y5	% mature tree	75%
Banana yield for coffee-banana system	Y1	kg/ha	7000
	Y2-	kg/ha	10000
Banana price	Y3-	USD/kg	0.05

CSA additional input costs	Year	Units	No.	Cost (USD)
Coffee seedlings	Y1	seedlings/ha	2200	0.10
ISFM compost alternate years	Y1-	tonnes/ha	0	0.00
SWC contour terraces	Y1	metres/ha	400	0.00
SWC cover crop seed	Y1	metres/ha	200	0.10
SWC grass on contour terraces (planting m	Y1	metres/ha	400	0.10
SWC rain water harvesting	Y1	No./ha	4	0.00
Agroforestry trees	Y1	trees/ha	250	0.20
Banana suckers	Y1	trees/ha	1000	0.50

CSA Input cost savings				
Inputs (fertiliser and pesticides)	Y2-	%	10%	

CSA additional labour costs						
ISFM compost	Y1-	days/ha	10	Y2-	days/ha	10
SWC contour terraces	Y1	days/ha	10	Y2-	days/ha	2
SWC cover crops	Y1	days/ha	4	Y2-	days/ha	2
SWC grass vegetation	Y1	days/ha	4	Y2-	days/ha	2
SWC rain water harvesting	Y1	days/ha	4	Y2-	days/ha	2
Agroforestry trees	Y1	days/ha	25	Y2-	days/ha	10
Agroforestry bananas	Y1	days/ha	10	Y2-	days/ha	5
Harvesting and loading	Y3-	days/100 kg	4			

CSA labour saving over base				
Input application	Y3-	%	5%	

7.4. Results

The key outputs of this exercise are a base case gross margin and farmer cost benefit analysis models for three scenarios for small scale coffee growers adopting climate-smart and sustainable land management measures required under the proposed climate-smart credit product. The base case and three alternative scenarios are presented below:

- **Base case farmer gross margin analysis:** where the grower has established varieties and the coffee is already bearing cherry, but no CSA practices have been adopted
- **Scenario 1:** where the grower has already established drought tolerant and pest resistant varieties and the coffee is already bearing cherry. In such circumstances, adoption of the other nine practices would be a requirement of any loan
- **Scenario 2:** where the grower plants new or rehabilitating existing coffee with improved varieties including the other CSA practices
- **Scenario 3:** where the grower plants new coffee varieties in an intercropping system with bananas, in circumstances where the bananas could be a food or marketable crop.

Results from the analysis are shown in the three following tables. These demonstrate, in the three generalised cases, the positive financial return to the climate-smart and sustainable land-management measures required under the climate-smart credit product.

This conclusion is not universal, and this model will need to be adapted for specific use-cases.

Table 25: Base Case Gross margin analysis existing coffee, no CSA practices adopted

	#			Units	Qty/ha	Price/unit USD	Maintenance Y1	Y2	Y3	Y4	Y5	Y6 on
Income	Yield			kg/ha			700	700	700	700	700	700
	Value			USD/kg			1.50	1.50	1.50	1.50	1.50	1.50
Gross Income				**USD per ha**			**1,050**	**1,050**	**1,050**	**1,050**	**1,050**	**1,050**
Input costs												
	Fertiliser	Urea		kg	300	0.60	180	180	180	180	180	180
		TSP		kg	80	0.60	48	48	48	48	48	48
		MOP		kg	500	0.60	300	300	300	300	300	300
	Herbicide			per tree	1,600	0.02	32	32	32	32	32	32
	Fungicides			per tree	1,600	0.02	32	32	32	32	32	32
	Insecticides			per tree	1,600	0.02	32	32	32	32	32	32
	Processing costs			per kg	700	0.20	140	140	140	140	140	140
				sub-total			**624**	624	624	624	624	624
Gross Margin over input costs before labour costs, loan repayments				**USD / ha**			**426**	**426**	**426**	**426**	**426**	**426**
Labour costs												
	Apply inputs		Y1-	days	8	2.50	20	20	20	20	20	20
	Canopy management		Y1-	days	8	2.50	20	20	20	20	20	20
	Hand weeding and roguing		Y1-	days	20	2.50	50	50	50	50	50	50
	Harvesting and loading		Y3-	days/100 kg	4	2.50	70	70	70	70	70	70
				sub-total			**160**	160	160	160	160	160
Total variable costs				**USD per ha**			**784**	**784**	**784**	**784**	**784**	**784**
Gross margin over inputs and labour costs before loan repayments or levies							**266**	**266**	**266**	**266**	**266**	**266**
Total labour input				**days**			**64**	**64**	**64**	**64**	**64**	**64**
Returns to labour				**USD /ha**			**426**	**426**	**426**	**426**	**426**	**426**
Returns to labour				**USD/ day**			**7**	**7**	**7**	**7**	**7**	**7**

Scenario 1: Gross margin for already established drought tolerant and pest resistant varieties, other CSA practices adopted. This is the situation where the grower has already established drought tolerant and pest resistant varieties and the coffee is already bearing cherry. In such circumstances the other nine practices are adopted

Table 26: Gross margin analysis –drought tolerant and pest resistant varieties already established, all other CSA practices adopted

			Units	Qty/ha	Price/unit USD	Y1	Y2	Y3	Y4 on
Benefits	Yield coffee		kg/ha			1400	1400	1400	1400
	Value		USD/kg			1.5	1.5	1.5	1.5
	Coffee income		**USD**			**2100**	**2100**	**2100**	**2100**
Input costs	Base costs		USD/ha			624	624	624	624
	Savings on base costs		%	10%			-62	-62	-62
	ISFM (compost)	Y1-	tonnes	0	-	-	-	-	-
	SWC (contour/ terraces)	Y1	metres	400	-	-	-	-	-
	SWC (plant grass on contour	Y1	planting materi	400	0.10	40	-	-	-
	SWC (cover crops)	Y1	seed	200	0.10	20			
	SWC rainwater harvesting	Y1	No.	4	-	-	-	-	-
	Agroforestry (trees)	Y1	seedlings	250	0.20	50	-	-	-
	Processing costs	Y3-	per kg		0.20	140	140	140	140
	sub total					**874**	**702**	**702**	**702**
Margin over inputs						**1226**	**1398**	**1398**	**1398**
Labour costs	Base costs		USD/ha	-	-	160	160	160	160
	Savings on base costs		%	5%				-8	-8
	ISFM (compost)	Y1-	days	5	2.5	13	13	13	13
	SWC (contour/ terraces)	Y1	days	20	2.5	50	-	-	-
		Y2-	days	5	2.5		13	13	13
	SWC (use grass as mulch)	Y3-	days	2	2.5		5	5	0
	SWC rainwater harvesting	Y1	days	4	2.5	10	-	-	-
		Y2-	days	1	2.5		3	3	3
	Agroforestry (trees)	Y1	days	10	2.5	25	25	25	25
		Y3-	days	10	2.5		25	25	25
	Harvesting and loading	Y3-	days/additional	4	2.50	70	70	70	70
	sub total					**328**	313	305	300
Total variable costs per ha			**USD per ha**			**1202**	**1014**	**1006**	**1001**
Gross Margin over inputs and labour costs before loan repayments or levies						**899**	**1086**	**1094**	**1099**
Total labour input			**days**			**131**	**125**	**122**	**120**
Returns to labour			**USD /ha**			**1226**	**1398**	**1398**	**1398**
Returns to labour			**USD/ day**			**9**	**11**	**11**	**12**

Scenario 2: Gross margin for planting improved varieties and adopting other CSA practices. This is the situation where the grower is either expanding and or rehabilitating existing coffee by planting new coffee bushes and adopting other CSA practices.

Table 27: Gross margin analysis - planting new varieties, all other CSA practices adopted

			Units	Qty/ha	Price/unit USD	Y1	Y2	Y3	Y4	Y5	Y6 on
Benefits	Yield coffee		kg/ha	-	-			350	700	1050	1400
	Value		USD/kg	-	-			1.5	1.5	1.5	1.5
	Coffee income		**USD**	-	-	**0**	**0**	**525**	**1050**	**1575**	**2100**
Input costs	Base costs		USD/ha			624	624	624	624	624	624
	Savings on base costs		%	10%			-62	-62	-62	-62	-62
	Coffee seedlings	Y1	seedlings	2200	0.10	220	-	-	-	-	-
	ISFM (compost)	Y1-	tonnes	0	-	-	-	-	-	-	-
	SWC (contour/ terraces)	Y1	metres	400	-	-	-	-	-	-	-
	SWC (plant grass on contour)	Y1	metres	400	0.10	40	-	-	-	-	-
	SWC (cover crops)	Y1	metres	200	0.10	20	-	-	-	-	-
	SWC rainwater harvesting	Y1	No.	4	-	-	-	-	-	-	-
	Agroforestry (trees)	Y1	seedlings	250	0.20	50	-	-	-	-	-
	Processing costs	Y3-	per kg		0.20			70	140	210	280
	sub total					**954**	**562**	**632**	**702**	**772**	**842**
Margin over inputs						**-954**	**-562**	**-107**	**348**	**803**	**1258**
Labour costs	Base costs		USD/ha	-	-	160	160	160	160	160	160
	Savings on base costs		%	5%				-8	-8	-8	-8
	ISFM (compost)	Y1-	days	5	2.5	13	13	13	13	13	13
	SWC (contour/ terraces)	Y1	days	20	2.5	50	-	-	-	-	-
		Y2-	days	5	2.5		13	13	13	13	13
	SWC (use grass as mulch)	Y3-	days	2	2.5			5	5	5	5
	SWC rainwater harvesting	Y1	days	4	2.5	10	-	-	-	-	-
		Y2-	days	1	2.5		3	3	3	3	3
	Agroforestry (trees)	Y1	days	25	2.5	63	63	63	63	63	63
		Y3-	days	10	2.5			25	25	25	25
	Additional hHarvesting and loading	Y3-	days/additional 100 kg	4	2.50	-70	-70	-35	0	35	70
	sub total					**225**	180	237	272	307	342
Total variable costs per ha			**USD per ha**			**450**	**360**	**474**	**544**	**614**	**684**
Margin over inputs and labour costs before loan repayments or levies						**-450**	**-360**	**51**	**506**	**961**	**1416**
Total labour input			**days**			**90**	**72**	**95**	**109**	**123**	**137**
Returns to labour			**USD /ha**			**-954**	**-562**	**-107**	**348**	**803**	**1258**
Returns to labour			**USD/ day**			**-11**	**-8**	**-1**	**3**	**7**	**9**

Scenario 3: Gross margin for planting improved varieties, intercropped with bananas, all other CSA practices adopted. This is the situation where the grower is planting new coffee varieties in an intercropping system with bananas, in circumstances where the bananas may be a food or marketable crop. All other CSA practices are adopted.

Table 28: Gross margin analysis - new varieties planted, intercropped with bananas, all other CSA practices adopted

			Units	Qty/ha	Price/unit USD	Y1	Y2	Y3	Y4	Y5	Y6 on
Benefits	Yield coffee		kg/ha			-	-	350	700	1,050	1,400
	Value		USD/kg			-	-	1.5	1.5	1.5	1.5
	Coffee income		**USD**					**525**	**1050**	**1575**	**2100**
	Yield bananas		kg/ha			-	7000	10000	10000	10000	10000
	Value		USD/kg			-	0.05	0.05	0.05	0.05	0.05
	Banana income		**USD**				**350**	**500**	**500**	**500**	**500**
	Total income		**USD**				**350**	**1025**	**1550**	**2075**	**2600**
Input costs	Base costs		USD/ha			624	624	624	624	624	624
	Savings on base costs		%	10%			-62	-62	-62	-62	-62
	Coffee seedlings	Y1	seedlings	2200	0.10	220	-	-	-	-	-
	ISFM (compost)	Y1-	tonnes	0	-	-	-	-	-	-	-
	SWC (contour/ terraces)	Y1	metres	400	-	-	-	-	-	-	-
	SWC (plant grass on contour)	Y1	metres	400	0.10	40	-	-	-	-	-
	SWC (cover crops)	Y1	metres	200	0.10						
	SWC rainwater harvesting	Y1	No.	4	-	-	-	-	-	-	-
	Agroforestry (trees)	Y1	seedlings	250	0.20	50	-	-	-	-	-
	Banana suckers	Y1	seedlings	1000	0.50	500	-	-	-	-	-
	Processing costs	Y3-	per kg	-	0.20	-	-	70	140	210	280
	sub total					**1434**	**562**	**562**	**562**	**562**	**562**
Margin over inputs						**-1434**	**-212**	**463**	**988**	**1513**	**2038**
Labour costs	Base costs		USD/ha	-	-	160	160	160	160	160	160
	Savings on base costs		%	5%				-8	-8	-8	-8
	ISFM (compost)	Y1-	days	5	2.5	13	13	13	13	13	13
	SWC (contour/ terraces)	Y1	days	20	2.5	50	-	-	-	-	-
		Y2-	days	5	2.5		13	13	13	13	13
	SWC (use grass as mulch)	Y3-	days	2	2.5			5	5	5	5
	SWC rainwater harvesting	Y1	days	4	2.5	10	-	-	-	-	-
		Y2-	days	1	2.5		3	3	3	3	3
	Agroforestry (trees)	Y1	days	25	2.5	63	63	63	63	63	63
		Y3-	days	10	2.5			25	25	25	25
	Additional hHarvesting and lo	Y3-	days/additi	4	2.50	-70	-70	-35	0	35	70
	Bananas	Y1	days	50	2.5	125					
		Y2-	days	10	2.5		25	25	25	25	25
	sub total					**350**	205	262	297	332	367
Total variable costs per ha			**USD per ha**			**700**	**410**	**524**	**594**	**664**	**734**
Margin over inputs and labour costs before loan repayments or levies						**-700**	**-60**	**501**	**956**	**1411**	**1866**
Total labour input			**days**			**140**	**82**	**105**	**119**	**133**	**147**
Returns to labour			**USD /ha**			**-1434**	**-212**	**463**	**988**	**1513**	**2038**
Returns to labour			**USD/ day**			**-10**	**-3**	**4**	**8**	**11**	**14**

Benefit cost ratios: Benefit cost ratios for the three scenarios have been compared based on a 10 year horizon based on a 10% discount rate.

Table 29: Benefit cost ratios over 10 years

	Scenario	#	Year										
			Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Total
Scenario 1	Base	Gross margin	266	266	266	266	266	266	266	266	266	266	2660
		Discounted gross margin	266	242	220	200	182	165	150	137	124	113	1798
	CSA + existing coffee	Gross margin	739	942	950	955	955	955	955	955	955	955	9315
		Discounted gross margin	739	856	785	717	652	593	539	490	445	405	6222
		B:C ratio	2.8	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5
Scenario 2	Base	Gross margin	266	266	266	266	266	266	266	266	266	266	2660
		Discounted gross margin	266	242	220	200	182	165	150	137	124	113	1798
	CSA + new coffee	Gross margin	-425	-335	76	531	986	1441	1441	1441	1441	1441	8038
		Discounted gross margin	-425	-305	63	399	673	895	813	739	672	611	4137
		B:C ratio	-1.6	-1.3	0.3	2.0	3.7	5.4	5.4	5.4	5.4	5.4	2.3
Scenario 3	Base	Gross margin	266	266	266	266	266	266	266	266	266	266	2660
		Discounted gross margin	266	242	220	200	182	165	150	137	124	113	1798
	CSA + new cofffee and bananas	Gross margin	-675	-35	526	981	1436	1891	1891	1891	1891	1891	11688
		Discounted gross margin	-675	-32	435	737	981	1174	1067	970	882	802	6342
		B:C ratio	-2.5	-0.1	2.0	3.7	5.4	7.1	7.1	7.1	7.1	7.1	3.5

Results Summary: Results are summarised below, providing gross margins per hectare, labour requirement, returns to labour and benefit cost ratios for each of the three scenarios compared with the base case, when coffee bushes are mature and yielding at or near maximum.

Table 30: Results summary at coffee maturity

Scenario	Yield per ha at coffee bush maturity kg per ha	Gross margin USD per ha	Labour required at coffee bush maturity days per ha	Returns to labour at coffee bush maturity USD per ha	Returns to labour at coffee bush maturity USD per day	Benefit/cost ratio
Base Case	700	266	64	426	7	-
Existing coffee plus CSA	1,400	1,099	120	1,398	12	4.2
New coffee plus CSA	1,400	1,416	137	1,258	9	2.2
New coffee plus CSA plus bananas	1,400	1,866	147	2,038	14	3.4
					Discount rate	**10%**

This clearly indicates an increase in overall productivity for the three scenarios over the base case. Despite an increase in labour, returns to labour per hectare and per day increase.

Replacement of existing coffee bushes remains an important decision for growers due the time taken for new bushes to reach peak yields as demonstrated by the lower benefit cost ratio shown in Scenario 2.

8. Lender financial impact model

8.1. Introduction

The key hypothesis of the climate-smart lending model is that business-as-usual agricultural loans are less profitable than climate-smart loans which incorporate requirements for climate-smart agricultural and land management practices into loan terms. Although this will always need to be assessed on a case-by-case basis, the purpose of this section is to create a generalised lender financial impact model which demonstrates the impact of climate-smart lending on bottom line performance and which can be extrapolated to new use cases.

8.2. Model assumptions

The underlying assumptions of this model are as follows:

- CSA farming practices improve farm yield
- CSA buffer or mitigate losses in the event of weather shock

Farmers take out loans against anticipated post-harvest profit (before input loan repayment), and must repay all loans, including input cost loans, from realised profit In the event of a yield shock, meaning a farmer may not have enough revenue to repay all loans and must therefore allocate available income uniformly across all creditors, resulting in a default experienced by all a farmer's creditors pro rata to the size of the credit issued to the farmer

8.3. Model outputs

Whilst the output of this exercise is the general model template for climate-smart lending for coffee, below are the summary outputs of the model showing improved cash position in the event of a 30% yield shock. The model projects (i) reduced savings on portfolio losses over time, and (ii) savings due to improvements in cost of capital due to the environmental return. This is because farmer loans are likely to increase in anticipation of increased earnings, and therefore larger defaults in the event of a crop-loss event.

Table 31: CSL Lender Impact

	Loan 1	Loan 2	Loan 3	Loan 4	Loan 5	Loan 6	Loan 7
Yield loss scenario	30%	30%	30%	30%	30%	30%	30%
Number of clients	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Loan book size (US$)	4,998,000	3,931,200	3,931,200	3,931,200	3,931,200	3,931,200	3,931,200
Portfolio loss with no climate-smart lending	**(950,857)**	**(1,600,000)**	**(1,600,000)**	**(1,600,000)**	**(1,600,000)**	**(1,600,000)**	**(1,600,000)**
Portfolio loss with climate-smart lending	**(1,148,350)**	**(793,520)**	**(705,744)**	**(633,927)**	**(574,080)**	**(523,440)**	**(480,034)**
Savings due to CSA practices	(197,493)	806,480	894,256	966,073	1,025,920	1,076,560	1,119,966
Cost of capital w/o climate-smart lending	20%	20%	20%	20%	20%	20%	20%
Cost of capital w climate-smart lending	8%	8%	8%	8%	8%	8%	8%
Annual interest savings (US$)	599,760.00	471,744.00	471,744.00	471,744.00	471,744.00	471,744.00	471,744.00
Cash position improvement with climate-smart-lending (US$)	**402,267**	**1,278,224**	**1,366,000**	**1,437,817**	**1,497,664**	**1,548,304**	**1,591,710**

9. ENVIRONMENTAL COST BENEFIT ANALYSIS

9.1. Introduction

Whilst the output of this exercise is the general model template for climate-smart lending for sugar this section presents the findings of a generalised or template environmental cost benefit analysis for sugar cane production under the terms of the proposed climate-smart credit product. The purpose of this is to (i) demonstrate that the terms of a climate-smart credit product creates valuable environmental benefits, and (ii) to provide a cost benefit analysis model template for creation of climate-smart credit products in specific contexts.

9.2. Model assumptions

Environmental cost benefit analysis estimates market and non-market values for ecosystem goods and services. We do not undertake this valuation, but instead use the accepted practice of value transfer to estimate values created by the implementation of land-use practice required by the climate-smart credit product. These values are obtained from the academic environmental economic research literature, which provides the ability to provide a dynamic set of environmental values in a dollar metric. Where the environmental economic literature does not provide adequate data, we conservatively assign a zero value.

We do not include yield benefits of the required measures to avoid double-counting.

9.3. Model outputs

The table opposite provides the summary outputs for the environmental cost benefit analysis. The net present value (NPV) of implementing the system is nearly US$ 30 over 7 years. Please note that as a template, this model uses dummy variables ahead of a site specific analysis, and also excludes farmer benefits which would be included in a full public cost benefit structure methodology.

Table 32: Template Environmental CBA Results

#	Benefits	0	1	3	4	5	6	7
1	Banana Suckers	57	57	57	57	57	57	57
2	Plant trees	13	13	13	13	13	13	13
3	Rainwater harvesting structures	40	40	40	40	40	40	40
4	Mulching with crop residues	30	30	30	30	30	30	30
5	Contour terracing	40	40	40	40	40	40	40
6	Crop rotation	1	1	1	1	1	1	1
7	Manure and compost spreading	25	-	-	-	-	-	-
8	Cover crops	12	12	12	12	12	12	12
9	Integrated soil fertility management through use of organic material with inorganic fertilisers at or before planting	4	4	4	4	4	4	4
10	Introducing an Integrated pest management programme	14	14	14	14	14	14	14
	Total Benefits (US$/ha)	179	154	154	154	154	154	154
	Additional Labour Costs	178.00	90.00	90.00	125.00	125.00	160.00	160.00
	Loan discounts	25.00	19.65	19.65	19.65	19.65	25.00	19.65
	Total Costs (US$/ha)	**203.00**	**109.65**	**109.65**	**144.65**	**144.65**	**185.00**	**179.65**
	Net Benefits (US$/ha)	**(24.27)**	**44.08**	**44.08**	**9.08**	**9.08**	**(31.27)**	**(25.92)**
	Discounted Net Benefits (US$/ha)	**(24.3)**	**40.1**	**33.1**	**6.2**	**5.6**	**(17.7)**	**(13.3)**
	NPV (US$/ha)	**29.8**						

ANNEX 1: AREA AND AVERAGE COFFEE YIELDS FOR PRODUCING COUNTRIES - 2017[49][50]

Country	Area (ha)	% of area	Yield (tonnes)	% of total yield	Yield (t/ha)
Brazil	1,800,398	16.61%	2,680,515	29.10%	1.49
Indonesia	1,253,796	11.57%	668,677	7.26%	0.53
Cote d'Ivoire	925,442	8.54%	103,514	1.12%	0.11
Colombia	798,358	7.36%	754,376	8.19%	0.94
Ethiopia	694,332	6.41%	471,247	5.12%	0.68
Mexico	638,603	5.89%	153,794	1.67%	0.24
Viet Nam	605,178	5.58%	1,542,398	16.74%	2.55
Honduras	505,115	4.66%	475,042	5.16%	0.94
India	449,357	4.15%	312,000	3.39%	0.69
Peru	423,545	3.91%	346,466	3.76%	0.82
Uganda	385,296	3.55%	209,325	2.27%	0.54
Guatemala	278,232	2.57%	245,441	2.66%	0.88
United Republic of Tanzania	187,517	1.73%	55,789	0.61%	0.30
Nicaragua	146,545	1.35%	128,111	1.39%	0.87
Venezuela	135,000	1.25%	46,650	0.51%	0.35
El Salvador	128,035	1.18%	39,460	0.43%	0.31
Kenya	114,700	1.06%	40,800	0.44%	0.36
Philippines	112,843	1.04%	62,078	0.67%	0.55
Cameroon	98,193	0.91%	30,984	0.34%	0.32
Dominican Republic	96,139	0.89%	15,241	0.17%	0.16
Costa Rica	84,133	0.78%	90,390	0.98%	1.07
Madagascar	81,943	0.76%	47,387	0.51%	0.58
Laos	80,890	0.75%	150,795	1.64%	1.86
Haiti	76,615	0.71%	39,537	0.43%	0.52
Democratic Republic of the Congo	76,362	0.70%	29,912	0.32%	0.39
Togo	56,334	0.52%	18,476	0.20%	0.33
Timor-Leste	54,506	0.50%	10,827	0.12%	0.20
Papua New Guinea	54,238	0.50%	58,840	0.64%	1.08
Angola	47,457	0.44%	15,436	0.17%	0.33
Thailand	45,038	0.42%	34,312	0.37%	0.76
China	40,496	0.37%	115,150	1.25%	2.84
Central African Republic	39,405	0.36%	9,355	0.10%	0.24
Rwanda	39,309	0.36%	17,824	0.19%	0.45
Guinea	39,077	0.36%	17,813	0.19%	0.46

[49] FAOSTAT, 2018. Statistical data base. Food and Agriculture Organisation of the United Nations, Rome, Italy. http://www.fao.org/faostat/en/#data/PP/ accessed 30th December 2018

[50]

Country	Area (ha)	% of area	Yield (tonnes)	% of total yield	Yield (t/ha)
Ecuador	37,260	0.34%	7,564	0.08%	0.20
Yemen	34,085	0.31%	19,514	0.21%	0.57
Bolivia	23,573	0.22%	21,181	0.23%	0.90
Cuba	19,867	0.18%	6,306	0.07%	0.32
Burundi	16,500	0.15%	14,000	0.15%	0.85
Sierra Leone	13,671	0.13%	35,720	0.39%	2.61
Panama	12,798	0.12%	5,730	0.06%	0.45
Myanmar	12,394	0.11%	8,546	0.09%	0.69
Equatorial Guinea	11,743	0.11%	4,272	0.05%	0.36
Congo	10,378	0.10%	3,197	0.03%	0.31
Sri Lanka	8,186	0.08%	5,437	0.06%	0.66
Zambia	7,727	0.07%	6,880	0.07%	0.89
Puerto Rico	6,937	0.06%	3,868	0.04%	0.56
Jamaica	6,874	0.06%	6,222	0.07%	0.91
Malawi	4,868	0.04%	8,420	0.09%	1.73
United States of America	2,910	0.03%	2,200	0.02%	0.76
Zimbabwe	2,673	0.02%	608	0.01%	0.23
Nepal	2,646	0.02%	466	0.01%	0.18
Liberia	2,558	0.02%	594	0.01%	0.23
Malaysia	2,076	0.02%	8,109	0.09%	3.91
Nigeria	1,198	0.01%	1,556	0.02%	1.30
Comoros	1,021	0.01%	140	0.00%	0.14
Mozambique	842	0.01%	793	0.01%	0.94
Dominica	788	0.01%	287	0.00%	0.36
Saint Vincent and the Grenadines	546	0.01%	184	0.00%	0.34
Guyana	520	0.00%	401	0.00%	0.77
Cambodia	460	0.00%	365	0.00%	0.79
Ghana	438	0.00%	727	0.01%	1.66
Paraguay	320	0.00%	442	0.00%	1.38
Gabon	280	0.00%	94	0.00%	0.34
Trinidad and Tobago	274	0.00%	39	0.00%	0.14
Benin	259	0.00%	50	0.00%	0.19
Cabo Verde	243	0.00%	47	0.00%	0.19
Suriname	214	0.00%	6	0.00%	0.03
Sao Tome and Principe	193	0.00%	12	0.00%	0.06
French Polynesia	101	0.00%	22	0.00%	0.22
Belize	69	0.00%	80	0.00%	1.16
Vanuatu	44	0.00%	26	0.00%	0.59
Samoa	43	0.00%	12	0.00%	0.28
New Caledonia	38	0.00%	5	0.00%	0.13

Country	Area (ha)	% of area	Yield (tonnes)	% of total yield	Yield (t/ha)
Guadeloupe	32	0.00%	31	0.00%	0.97
Martinique	29	0.00%	28	0.00%	0.97
Fiji	18	0.00%	9	0.00%	0.50
Tonga	11	0.00%	16	0.00%	1.45
Total/mean	**10,840,132**	**100 %**	**9,212,168**	**100%**	**0.73**
				Min	0.03
				Max	3.91

Annex 2: Coffee industry country profiles:

Brazil[51]

Brazil has dominated the global coffee market for over 150 years, contributing to one-third of the world's total coffee production. The country's leading position is mainly attributed to the country's large plantation area with beneficial climate to grow both Arabica and Robusta. Investments in technology is a major factor to drive the coffee industry including widespread use of clonal coffee planting. Brazil's leading position in the global coffee market has attracted significant numbers of buyers and traders from all over the world

Ethiopia[52] [53]

The agriculture sector is the backbone of Ethiopia's economy and livelihoods. The sector is particularly vulnerable to variability in rainfall and temperature. Climate-Smart Agriculture has focused on restoring degraded lands through soil and water conservation measures, agroforestry, farmer-managed natural regeneration (FMNR), area closures, and dissemination of improved varieties. Such CSA practices and technologies are largely supported by the government and its development.

Ethiopia is the world's seventh largest producer of coffee, and Africa's top producer, half being consumed locally. The total area used for coffee cultivation is estimated to be about 4,000 km^2 the exact size being unknown due to the fragmented nature of the coffee farms. There are four main types of coffee production systems forest, semi-forest, garden and plantation. The challenges faced by many producers include: poor infrastructure, old coffee trees, reliance on traditional cultural practices, scarcity of finance and limited use of inputs, all of which contribute to low-quality coffee. Farmers produce and market coffee through cooperatives, which provide production services including processing, developing producer/buyer linkages, warehouse services, quality promotion, training and education, and provision of credit and savings services to members. The Ethiopian Commodity Exchange provides a marketplace that compliments the role of cooperatives, providing a forum where buyers and sellers come together to trade. The Ethiopian Coffee Growers, Producers and Exporters Association is a members' association involved mainly in advocacy. The Jimma Agricultural Research Centre provides coffee research that provides technical support to coffee producers.

Indonesia [54]

The Coffee industry in Indonesia was initially established during Dutch colonisation. Climate and soil conditions are particularly suitable for growing Robusta, which although less valued than the Arabica still make Indonesia one of the top producers of coffee in the world. The crop covers some 1.25 million ha, more than 90% of which is grown by smallholders on farms averaging around one hectare. Some of this production is organic and many farmers' cooperatives and exporters are internationally certified to market organic coffee. However, the area of coffee is declining as farmers shift focus to oil palm, rubber and cocoa which all have higher yields on the international market.

[51] https://www.bizvibe.com/blog/coffee-industry-brazil-largest-producer-world/
[52] Climate-Smart Agriculture in Ethiopia. https://ccafs.cgiar.org/publications/climate-smart-agriculture-ethiopia
[53] Adekunle AA, Ellis-Jones J, Ajibefun I, Nyikal RA, Bangali S, Fatunbi O and Ange A., 2012. Agricultural innovation in sub-Saharan Africa: experiences from multiple-stakeholder approaches. Forum for Agricultural Research in Africa (FARA), Accra, Ghana.
[54] https://www.indonesia-investments.com/business/commodities/coffee/item186

Kenya[55 56]

Kenya agriculture is characterized by both very small landholdings (0.3–3 ha) and extremely limited irrigation (less than 0.16% of arable land). This poses the greatest challenge on sustainably intensifying agricultural productivity. However, intensive agriculture using sustainable land management (SLM) practices with basic irrigation presents an opportunity for redressing this issue.

While continuing to rely on traditional practices, Kenyan farmers are also embracing new and improved technologies, as evident in dairy and horticulture production systems. These value chains have the potential to generate enough revenue to enable farmers to invest in promising CSA interventions, such as the use of forage (improved feeding systems) and irrigation (water management practices). Declining productivity of many staples (particularly wheat and maize) is alarming. However, there is also great potential to redress this through investing in CSA interventions that would increase productivity and mitigate climate change risks, such as new improved seeds, drought-resistant seeds, alley cropping, coupled with small-scale irrigation or production diversification.

Targeted CSA interventions, such as the inclusion of agroforestry in the cultivation of fruit trees and vegetables or keeping small ruminants and poultry, have the potential to reduce the prevalence of undernourishment from the current rate (24%).

Although coffee is a high-value commodity and a major contributor to the economy of Kenya, many smallholder producers remain poor because of low productivity. A major reason is losses due to pests and diseases such as coffee berry disease and coffee leaf rust. In an attempt to boost productivity and incomes, researchers have developed coffee varieties resistant to these diseases, which have been shown to cut production costs by up to 60%.

The challenge now is to make the improved varieties readily available to smallholder farmers in both countries. Demand for affordable seedlings is high, but the current capacity of research institutions to supply them is limited. “Weaning” nurseries are being established to give farmers access to tissue culture planting material with staff at co-operatives being trained in the management of these nurseries, and a training-of-trainers course is encouraging dissemination and ensures that quality standards are met throughout the production process. In addition, research-based advisory services are being strengthened. Laboratories for fertilizer and pesticide analysis are being upgraded and staff trained to carryout soil and leaf sampling and analysis. A combination of new planting materials along with improved fertilizer use and better pest control measures is being promoted. Information relating to Integrated Pest Management practices and pesticide recommendations are being disseminated through training sessions and trade and agricultural shows.

Uganda[57 58]

Agriculture in Uganda is mainly rain fed and based on subsistence farming; challenging the sustainability and food security of farmers, and making the sector highly vulnerable to weather variability, climate hazards (particularly droughts) and climate change. Crop diversification, small-scale irrigation, permanent planting basins, green manuring, conservation agriculture (rotations, intercropping, mulching and reduced tillage) and agroforestry are among the most common climate smart practices being promoted in the country to improve productivity, food availability and resilience to climate hazards.

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[55] World Bank; CIAT. 2015. Climate-smart agriculture in Kenya. CSA Country Profiles for Africa, Asia, and Latin America and the Caribbean Series. Washington D.C.: The World Bank Group. Climate-Smart Agriculture in Kenya. https://ccafs.cgiar.org/publications/climate-smart-agriculture-kenya

[56] CABI, 2018. Boosting coffee productivity in Kenya and Malawi. ACP Science and Technology Programme II, funded by the European Development Fund. CABI and Coffee Research Institute, Kenya, Lunyangwa Agricultural Research Station

[57] Uganda Coffee Development Authority https://ugandacoffee.go.ug/fact-sheet

[58] Climate-Smart Agriculture in Uganda. https://ccafs.cgiar.org/publications/climate-smart-agriculture-uganda

The Uganda Coffee Development Authority focus is to facilitate increase in quality coffee production, productivity, and consumption working with stakeholders who include; Farmers, nursery operators, processors, exporters and Coffee traders.

There are 112 Districts Coffee Districts, 88 growing Robusta only, 15 Arabica only and 9 growing both Robusta and Arabica. The Authority offers a broad range of coffee development services targeting 93 of these Districts and 1.7million households. These include generation of clean planting material, promotion of a re-planting program and yield improvements of existing old coffee trees, enhancing use of Good Agricultural Practices, supporting pest and diseases management and use of agro-inputs as well as promoting coffee growing in new areas, especially in Mid-Northern Uganda. At the same time it operates a Quality Assurance and Regulation services aimed at improving the quality at all stages of the coffee value chain. This includes, training and skills development of the industry stakeholders. In 2017/18 key industry stakeholders included 92 export companies, 36 export grading Plants, 537 dry processing plants, 22 washing stations, 17 roasters producing 20 local coffee brands. 18% of export earnings are derived from coffee with 3% of Uganda's exports being verified or certified "sustainable" below the global average of 8%.

Vietnam[59]

Vietnam remains the second of the top coffee producing countries. In 2017-18 season, Vietnam produced over 29.5 million bags of coffee beans. Over the last 30 years, the country's rapid growth in agricultural production has transformed the country's socioeconomic status: alleviating national food insecurity, reducing poverty, fostering agricultural exports and providing livelihoods to nearly half of the labour force nationwide. Viet Nam outperforms its neighbouring countries in Southeast Asia in its productivity including coffee. But the substantial growth in agricultural production has come at significant environmental cost. Intensive use of chemical fertilizers, pesticides and water to boost productivity has made agriculture the second largest source of greenhouse gas (GHG) emissions after energy. Changing business as usua agricultural production practices to climate-smart and environmentally sustainable practices will help to overcome the challenges associated with climate change in the agricultural sector. The relatively low level of technology use among farmers highlights that several challenges and barriers to adoption persist. Barriers often relate to low availability of required inputs (such as seeds for improved varieties, or water scarcity during droughts), high costs of installation (e.g. of improved irrigation facilities) with limited access to credit and markets, high labor costs and a limited level of technical knowledge and skills. Addressing those barriers will be a key requirement for successful out-scaling of CSA practices.

Cote d'Ivoire (Ivory Coast)[60]

Coffee mostly Robusta production is the second largest export commodity of the country. The crop was introduced in the 19th century with primarily French companies investing in the sector. Production peaked in 2000 and subsequently declined over more than a decade of upheaval in the country. The production continued to decline even after the restoration of peace and stability attributed to persistently low coffee prices brought about continued neglect of coffee farms and conversion to other crops. However in 2014, the Ministry of Agriculture announced a new annual production targets by 2020.

[59] Climate-Smart Agriculture in Viet Nam. https://ccafs.cgiar.org/publications/climate-smart-agriculture-vietnam
[60] Bayetta Bellachew, 2009. An Overview of the Current Status of Coffee Production in Some Coffee Producing Areas of Cote d'Ivoire: A brief Field Visit Report. African Coffee Research Network, Inter-African Coffee Organization, Abidjan, Cote d'Ivoire.

ANNEX 3: CLIMATE SMART MANAGEMENT PRACTICES FOR COFFEE

CSA Practice		Detail	Benefits for the environment	Benefits for the grower	Challenges for the grower
Improved Coffee varieties	Plant improved varieties - more tolerant of temperature and drought as well as pests and diseases	Improved seedlings can be self-grown or purchased from an approved nursery. These might be grown from improved seed, cloned material or be grafted	Many farmers continue to use traditional and old low yielding old varieties, unsuitable for changing climate conditions	Improved yields, improved quality, better pest and disease control	Sourcing suitable material as it may be unavailable or in short supply
Integrated soil fertility management	Make compost and apply to coffee	5 kg of compost should be mixed with the soil when each coffee seedling is planted. Basal fertiliser can be applied at the same time	Many soils are showing signs of decreasing soil health due to low organic matter content	Increased production with a reduced need for inorganic fertiliser	Biomass and labour availability
Soil and water conservation	Construct contours and terraces	These are especially important when coffee is grown on steep or sloping land. The distance between contours will be smaller on steeper fields and will not be necessary of slopes less than 2%.	Designed to reduce soil erosion and increase capture of run-off rainfall during high rainfall intensity events	Increased production through improved soil fertility and soil moisture availability	Labour availability
	Plant grass on contours/terraces	The specie used should be suitable for the agro-environment and not be allowed to compete with coffee growth or quality	Designed to stabilise the contours/terraces as well as providing biomass that can be used for compost, livestock feed and mulch material	Improved stability of contours/terraces which are better able to withstand heavy rainfall and therefore reduce maintenance costs	Plant and labour availability

CSA Practice		Detail	Benefits for the environment	Benefits for the grower	Challenges for the grower
	Cut grass and mulch around coffee trees	As the grass mature, it can be cut in and used as mulch material. If there is insufficient mulch can be brought from outside the field	Designed to protect the soil from high temperatures, water run-off and soil erosion	Mulch is available in situ and need to be carried to the field	Labour requirement
	Plant cover crops	Alternative species of cover crops can be planted between coffee plants to provide a ground cover that will suppress weeds. Care must be taken to ensure that the cover crop does not compete with the coffee tree	Cover crops will protect against soil erosion, reduce soil temperatures as well as suppressing weed growth, but may compete with the coffee for soil moisture in dry periods.	Can be used as a mulch as well reducing labour for weeding	Plant and labour availability
	Establish rainwater harvesting structure linked to contours/terraces	Opportunity should be used to divert rainfall from run-off areas such as paths and roads to water to storage structures within the coffee field.	Designed to provide opportunity to collect run-off rainfall to increase soil moisture availability during dry periods	Increased production	Labour availability
Trees	Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	A number of different tree species are suitable for planting in coffee fields or on field boundaries designed to provide shade, windbreaks, erosion control and biomass for	Improved micro-climate for coffee production	Biomass availability increased and more sustainable production	Plant and labour availability

CSA Practice		Detail	Benefits for the environment	Benefits for the grower	Challenges for the grower
		fuel, fodder. Some fruit trees are also suitable.			
	Intercrop with bananas where appropriate	In parts of some countries (Uganda, Rwanda, Tanzania and Kenya) interplanting with bananas is becoming a recognised practice	Improved micro-climate for coffee production	Biomass availability increased and more sustainable production	Slight reduction in coffee yields may occur
Integrated pest and disease management		Use of multiple pest and disease management tactics to prevent economically damaging out-breaks	Reduced risks to human health and the environment	Reduced costs of pest and disease control	Knowledge availaibility

ANNEX 4: THE IMPACT OF CSA COFFEE MANAGEMENT PRACTICES[61]

1. Improving the resilience of natural resource use (farm level biodiversity, groundwater availability, soil erosion, plant available nutrients, infiltration of water into the soil, soil microbial diversity soil aggregation and soil water holding capacity)
2. Reducing the risks associated with climate change (increased temperature, intra-seasonal droughts, in season droughts, shortened growing season, increased rainfall intensity and unpredictable seasons)
3. Mitigating the effects of some of the causes of climate change (change in land use, emission from inputs, carbon sequestered in the soil, carbon sequestered in biomass, N20 emissions, and CH4 emissions)
4. Increasing productivity (yield, yield variability, labour and income)
5. Quantification of the impact of CSA practice on productivity (farmer benefits and costs)

[61] Derived from Bell P, Namoi N, Lamanna C, Corner-Dollof C, Girvetz E, Thierfelder C, Rosenstock TS. 2018. A Practical Guide to Climate-Smart Agricultural Technologies in Africa. CCAFS Working Paper no. 224. Wageningen, the Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Available online at: www.ccafs.cgiar.org

Table 33: The impact of coffee CSA practice on the resilience of natural resource uses

CSA practice			Farm level biodiversity	Groundwater availability	Soil erosion	Plant available nutrients	Infiltration of water into the soil	Soil microbial diversity	Soil aggregation	Soil water holding capacity
Improved Coffee varieties	1	Plant improved varieties - more tolerant of temperature and drought as well as pests and diseases	-	-	-	-	-	-	-	-
Integrated soil fertility management	2	Make compost and apply 5 kg to each coffee plant annually			+	+++	+++	+++	+++	+++
Soil and water conservation	3	Construct contours and terraces*	+++	+++	+++	+++	+++	+++	+++	+++
	4	Plant grass on contours/terraces*	-	-	+++		+	+	-	+
	5	Cut grass and mulch around coffee trees			++	+	++	+	+	++
	6	Plant cover crops	+		+++	++	++	++	++	++
	7	Establish rainwater harvesting structure linked to contours/terraces**		++	++	+	+++			+++
Agro-forestry	8	Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	+++	++	++	+++	+++	++	+	++
	9	Intercrop with bananas where appropriate	+++	++	++	+++	+++	++	+	++
Integrated pest and disease management	10	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	+++	++	++	+++	++	+++	+++	++

* greatest on steeper slopes
** especially on areas without irrigation

-	no effect
+	small effect
++	intermediate effect
+++	large effect

Table 34: CSA coffee practices impact on risks associated with climate change

CSA practice			Increased temperature	Intra-seasonal droughts	Inter-seasonal droughts	Shortened growing season	Increased rainfall intensity	Unpredictable seasons
Improved Coffee varieties	1	Plant improved varieties - more tolerant of temperature and drought as well as pests and diseases	++	++	++	++	-	++
Integrated soil fertility management	2	Make compost and apply 5 kg to each coffee plant annually	-	-	-	-	-	-
Soil and water conservation	3	Construct contours and terraces*	-	+++	+++	+++	+++	+
	4	Plant grass on contours/terraces*	-	-	-	-	+++	-
	5	Cut grass and mulch around coffee trees	++	++	++	++	++	++
	6	Plant cover crops	+	+	+	+	+++	+
	7	Establish rainwater harvesting structure linked to contours/terraces**	-	++	+	++	+	+
Agro-forestry	8	Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	+++	+++	+++	+++	+++	+++
	9	Intercrop with bananas where appropriate	++	++	++	++	++	++
Integrated pest and disease management	10	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	++	++	++	++	++	++

* greatest on steeper slopes
** especially on areas without irrigation

-	no effect
+	small effect
++	intermediate effect
+++	large effect

Table 35: The impact of coffee CSA practices on mitigation of the factors causing climate change

Climate smart agricultural practice			Change in land use	Emission from inputs	Carbon sequestered in the soil	Carbon sequestered in biomass	N20 emissions	CH4 emissions
Improved Coffee varieties	1	Plant improved varieties - more tolerant of temperature and drought as well as pests and diseases	+	-	-	-	-	-
Integrated soil fertility management	2	Make compost and apply 5 kg to each coffee plant annually	+	-	+++	+++	+	-
Soil and water conservation	3	Construct contours and terraces*	+	-	+	-	-	-
	4	Plant grass on contours/terraces*	++	-	+	+	+	-
	5	Cut grass and mulch around coffee trees	-	-	++	-	+	-
	6	Plant cover crops	++	++	+	-	-	-
	7	Establish rainwater harvesting structure linked to contours/terraces**	+	-	-	-	-	-
Agro-forestry	8	Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	+++	-	++	+++	-	-
	9	Intercrop with bananas where appropriate	+++	-	++	+++	-	-
Integrated pest and disease management	10	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	++	++	-	-	+	+

* greatest on steeper slopes
** especially on areas without irrigation

-	no effect
+	small effect
++	intermediate effect
+++	large effect

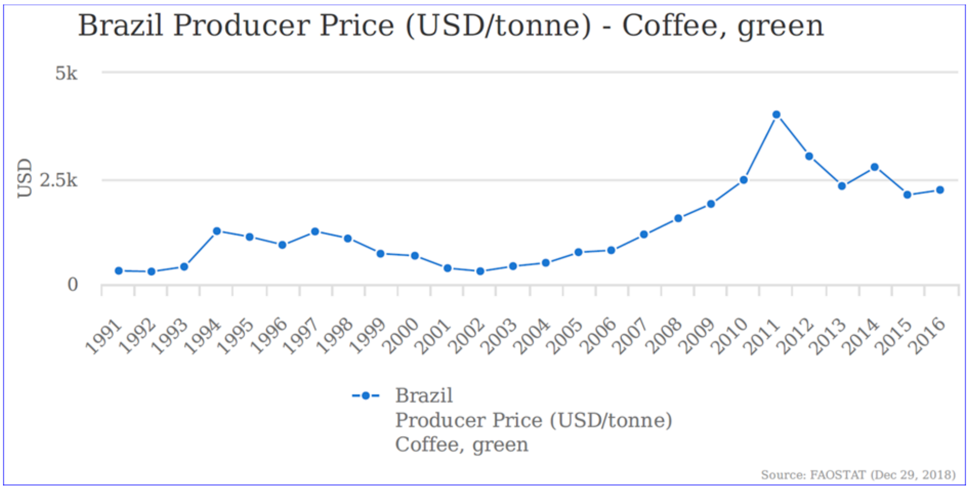
Table 36: The impact of coffee CSA practices on productivity

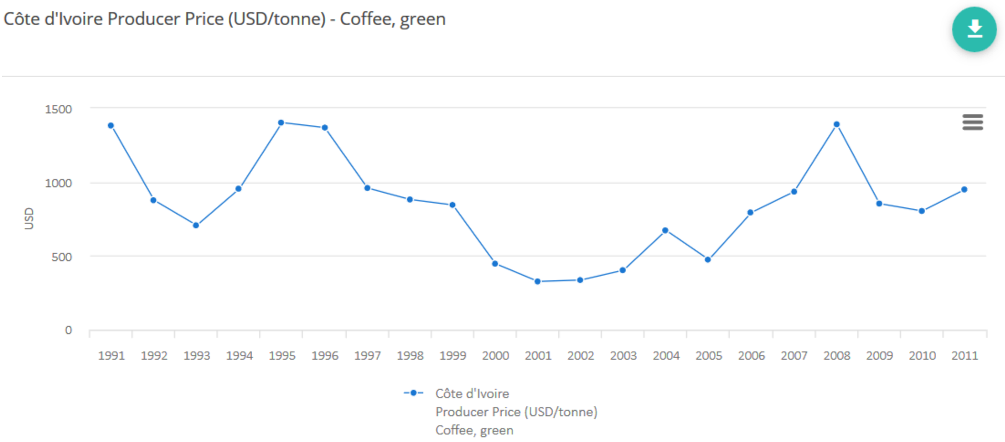
Climate smart agricultural practice			Yield	Yield variability	Labour	Income
Improved Coffee varieties	1	Plant improved varieties - more tolerant of temperature and drought as well as pests and diseases	+++	+++	-	+++
Integrated soil fertility management	2	Make compost and apply 5 kg to each coffee plant annually	+++	+++	-	+++
Soil and water conservation	3	Construct contours and terraces*	+++	+++	+++	+++
	4	Plant grass on contours/terraces*	+++	+++	+++	+++
	5	Cut grass and mulch around coffee trees	+++	+++	+++	+++
	6	Plant cover crops	++	++	++	++
	7	Establish rainwater harvesting structure linked to contours/terraces**	+++	+++	+++	+++
Agro-forestry	8	Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	+++	+++	+++	+++
	9	Intercrop with bananas where appropriate	++	++	-	+++
Integrated pest and disease management	10	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	+++	+++	++	++

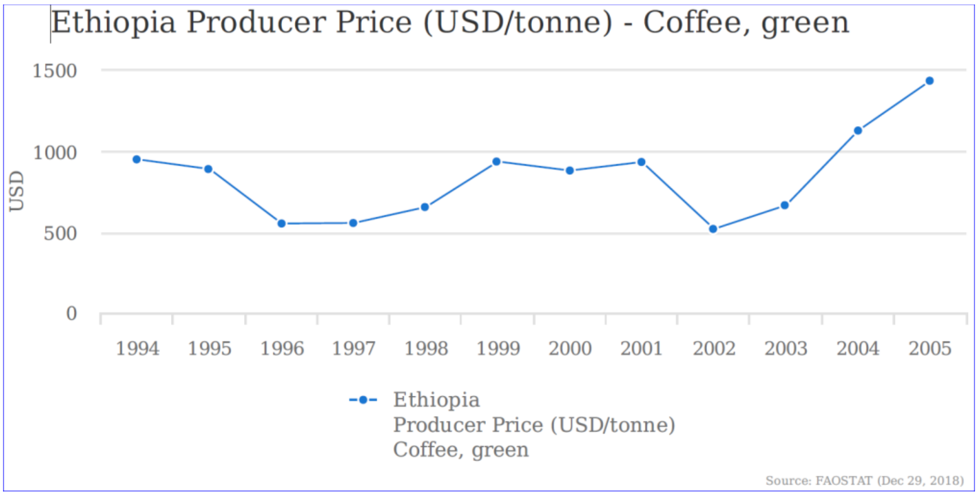
** greatest on steeper slopes*
*** especially on areas without irrigation*

-	*no effect*
+	*small effect*
++	*intermediate effect*
+++	*large effect*

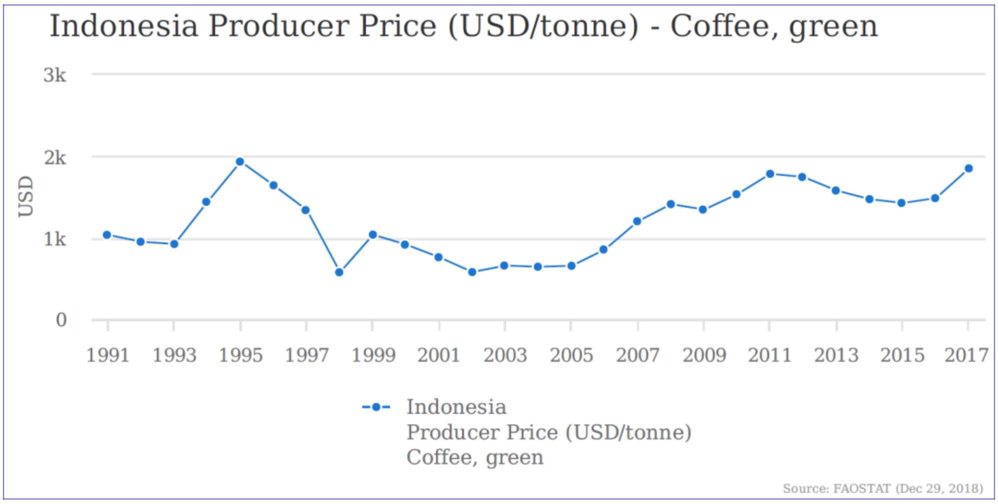
ANNEX 5: GREEN BEAN COFFEE PRICES (1991-2016) - BRAZIL, ETHIOPIA, INDONESIA, KENYA, VIETNAM [62]

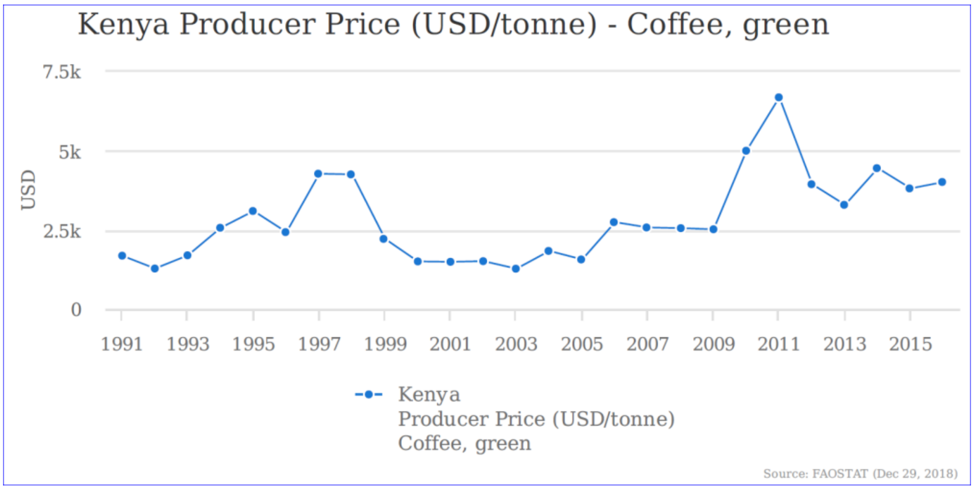


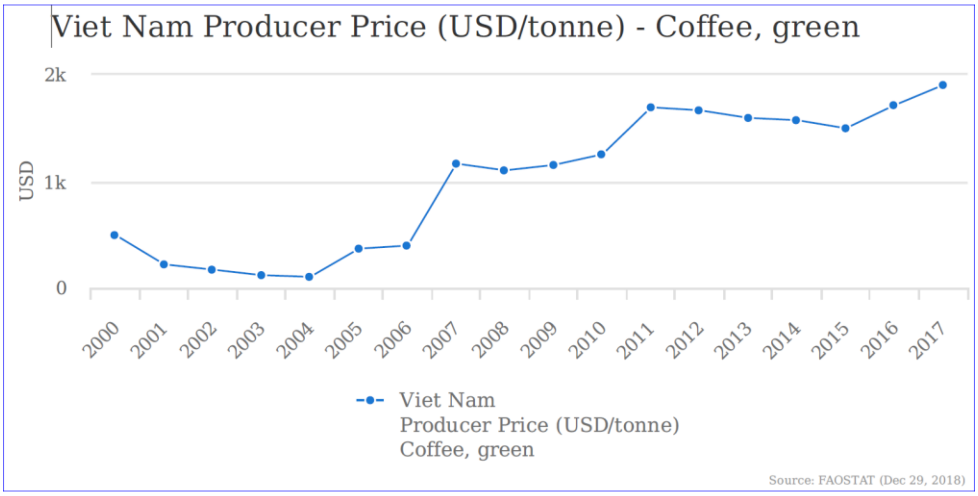




[62] FAOSTAT, 2018. Statistical data base. Food and Agriculture Organisation of the United Nations, Rome, Italy. http://www.fao.org/faostat/en/#data/PP/visualize accessed 29th December 2018


Indonesia Producer Price (USD/tonne) - Coffee, green
3k
2k
1k
0
USD
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017
Indonesia
Producer Price (USD/tonne)
Coffee, green
Source: FAOSTAT (Dec 29, 2018)


Kenya Producer Price (USD/tonne) - Coffee, green
7.5k
5k
2.5k
0
USD
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Kenya
Producer Price (USD/tonne)
Coffee, green
Source: FAOSTAT (Dec 29, 2018)


Viet Nam Producer Price (USD/tonne) - Coffee, green
2k
1k
0
USD
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Viet Nam
Producer Price (USD/tonne)
Coffee, green
Source: FAOSTAT (Dec 29, 2018)