TEMPLATE SUGAR CANE CLIMATE-SMART CREDIT PRODUCT

F3 Life

December 2018

1. Executive Summary

Introduction

The purpose of this document is to establish a generalised "climate-smart credit product" for small scale sugar 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.

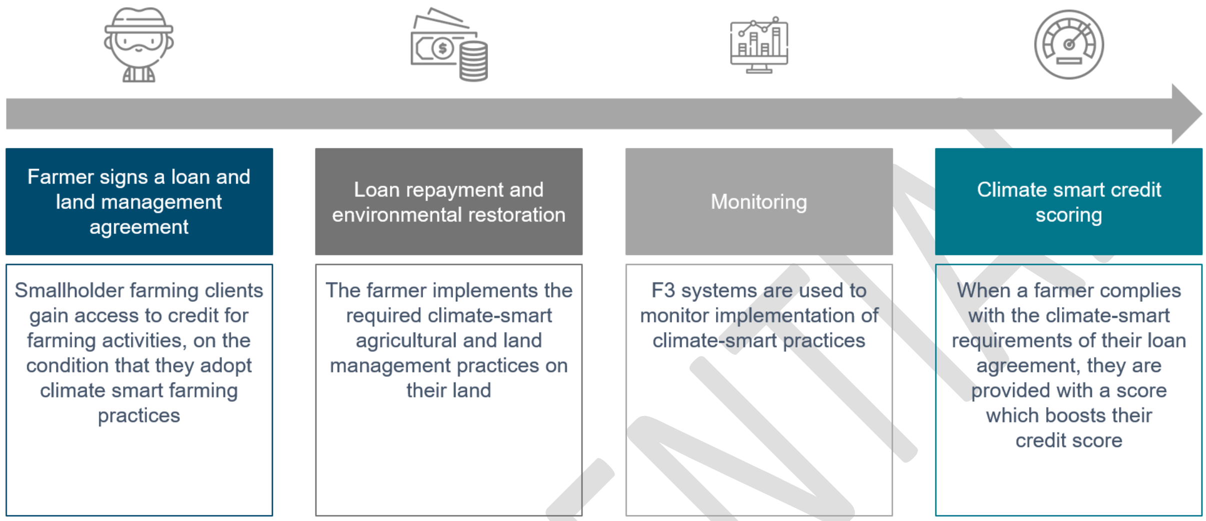

FIGURE 1: CLIMATE-SMART LENDING PROCESS

Growing conditions for sugar cane vary according to agro-ecological context. Therefore, the climate-smart credit product requirements presented in this document are generalised, ie 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 sugar product and related models which can be easily adapted for use with specific application.

The purpose of this document is <u>not</u> to propose interest rates and appropriate loan tenor for loans for small scale sugar 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 sugar growers, the agricultural economic analysis in this document would serve as the basis (only) for the loan product to be developed.

Climate risks to sugar production

Impact studies of climate change on sugar production are largely focused on Brazil, Africa and Australia, with less focus on other major sugarcane regions such as India, Thailand, China, Pakistan, or Mexico[1]. Available studies are diverse and point largely to the chief risks posed by climate change to sugar 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

[1] Linnenluecke, M. K., Nucifora, N., & Thompson, N. (2018). Implications of climate change for the sugarcane industry. WIREs Climate Change, 9. https://doi.org/10.1002/wcc.498

intensity[2,3]. Reductions of sugar production of 20-40% globally due to climate change are estimated, but there has been limited research on this topic to date. A further risk is that declining yield associated with climate change results in extensification of production and associated development of forest areas to meet growing sugar demand[4].

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[5]. 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 sugar cane caused by the likely impacts of climate change listed at (i) to (v) above.

Climate resilient / sustainable crop and land management measures for sugar cane production

Certain established, proven and de-risked sustainable crop and land management practices are widely used for improving sugar cane yield. These measures create agronomic benefit for crop production, and for this reason are also appropriate in mitigating the impacts of climate change on sugar cane production. Measures proposed in this report are designed to be implemented over successive loan cycles, starting with a cane establishment or plant crop and being continued during successive ratoon crops. A ratoon crop is a new crop that grows from the stubble of the crop already harvested. The figure opposite sets out the climate-smart requirements for a sugar climate-smart credit product.

Since farmers are likely to have different fields or blocks at different stages in the production cycle, this is intended to encourage the adoption of new practices as experience is gained.

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

The proposed 19 CSA practices required under CSA Loans 1-4 in Figure 1 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.

(a) CSA-related yield increases

Yields will increase over time as soil organic matter builds, soil health is restored and soil conservation measures become effective. Yield improvements, derived from research and/or practical experience in Australia[6], Brazil[7] and South Africa[8], are estimated to increase from a base of 50 tonnes ha^{-1} by between 5% and 20% over each successive loan cycle (53-62 tonnes ha^{-1} (Loan 1) to 70-120 tonnes ha^{-1} (Loan 4).

Increases will be highest where the impact of CSA practices is greatest. The impact of CSA practices will be greatest where yield levels are declining due to poor soil health and soil erosion, often on steeper slopes with poor soil conservation practices and under rainfed conditions.

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[2] Eg Singh B, El Maayar M. Potential impacts of greenhouse gas climate change scenarios on sugar cane yields in Trinidad. Trop Agric 1998, 75:348–354
[3] Cheeroo-Nayamuth FB, Nayamuth RAH. Climate change and sucrose production in Mauritius. In: Proceedings of the International Society of Sugar Cane Technologists, Brisbane, Australia, 17 September-21 September 2001.
[4] Phalan B, Bertzky M, Butchart SHM, Donald PF, Scharlemann JPW, Stattersfield AJ, Balmford A. Crop expansion and conservation priorities in tropical countries. PLoS One 2013, 8:e51759.
[5] Linnenluecke, M. K., Nucifora, N., & Thompson, N. (2018). Implications of climate change for the sugarcane industry. WIREs Climate Change, 9. https://doi.org/10.1002/wcc.498
[6] Sugar Research Australia, 2018 Sugarcane Advisors Information Kit. Published by Sugar Research Australia Limited. ISBN: 978-0-949678-29-4.
[7] UNICA, 2018. Best practices. The Brazilian Sugarcane Industry Association and the Brazilian Trade and Investment Promotion Agency https://sugarcane.org/best-pratices/
[8] SASRI, various. Sugar cane information Sheets. South African Sugar Research Industry.

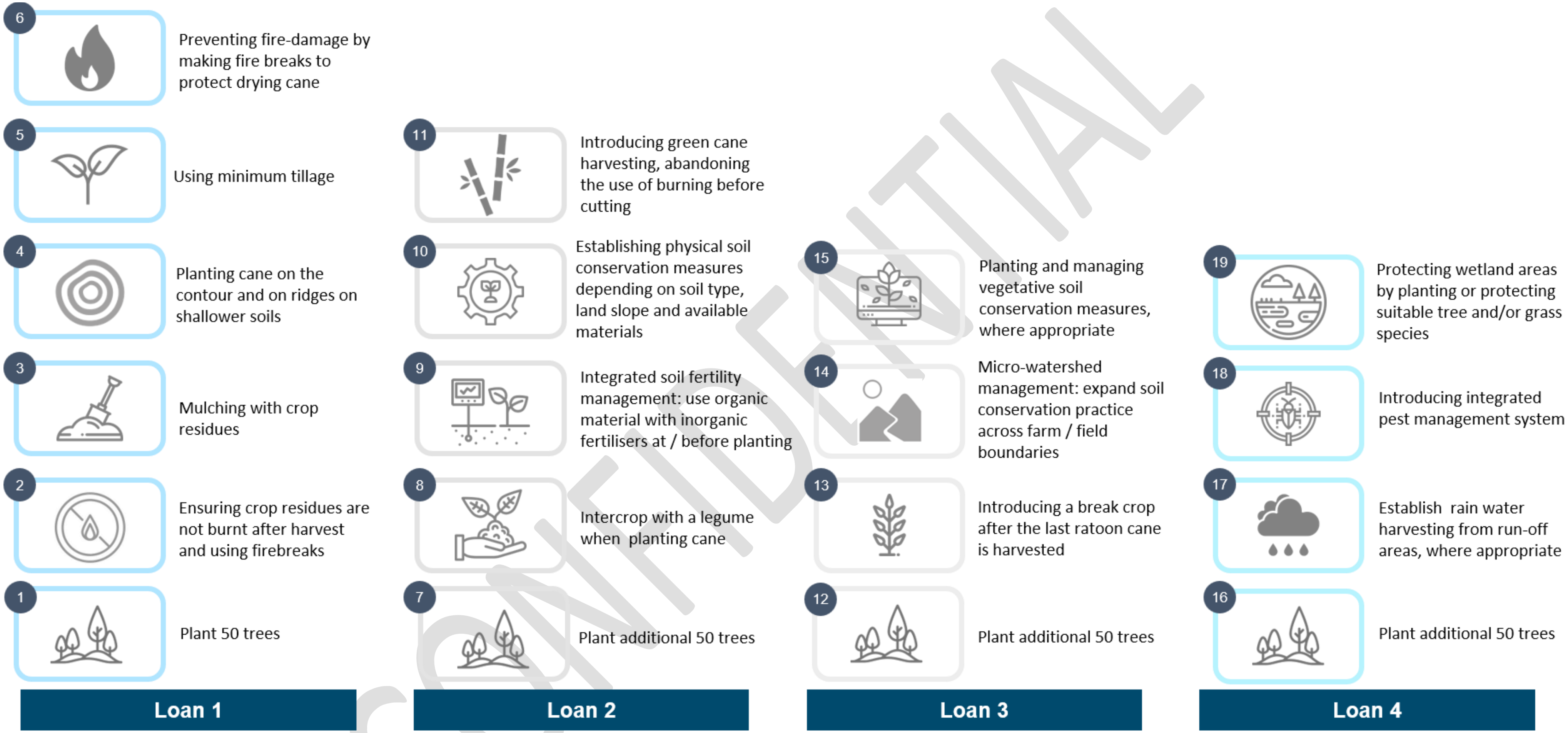

FIGURE 2: CLIMATE-SMART CREDIT PRODUCT FOR SMALL SCALE SUGAR GROWERS (ACTIVITIES REQUIRED/HA OF LAND)

(b) CSA-related cost reductions

Estimates indicate that considerable cost savings[9] can be made by adopting CSA practices, for: (i) fertiliser: 30-50% reduction; (ii) water requirements for irrigation: 30% reduction; (iii) fuel consumption for land preparation and planting: 60% reduction; and (iv) pesticide applications: 20% reduction.

(c) CSA-related risk mitigation

Agricultural research has not yet meaningfully attempted to quantify benefits of CSA in terms of mitigating sugar-grower losses associated with climate-change related weather events. Agronomy suggests these 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 sugar CSA and land-management requirements

Proposed CSA measures achieve their objectives by (i) reducing or eliminating soil erosion; (ii) improving soil fertility; (iii) reducing the use of inorganic in favour of organic fertilisers; (iv) reducing the use of agrochemicals (as a cost reduction measure); (v) reducing or eliminating pre-harvest cane field burning, and (vi) protecting or recovering land alongside streams and riverbanks. Precise estimates, together with an explanation of their agronomic basis are explained more fully in the body of this report.

Sugar farmer climate-smart lending cost-benefit analysis

As part of our climate-smart credit product design process, we undertake a 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[10].

Recent studies[11] 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 cost benefit ratios associated with deploying the climate-smart credit product:

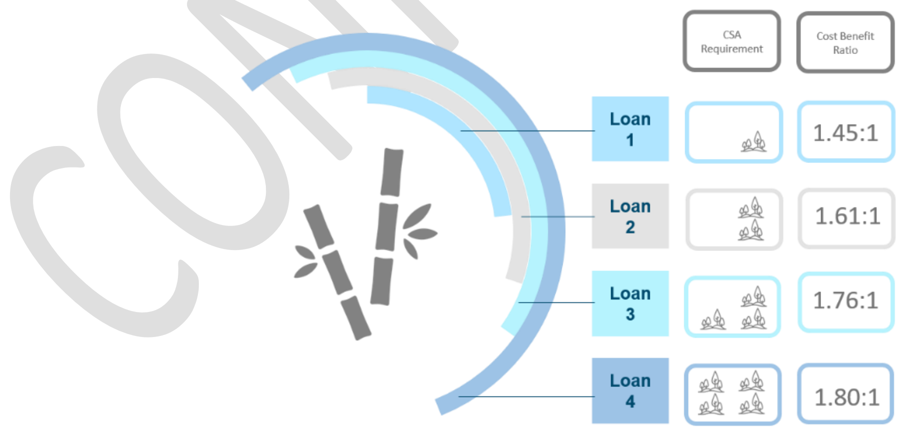

FIGURE 3: CLIMATE-SMART LENDING COST BENEFIT RATIOS

[9] Brian Sims and Josef Kienzle, 2015. *Mechanization of Conservation Agriculture for Smallholders: Issues and Options for Sustainable Intensification.* Environments 2015, 2, 139-166; ISSN 2076-3298. www.mdpi.com/journal/environments

[10] 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

[11] Eg 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

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

Sugar "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 that climate-smart lending is likely to have an appreciable effect on the cash position of the agri-lender.

TABLE 1: CLIMATE-SMART LENDING LENDER CASH POSITIONS

	Yield Loss			
Cash Position Improvement with CSL	10%	20%	30%	40%
Lending (US$/10,000 clients)	702,105	1,120,605	1,539,105	1,539,105

Sugar "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 1,830.

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2. AN INTRODUCTION TO SUGAR CANE AND CLIMATE RISKS TO PRODUCTION

2.1. Introduction[12]

Sugar cane (*Saccharum officinarum L.*) is a global agricultural crop of commercial significance, with the potential to contribute to developmental and societal needs of the many developing countries that grow it. It accounts for about 80% of the sugar produced worldwide; the remaining 20% being produced from sugar beet. Some 20 million ha of sugarcane are grown by over 100 countries, major producers including: Brazil-51% of the total, India-25%, China-17%, Thailand-7%, Pakistan-6%, Mexico-4%, Indonesia-2%, Australia-2%, Cuba-2%, Colombia-2%, Philippines-2%, United States of America-2%, Argentina-2%, Guatemala-1%, Viet Nam-1%, South Africa-1%, with 25 countries in Africa contributing 9%. 83% of Africa's contribution comes from sub-Saharan Africa's 9%, which with its tropical and subtropical climate, is well-suited to expanding its production.

The area and average cane yields for countries producing cane sugar are shown in Annex 1. Some individual country sugar industry profiles are shown in Annex 2. These include Australia, Ethiopia, Indonesia, Kenya, Malawi, South Africa and Zambia.

Sugar cane is considered one of the best converters of solar energy into biomass and sugar, with a conversion efficiency of more than 2%, compared to maize at 0.2%. Compared to the three major cereal crops (maize, rice and wheat), which collectively occupy 41% of the world's cropland, sugarcane is the highest-yielding crop in tonnage worldwide (over two billion tonnes) while occupying only 2% of the world's cropland.

Sugar cane is emerging as a versatile resource, diversifying into a wide range of value-added products that go beyond sugar, particularly bio-ethanol, bio-electricity, bio-plastics, bio-hydrocarbons and bio-chemicals. Ethanol production does not necessarily require additional cane production and does not impact sugar production, because it can be produced from sugarcane bagasse, an underutilized by-product of sugar factories. Ethanol can be produced without increasing the area planted with sugarcane and therefore without competing with food security.

The development of high sugar and biomass-yielding sugarcane varieties with resistance to disease is essential for improving the value and sustainability of the sugarcane industry.

Although sugarcane is often grown on large estates owned either by milling companies or large commercial farmers, the role of small scale cane growers (SSGs) producing on a contract basis for sugar mills is becoming increasingly important especially in developing countries. However, the sugar supply chain involves thousands of companies around the world, including producers, mills, refiners, wholesalers, traders and retailers. The role of SSGs is restricted to the start of the chain, with most value added to through processing and marketing activities, by actors which have the capacity to invest in the capital-intensive technologies needed to process sugar.

2.2. Climate Risks to Sugar Cane Production

The risks to sugar cane associated with climate change are increased droughts both between and within growing seasons and consequently shortened growing seasons, increased rainfall intensity increased temperatures and more unpredictable seasons. These means that cane yields become more unpredictable and likely to be reduced. In worst case scenarios, 100% losses are possible.

[12] FAO, 2018. http://www.fao.org/land-water/databases-and-software/crop-information/sugarcane/en/

Impact studies of climate change on sugar production are largely focused on Brazil, Africa and Australia, with less focus on other major sugarcane regions such as India, Thailand, China, Pakistan, or Mexico[13]. Available studies are diverse and point largely to the chief risks posed by climate change to sugar 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[14,15]. Reductions of sugar production of 20-40% globally due to climate change are estimated, but there has been limited research on this topic to date. A further risk is that declining yield associated with climate change results in extensification of production and associated development of forest areas to meet growing sugar demand[16].

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[17]. 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 sugar cane caused by the likely impacts of climate change listed at (i) to (v) above.

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13 Linnenluecke, M. K., Nucifora, N., & Thompson, N. (2018). Implications of climate change for the sugarcane industry. WIREs Climate Change, 9. https://doi.org/10.1002/wcc.498

14 Eg Singh B, El Maayar M. Potential impacts of greenhouse gas climate change scenarios on sugar cane yields in Trinidad. Trop Agric 1998, 75:348–354

15 Cheeroo-Nayamuth FB, Nayamuth RAH. Climate change and sucrose production in Mauritius. In: Proceedings of the International Society of Sugar Cane Technologists, Brisbane, Australia, 17 September-21 September 2001.

16 Phalan B, Bertzky M, Butchart SHM, Donald PF, Scharlemann JPW, Stattersfield AJ, Balmford A. Crop expansion and conservation priorities in tropical countries. PLoS One 2013, 8:e51759.

17 Linnenluecke, M. K., Nucifora, N., & Thompson, N. (2018). Implications of climate change for the sugarcane industry. WIREs Climate Change, 9. https://doi.org/10.1002/wcc.498

3. CSA SUGAR CROP AND LAND MANAGEMENT REQUIREMENTS

3.1. Introduction

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

3.2. Sugar Cane Production[18]

Sugar cane is a tropical, perennial grass that tillers at the base to produce multiple stems, 3-4 metres high and approximately five centimetres in diameter. Its composition varies depending upon climate, soil type, varieties, fertilisers, insects, disease control, the harvest period and irrigation. When harvested, the air-dry cane stalk, approximately 75% of the entire plant, contains 11–16% fibre, 12–16% soluble sugars, 2–3% non-sugars, and 63–73% water.

Most rainfed and irrigated commercial sugarcane is grown between 35°N and 35°S of the equator. The crop flourishes under a long, warm growing season with a high incidence of radiation and adequate moisture, followed by a dry, sunny and fairly cool but frost-free ripening and harvesting period. Optimum temperatures for sprouting of cane stem cuttings are 32-38°C. Optimum growth is achieved with mean daily temperatures from 22-30°C. Minimum temperature for active growth is approximately 20°C. For ripening, however, relatively lower temperatures in the range of 10-20°C are desirable, since this has a noticeable influence on the reduction of vegetative growth rate and the enrichment of sucrose in the cane.

A long growing season is essential for high yields. The normal length of the total growing period varies from 9-24 months but is generally 15-16 months with harvest before temperatures drop or frost onset (as occurs in some cane-growing countries). The first crop-harvest is normally followed by 2- 4 ratoon crops, but in certain cases especially with irrigation up to a maximum of eight crops can be taken, each taking about 12 months to mature, but often with decreasing yields.

TABLE 2: TYPICAL SUGARCANE PRODUCTION STAGES (DAYS)

Crop	Altitude	Initial Establishment	Early Season	Mid-Season	Late Season	Total
			Tillering-stem elongation-yield formation-ripening			
Initial Establishment	Lower	35	60	190	120	405 (12-13 months)
	Higher	50	70	220	140	480 (16 months)
Ratoon 2-8 crops	Lower	25	70	135	50	280 (9-12 months)
	Higher	30	50	180	60	320 (11-16 months)

Growth of the cane stem is slow at first, gradually increasing until the maximum growth rate is reached after which growth slows as the cane ripens and matures. The flowering of sugarcane is controlled by day-length, but is also influenced by soil moisture and nitrogen supply.

[18] FAO, 2018. http://www.fao.org/land-water/databases-and-software/crop-information/sugarcane/en/

Flowering has a progressive deleterious effect on sucrose content. Normally, therefore, flowering can be prevented or non-flowering varieties used.

Sugarcane does not require a special type of soil. However, the best soils are those that are over a metre deep, well-aerated and drained with total available soil moisture of 15% or more after rain or irrigation. When there is a groundwater table, it should be more than 1.5-2.0 m below the soil surface. In some countries cane is grown on shallower soils, often with drainage problems, but under such circumstances requires ridging, during land preparation. The optimum soil pH is about 6.5, but sugarcane will grow in soils with pH in the range of 5 to 8.5. Increasing acidity is an issue in a number of countries and liming may be required. Sugarcane is also sensitive to salinity with yields decreasing with increasing salinity.

Sugarcane has high nitrogen (N) and potassium (K) needs and relatively low phosphate (P) requirements, typically ranging from 100-200 kg/ha N, 20-90 kg/ha P and 125-160 kg/ha K, with additional micro-nutrients on some soils, to obtain yields of 50-100 tonnes ha^{-1} cane. Nutrient leaching can be a problem especially on shallower or sandier soils. At maturity, the N content of the soil must be as low as possible for good sugar recovery, particularly where the ripening period is moist and warm. Row spacing varies usually from 1.0-1.5 m; with the number of cane sets required for planting dependent on the number of buds per set, which can vary from 20,000-35,000 ha^{-1}. In countries where mechanised land preparation and cane harvesting is the norm, soil compaction by heavy tractors or transport vehicles can be a problem and alternate row widening in a tramline system may be practiced.

3.3. Sugar Value Chain

A typical sugarcane value chain is shown in the table below, with government (often the Ministry of Agriculture) being responsible for policy and the regulatory requirements for creating an enabling environment.

TABLE 3: TYPICAL SUGAR VALUE CHAIN

Improved cane varieties, land management & agronomic practices	Production Advice & Agri-Input Acquisition	Cane Production	Transport to Mill	Sugar and bi-product Production	Marketing	Consumption
▪ Researchers	**Production advice** ▪ Extension agents (Govt & NGO) ▪ Milling Company ▪ Grower Associations ▪ Cooperatives **Seed cane** ▪ Research stations ▪ Milling Companies ▪ Seed growers ▪ Farmers **Agri-inputs** ▪ Agro-dealers ▪ Milling Companies **Production credit** ▪ Micro-finance institutions, NGOs ▪ Banks, Agri-banks	▪ Milling Companies ▪ Large Scale Farmers ▪ Small scale growers ▪ Community companies ▪ Cooperatives	▪ Transporters ▪ Farmers' cooperative ▪ Milling Company	▪ Milling Company ▪ Sugar refining plants ▪ Bio-ethanol, electricity and chemical production	▪ Importers & Exporters ▪ Product factories ▪ Wholesalers ▪ Retailers	▪ Consumers

- Milling Company

Small scale growers (SSGs) are usually regarded as those growing typically 0.5-5 ha of sugar cane with or without irrigation. This might comprise only cane or be one of different crop enterprises. SSGs may or may not own livestock, including draft animals used for cane production. Alternatively, mechanisation contractors may be hired.

Other SSG models include farmer groups, cooperatives or community owned companies undertaking block farming of typically 30-100 ha, possibly with an employed manager using their own equipment or relying on contractors for planting, harvesting and transport.

The production capacity of a sugar mill determines the amount and area of cane required to feed the mill. Some typical mill capacities in '000 tonnes of cane per day are Thailand -12, Australia-10, Brazil-5, Mexico-5, Cuba-4 and India-3. At the same time, the milling season varies from 130-200 days dependent on the agro-climatic conditions for cane growth. Clearly larger mills draw cane from a wider area increasing transport costs. There has been a trend towards building higher capacity sugar mills to reduce the unit cost of sugar and its bi-products, often meaning that transport costs increase and less suitable land is used for cane production. In some countries, smaller or mini-mills have been introduced.

In many countries, mills are also major producers of cane, often supported by both large commercial farmers and SSGs.

3.4. Land Management Systems for Small Scale Growers

SSGs in many countries have been faced with challenges including low and declining productivity of crop land; lack of farmer capacity (knowledge, technical, business / management, and institutional) including the lack of capital or credit; poor regulatory systems; rising costs of inputs and transportation and inadequate irrigation infrastructure[19].

At the same time, it has been recognised that management strategies for sugarcane production should incorporate ecological principles in order to arrest the adverse effects of mono-cropping on soil degradation and consequent yield decline[20]. For instance, soil management strategies based on crop residue retention, nutrient recycling, reduced tillage, legume intercropping, green cane harvesting as well as break or rotation crops will help to conserve soil and water more effectively, increase soil organic matter, improve fertiliser use efficiency, reduce disease and pest damage, and reduce physical damage to soils during harvesting. Such practices will help to develop productive, profitable and sustainable production systems, more especially with the additional risks associated with climate warming. If soil degradation remains left unchecked the full potential of improved cane varieties will not be realised. Environmental quality issues, particularly air, ground and surface water quality, make it imperative to base soil management practices on an understanding of the ecosystem.

A Climate Smart Agriculture (CSA) approach requires that these interrelated challenges be addressed in a systematic manner that reverse declining productivity, increases farmer capacity and introduces regulatory policy changes that will create an enabling environment to ensure sustainable production.

Annex 3 provides details of "best" practices for producing cane that should be considered for sustainable production. These include those for land preparation, crop diversification,

[19] International Sugar Organisation (2008). Sugarcane smallholders in sub-Sahara Africa: Status, challenges and strategies for development. MECAS (08)05.

[20] JH Meyer, R Van Antwerpen and E Meyer, 1996. A review of soil degradation and management research under intensive sugarcane cropping. Proc S Afr Sug Technol Ass (1996) 70.

agronomic practices, soil fertility management, soil and water management and harvest. Inevitably many practices will be location specific, dependent on individual agro-climatic and market environments. Many of the best agronomic practices have often been incorporated into recommendations for growers, especially in those countries with strong research and advisory services such as Australia[21], Brazil[22] , and South Africa[23], although these may not always be implemented. Many of these practices are suitable for SSGs in developing countries. Details on each practice include its environmental benefit, the benefits and challenges to the grower, as well identifying and prioritising those practices that could be considered for climate smart lending. Indicators for each have been identified and suggestions made for how these can be monitored or adoption proved using photographic evidence.

The table below (summarising Annex 3), identifies those CSA sugar cane management practices considered suitable for Climate Smart Lending (CSL). It would be expected that all growers would utilise best base-line production practices, based on location-specific advice from the sugar mill or other extension agency. An additional 15 CSA practices have been prioritised and grouped at four levels: Level A - Basic level; Level B – Intermediate-1; Level C – Intermediate-2; and Level D -Advanced level. These can be used as progressive steps in making CSL loans available to SSGs.

TABLE 4: CLIMATE SMART AGRICULTURE PRACTICES FOR SUGAR CANE

Best baseline-agronomic practices recommended by extension agencies	**Prioritised Additional Climate Smart Agriculture Practices**[24] Detail to be agreed with location specific extension and funding agencies			
	Level A **Basic level**	**Level B** **Intermediate 1**	**Level C** **Intermediate 2**	**Level D** **Advanced level**
▪ Improved varieties ▪ Correct planting time ▪ Correct fertiliser rates ▪ Effective weed control ▪ Effective pest and disease manage-ment ▪ Correct harvest practices	1. Ensuring crop residues are not burnt after harvest 2. Mulching with crop residues 3. Using minimum tillage 4. Planting cane on the contour and on ridges on shallower soils 5. Preventing fire-damage by making fire breaks to protect drying cane	6. Intercropping with a legume when planting cane 7. Integrated soil fertility management through use of organic material with inorganic fertilisers at or before planting 8. Establishing physical soil conservation measures depending on soil type, land slope and available materials 9. Introducing green cane harvesting, abandoning the	10. Introducing a break crop after the last ratoon cane is harvested 11. Micro-watershed management, expanding soil conservation measures integrated across farm or field boundaries 12. Planting and managing vegetative soil conservation measures, where appropriate[1]	13. Establishing rain water harvesting from run-off areas, where appropriate 14. Introducing an Integrated pest management programme 15. Protecting wetland areas by planting or protecting suitable tree and/or grass species

21 Sugar Research Australia, 2018 Sugarcane Advisors Information Kit published by Sugar Research Australia Limited. ISBN: 978-0-949678-29-4.
22 UNICA, 2018. Best practices. The Brazilian Sugarcane Industry Association) and the Brazilian Trade and Investment Promotion Agency https://sugarcane.org/best-pratices/
23 SASRI, various. Sugar cane, information Sheets. South African Sugar Research Industry.
24 References for each of these is given in the sections that follow

	use of burning before cutting

The role of agro-forestry in CSA and promoting sustainable farming systems is such that planting the equivalent of 50 trees per ha year, or 250 trees over five years on either field boundaries, on steep slopes or around SSG homesteads is considered desirable and has therefore been included as a pre-condition for all CSA lending levels.

3.5. Practice descriptions

Level A (Basic level)

Each potential borrower would be required, if not already a member to join a farmer's group or association that meets regularly exchanges ideas, shares knowledge on good farming practices and is prepared to try out new methodologies and technologies. This is intended to promote farmer-to-farmer extension and adoption and possibly adaptation of best practices to suit local conditions.

1. Crop residues. Crop residues remaining after cane harvest should not be burnt but scattered on the soil surface as a mulch to protect the soil from heavy rain and reduce run-off velocity, when a new crop is planted or the cane is ratooned.

2. Mulching. As well as mulch material, most of the crop residues should be left on the field and only some removed for fuel, animal feed, to mulch another crop or used for making compost.

3. Minimum tillage. Minimum tillage[25] should be practised for land preparation and subsequent planting rather than conventional ploughing. Minimum tillage is the practice of reducing soil disturbance, when preparing the land for planting to reduce the risk of soil erosion. Together with use of crop residues as mulch, this forms a key component of conservation agriculture (or CA)[26]. This requires that at least 30 percent ground cover is covered with crop residues and mulch material. Even better would be a complete trash blanket, where crop residues allow. There are only two situations in which it is not suitable: where the row alignment of the previous crop needs to be changed for soil conservation or mechanisation purposes and where lime must be incorporated to correct soil acidity problems.

4. Planting on the contour and using ridges[27] on shallow soils. Cane sets should always be planted on the contour and not up and down the slope to avoid soil erosion. In addition, ridges should be used on shallow soils. Cane grown on shallow soils will suffer from poor growth, low yields and the need for frequent crop re-establishment due to poor root distribution and rainfall efficiency being limited by low plant available water capacity and surface crusting. In addition, there is a high compaction hazard that leads to waterlogged fields and increased run-off during storms. These soils are vulnerable to the development of saline/sodic conditions and have a high erodibility status. Ridging should also be undertaken where the water table is within 0.6 m of the soil surface or an impervious layer is found within 0.6 m of the soil surface, or where soils have a low infiltration rate and water will collect on the surface for several days after rain or irrigation. Ridging can be implemented before planting in the case of new cane or within three weeks after harvest after harvesting in the case of ratoon crops.

[25] SASRI, 1998. Minimum tillage. Information Sheet. South African Sugar Research Institute

[26] FAO, 2008. Investing in sustainable intensification – the role of conservation agriculture. Rome: Food and Agriculture Organization of the United Nations.

[27] SASRI, 2001. Ridging. Information Sheet. South African Sugar Research Institute

5. Preventing fire damage[28]. Runaway fires can spread over entire hillsides and destroy many ha of standing cane exposing the land to soil erosion. A hot fire will also partially destroy recently applied nitrogen fertiliser. Hence the use of fire-breaks is essential as a risk reduction strategy.

Level B (Intermediate 1)

6. Intercropping[29]. When new cane sets are planted, the inter-rows can be used for inter-cropping with a legume suitable for the location. Options include soya beans, Lablab-Dolichos, cowpeas, mung bean or groundnuts designed to utilise the unused land between rows providing an additional crop as well as adding to soil N and adding soil cover protection to reduce soil erosion. The practice should not be repeated for the ratoon crops due to competition with the cane, which will quickly cover the inter-row spacing.

7. Integrated soil fertility management (ISFM). This involves the incorporation of organic material (including crop residues, compost, manure or organic waste from the mill) together with inorganic fertilisers at cane planting. ISFM practices are designed to increase soil organic matter or soil carbon and contribute to reducing input of inorganic fertilisers. Examples include the wastes and residues from the mill such as filter-mud and the liquid effluents as irrigation water. Both filter-mud and agricultural crop wastes may be improved considerably through relatively simple compost processes, whereby ashes from bagasse furnaces and other elements contributing phosphorous and potassium - of great importance to the crop -- are added. Condensed mass solid (CMS) a waste mill product is primarily a source of potassium with smaller quantities of nitrogen, phosphorus, calcium, magnesium and sulphur[30], which can be applied to both plant and ratoon cane. This will require SSGs and their associations developing close relationships with milling companies.

8. Initial physical soil conservation measures. The establishment of appropriate soil conservation measures depends on soil type, land slope and available materials, designed to prevent soil erosion and consequent decline in soil health. Soil erosion may not be a problem on sugar growing areas located on gentle slopes (less than 2%) especially those with heavier well-drained soils. However, where cane is grown on slopes of more than 2%, physical measures constructed on the contour are likely to be required. Options, depending on materials available locally, include stone walls, *fanya juu* (ditches with soil bunds on the upper side of the ditch) constructed on the contour forming terraces. Vegetative measures may not be suitable due to completion with the crop. Slope steepness will dictate the distance between terraces.

9. Green cane harvesting. The practice of burning sugarcane before harvesting is widespread. The main reason for this is to eliminate excess trash to ease harvesting, handling and milling efficiencies of the cane. However, there are several disadvantages to burning, such as poorer soil and moisture conservation, the public nuisance of smoke and soot, and possible pollution and health hazards from cane fires. Not only does this result in loss of crop residues for mulching the subsequent ratoon crop but also releases CO_2. The negative environmental effects of burning are being increasingly recognised and harvesting green (unburnt) cane is increasingly being used.

Level C (Intermediate 2)

10. Break crops. Adding organic matter through a green manure or legume crops for one year or longer after the final ratoon cane is removed is an important means of improving soil health as well as reducing disease and pest problems. The lack of an appropriate fallow

[28] SASRI, 2014. Management of fire cane. Information Sheet. South African Sugar Research Institute
[29] SASRI, 2016. Condensed Molasses Solids. Information Sheet 7.18. South African Sugar Research Institute
[30] Sugar Research Australia, 2018. The Sugarcane Advisors Information Kit. ISBN: 978-0-949678-29-4

period means there is no opportunity to break the reproductive cycle of disease or pest pathogens. For example, use of *Desmodium spp*. as a green manure fixes N leaving crop residues on the surface as well as being of use in pest management31). Other options that can be considered include those used for intercropping (soya beans, Lablab-Dolichos, cowpeas, mung bean or groundnuts). Research shows that yield increases by up to 84% following a break, compared to conventional plough out and immediate replant[32]. Yield increases of 20% can be expected in ratoon crops[33]. The main disadvantage is that there is a season when no cane is harvested. However, this can be more than offset by the higher yields in both the plant and ratoon crops. Although cane diseases can be controlled by new varieties, crop rotations and inter-cropping, although practised only to a limited extent at present, have shown an excellent economic possibility and positive effect for soil health and consequently cane yields, when used with legumes.

11. <u>Micro-watershed management.</u> This allows for extending and integrating soil conservation measures across farm or field boundaries for safe water run-off into uncropped natural waterways along natural drainage lines. These may be natural wetlands which may require additional protection. If waterways are badly degraded gully reclamation measures may be required. Clearly micro-watershed management will be easier to implement, where SSGs are utilising block farming over larger areas.

12. <u>Vegetative conservation measures.</u> The use of grass strips is unlikely to be a benefit, cane already being a grass. However, the use of carefully managed hedge-rows or trees species on a terrace or contour may be an option on steep slopes, although competition with cane may be an issue. Sugar cane is strongly light demanding, so intercropping trees and sugar cane is not usually recommended[34], when sugar cane is commercially grown. However, cane growing areas are often associated with severe shortages of wood, so intensified tree growing on field boundaries, areas with steep slopes and around homesteads should be considered. Suitable species will be location specific and consequently vary depending on agro-climatic conditions. They will include multi-purpose species that enhance soil fertility through mulching, use in compost and protect from soil erosion, as well as providing fodder for livestock, fuelwood and / or timber products. Species that can be considered include: *Aleurites fordii*; *Acacia tortilis*; *Ficus sycomorus*; *Grevillea robusta*; *Azadirachta indica*; *Faidherbia albida*; *Leucaena* and *Gliricidia spp*., as well as those that provide natural pesticides such as *Tephrosia vogelii* and *Tithonia diversifola* or nutritional or medicinal value such as *Moringa oleifera*. Recent research[35] using *Aleurites fordii* examined the possibility of agro-forestry in sugarcane providing information which can be used to assist in the planning of more ideal agroforestry arrangements.

    The role of agro-forestry in CSA and supporting sustainable farming systems is such that planting the equivalent of 50 trees per ha year, or 250 trees over five years on either field boundaries, on steep slopes or around SSG homesteads has considerable benefit and has therefore been included as a pre-condition for all CSA lending levels.

Level D (Advanced level)

13. <u>Rain water harvesting.</u> Options should be considered especially where irrigation is not available. This will involve collection of rainfall from run-off areas, such as roads, and

[31] Rutherford, R.S. & Conlong D.E., 2010. Combating sugarcane pests in South Africa: from researching biotic interactions to bio-intensive integrated pest management in the field. Proc. Int. Soc. Sugar Cane Technol., Vol. 27, 2010

[32] Ibid

[33] Ibid

[34] Tengnas B. 1994. Agroforestry extension manual for Kenya. Nairobi: International Centre for Research in Agroforestry. ISBN 92 9059116 1

[35] Schwerz, F., Elli, E., Behling, A., Schmidt, D., Caron, B., & Sgarbossa, J. (2017). Yield and qualitative traits of sugarcane cultivated in agroforestry systems: Toward sustainable production systems. Renewable Agriculture and Food Systems, 1-13. doi:10.1017/S1742170517000382

channelled safely, so as not to cause soil erosion into cane fields to increase soil moisture plant availability. Design will need to ensure protection from soil erosion damage after heavy rain events and ideally included in micro-watershed implementation plans. This is best suited to SSG block farming areas.

14. Integrated pest management (IPM). IPM combines a range of suitable pest control methods in as compatible a manner as possible to maintain pest populations below levels to limit economic damage and reduce synthetic pesticide use. IPM uses multiple pest management tactics to prevent economically damaging pest out-breaks, while reducing risks to human health and the environment. Basic-IPM consists of scouting and insecticide application according to economic thresholds. Intermediate–level IPM additionally includes cultural controls (green manure such as Desmodium) and plant resistance (resistant varieties), coupled with efforts to reduce broad spectrum pesticide use to protect beneficial organisms usually targeted at a single pest. Advanced–level bio-IPM includes multiple integrated bio-interventions targeting multiple pests. These include attractant traps, habitat management and biological control[36]. Examples are the control of thrips at planting and stalkborer (*Eldana spp*) in older cane and sterile insect technologies and in Cuba control of the sugar cane borer[37] (*Diatrea Saccharilis*) can be achieved through the systematic reproduction and release of a natural enemy - a fly (*Lixophaga Diatrea*).

15. Protecting wetlands. Wetlands located in sugar growing areas are areas of high biodiversity as well as being areas where run-off water from cane-lands naturally collect. Their cultivation leads to loss of bio-diversity and soil erosion. As such wetlands require special protection and may be already protected by law in some countries. Protection or removal from cultivation may require introduction of suitable tree or grass species. Wetlands include hillside seeps, spongy meadows of grasses and sedges, reedy marshes, swamp forests, moist riparian habitats and coastal estuaries. Wetlands and their connecting streams and rivers are interlinked and assist in stabilising the watershed, providing a stable supply of water throughout the year, maintaining water quality by constant filtration, reducing the intensity of floods and droughts, preventing soil erosion, providing wildlife habitat and can serve as recreational areas. Many wetlands in cane growing areas have been extensively degraded through the removal of trees, uncontrolled grass burning, cultivation up to river banks and drainage. Protection[38] can involve:

    - Allowing indigenous trees, grasses, sedges and reeds to regenerate, and if necessary, removing alien invasive plants and other forms of disturbance to protect the river banks. In severely degraded areas, a mulch of grass heads collected in similar local habitats can be used.
    - Replanting key local riverine tree species trees in clumps at stress points in degraded areas and along the watercourse.
    - Maintaining the conserved area, watering young trees, controlling weeds and protect the area to encourage the natural processes to rehabilitate the diverse wetland vegetation.

3.6. Challenges for Small Scale Growers

The sugar supply chain involves thousands of companies around the world, including producers, mills, refiners, wholesalers, traders and retailers. The role of SSGs is restricted to

36 Rutherford, R.S. & Conlong D.E., 2010. Combating sugarcane pests in South Africa: from researching biotic interactions to bio-intensive integrated pest management in the field. Proc. Int. Soc. Sugar Cane Technol., Vol. 27, 2010
37 Marianela Cordovés Herrera , Director, Industrial Promotion, GEPLACEA. Cane, sugar and the environment. FAO - Cuba Conference, Cuba, 7-9 December 1999. http://www.fao.org/docrep/005/X4988E/x4988e01.htm
38 SASRI, 2001. Establishing vegetation in degraded wetlands Information Sheet. SASRI.

the start of the chain, when they deliver cane to the local mill. Most value is added to through processing and marketing activities, where actors have the capacity to invest in the capital-intensive technologies needed to process sugar.

Most SSGs work farms of a few hectares and many live on less than $2 a day. They receive low or volatile prices for their cane while, in effect, competing against wealthier countries that subsidise sugar production. Many SSGs farm in increasing precarious climatic conditions with limited access to credit to enable them to invest in production. At the same time costs of key farm inputs, such as labour, fertiliser and pesticides are also rising with many SSGs lacking the capital or access to affordable credit to invest in improving their production[39].

Several production models operate in sugar cane producing countries. The predominant one is a vertically integrated estate, in which a mill owns and operates the cane estates that supply it with cane. Because mills aim to optimise their efficiency by operating at near capacity there is a growing trend for SSGs to grow cane to supplement estate production. Trade relationships are based on market forces and prices set by the mill, so SSGs often have little security.

Another production model is the revenue-sharing model, used in countries with a high dependency on small farmers. Here, the terms are based on the price received for sugar and are negotiated between the mill and an SSG Association, often at national level with government input. SSG share can vary from 50-75%. SSGs are responsible for the delivery of good-quality, clean cane, with high sucrose content, while the mill is responsible for optimum recovery of sugar from the cane and for maintaining the equipment to avoid breakdowns.

As well as manufacturing, the mill is often responsible for marketing the sugar. Sometimes this is done on behalf of the mills by an independent body, while a few countries still operate state-run marketing boards. In some cases, cane prices are fixed by government, while in others the price is negotiated between growers and processors at the start of the season.

"Fairtrade Certification"[40] in sugar cane focuses on SSGs. Through Fairtrade certification, and by working in partnership with sugar cane processors, SSGs can get improved access to international markets and develop the necessary business skills and technical capacity to be more competitive in the global market. More than 37,000 sugar cane farmers from 15 countries benefitted from Fairtrade sugar in 2013.

CSA lending products can also play an important role in increasing productivity in those developing countries (i) seeking to supply their own domestic markets, ii) providing protection against low cost or dumped imports, as well as iii) that have access to the protected markets of the US and EU. At the same time "Fairtrade Certification" will enable farmers to earn income levels supported by fair trade policies.

3.7. Roadmap for Small-Scale Grower Sustainability

The South African sugar industry is often used as an example of how agribusiness and SSGs can benefit from development from technical and financial support received from the sugar industry[41][42]. This requires a sustainable livelihoods approach[43], which links the concept of sustainability to a reduction in vulnerability and an increase in resilience to stress or shocks. A roadmap for SSG livelihood sustainability in the sugar industry includes several key steps.

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[39] Fairtrade, 2013. Sugar Commodity Briefing Paper. Fair Trade Foundation, January 2013 www.fairtrade.org.uk

[40] Ibid

[41] Armitage RM, Hurly KM and Gillitt CG, 2009. Enhancing support measures to SSG and new freehold growers in the South African sugar industry. Proc S Afr Sug Technol Ass 82: 354-369.

[42] Hurly KM, Sibiya TG, Nicholson R and King M, 2015. Roadmap for Small-Scale Grower Sustainability. Proc S Afr Sug Technol Ass (2015) 88: 318 – 336.

[43] Chambers R and Conway GR (1991). Sustainable rural livelihoods: Practical concepts for the 21st century. Institute of Development Studies, Discussion Paper 296. ISBN 0 903715 58 9.

- The creation of an enabling environment ensuring that the basic rural infrastructure such as roads and communication are in place. It also requires that fair prices are agreed as an industry standard between sugar millers and sugar-cane growers, and that payments for cane delivered to mills are promptly paid. This might include a preliminary payment based on the tonnage delivered to the mill, followed by a further payment dependent on cane sucrose content and the sugar price realised by the mills. A mechanism for this is particularly important when credit is advanced to SSGs. In addition, some countries have introduced and enforce legislation protecting the natural environment from misuse by the sugar industry.
- Ensuring multiple stakeholder processes and partnerships are in place in supporting SSGs and ensuring that cane production contributes positively and sustainability to their livelihoods. This is likely to involve establishing an "Innovation Platform"[44], where sugar value chain stakeholders can discuss the sugar industry, its constraints and opportunities, plan and implement strategies for increasing productivity on a sustainable basis, including fair distribution of benefits and costs as well as regular reviews of progress and agreeing mechanisms for resolving challenges and/or disputes. SSG representation, through Associations or Cooperatives, will be important.
- Reviewing industry support in light of SSG circumstances. This may include a focus on attracting new or younger growers, the use of contractors for example for land preparation and harvest, as well as the willingness and ability of SSGs to adopt CSA practices.
- CSA financing will play an important role in providing the incentives for adoption of sustainable practices.

[44] 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. ISBN 978-9988-8373-2-0 (print), ISBN 978-9988-8373-2-4 (pdf)

4. THE CLIMATE SMART SUGAR CREDIT PRODUCT

4.1. Introduction

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

4.2. Climate-smart credit product land management requirements

The 15 CSA practices have been grouped at four levels from a Basic to an Advanced level (see table below) which lend themselves to four groups of climate smart lending practices. In addition, an agro-forestry component has been added, this being for 50 trees for each one hectare loan to be planted annually over a five year period making 250 trees in total.

TABLE 5: PRACTICES REQUIRED UNDER THE CLIMATE-SMART CREDIT PRODUCT

Baseline-production practices	**Prioritised Additional Climate Smart Agriculture Practices** Detail to be agreed with location specific extension and funding agencies			
	Loan 1 **Basic level**	**Loan 2** **Intermediate 1**	**Loan 3** **Intermediate 2**	**Loan 4** **Advanced level**
Based on best agronomic practices, provided by extension agencies including ▪ Improved varieties ▪ Correct planting time ▪ Correct fertiliser rates ▪ Effective weed control ▪ Effective pest and disease manage-ment ▪ Correct harvest practices	1. Plant 50 trees 2. Ensuring crop residues are not burnt after harvest 3. Mulching with crop residues 4. Using minimum tillage 5. Planting cane on the contour and on ridges on shallower soils 6. Preventing fire-damage by making fire breaks to protect drying cane	7. Plant an additional 50 trees 8. Intercropping with a legume when planting cane 9. Integrated soil fertility management through use of organic material with inorganic fertilisers at or before planting 10. Introducing physical soil conservation measures depending on soil type, land slope and available materials 11. Introducing green cane harvesting, abandoning the use of burning before cutting	12. Plant an additional 50 trees 13. Introducing a break crop after the last ratoon cane is harvested 14. Micro-watershed management, expanding soil conservation measures integrated across farm or field boundaries 15. Planting and managing vegetative soil conservation measures, where appropriate[1]	16. Plant an additional 50 trees 17. Establishing rain water harvesting from run-off areas, where appropriate 18. Introducing an Integrated pest management programme 19. Protecting wetland areas by planting or protecting suitable tree and/or grass species

For a farmer with one hectare of sugar cane, they should be encouraged to replant 1/5th of their land each year as demonstrated. Establishment loans would be provided to coincide with each cane plant crop at the selected level selected and subject to agreement between the lender and the farmer, which can be accompanied by a working capital component. Those at Level C would introduce a break crop after the last ratoon before replanting cane.

TABLE 6: PLOT ROTATION WITH LOANS

Plot 1	**Plot 2**	**Plot 2**	**Plot 3**	**Plot 4**
Plant **Loan 1**	Ratoon 4	Ratoon 3	Ratoon 2	Ratoon 1
Ratoon 1	Plant **Loan 2**	Ratoon 4	Ratoon 3	Ratoon 2

Ratoon 2	Ratoon 1	Plant **Loan 3**	Ratoon 4	Ratoon 3
Ratoon 3	Ratoon 2	Ratoon 1	Plant **Loan 4**	Ratoon 4
Ratoon 4	Ratoon 3	Ratoon 2	Ratoon 1	Plant **Loan 5**

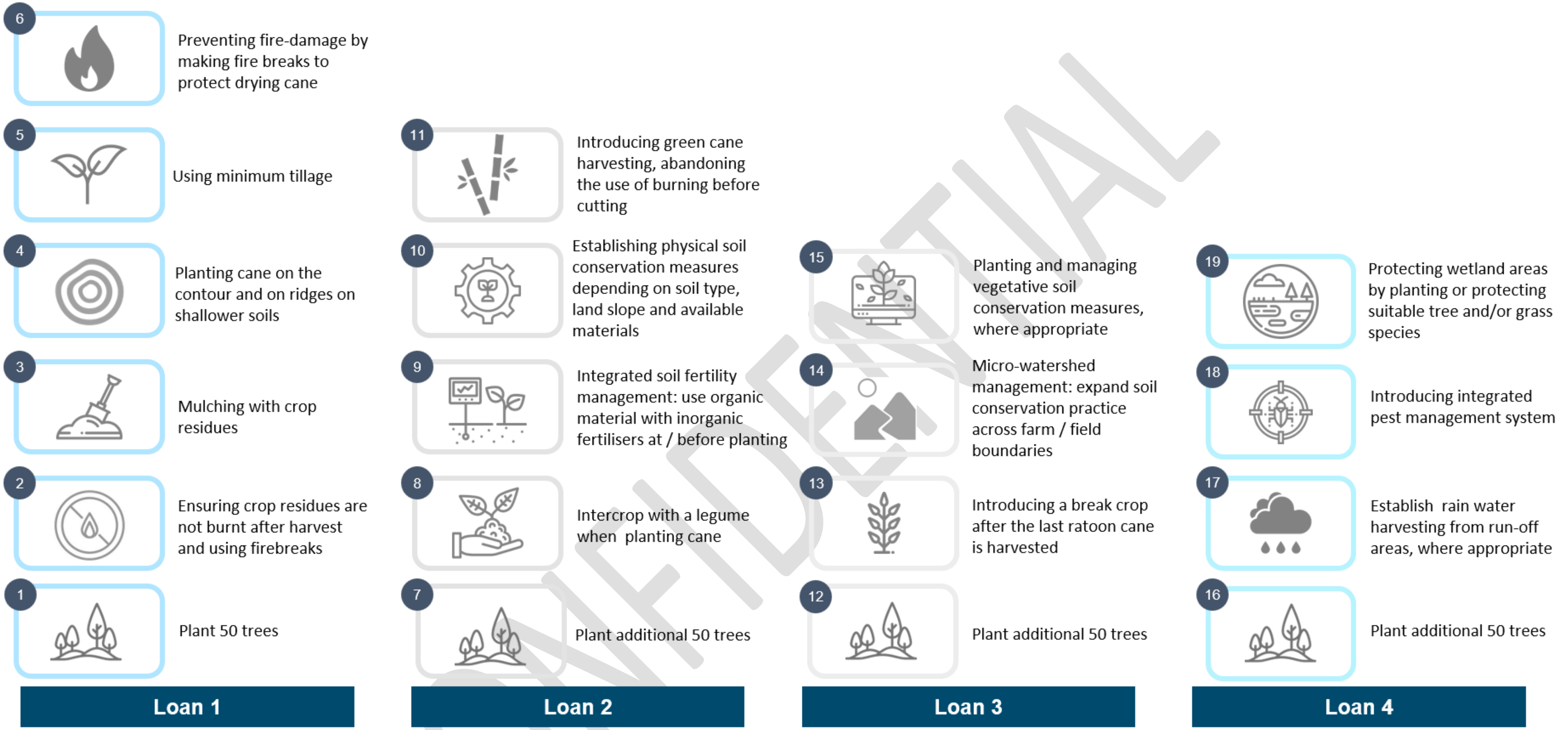

FIGURE 4: SUGAR CLIMATE-SMART CREDIT PRODUCT (ACTIVITIES/HA LAND)

5. Yield and climate 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[45] for 2016 showed that of the 105 countries producing sugar cane, 66 grew over 10,000 ha comprising 99% of cane growing areas (Annex 1). Yields from these countries show a mean of 62 tonnes ha^{-1} with a range from six to 129 tonnes ha^{-1}. The figure below demonstrates this range.

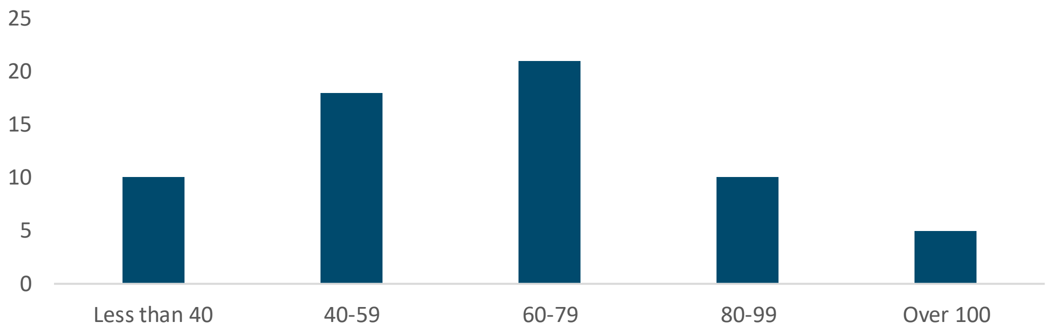

FIGURE 5: RANGE OF SUGAR CANE YIELDS (TONNES HA-1) (NO. OF COUNTRIES) (RAINFED AND IRRIGATED)

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 cane grown, yields achieved and world ranking in terms of area grown and yield ha-1 are shown for countries of interest in the table below.

TABLE 7: AREA OF CANE, CANE YIELDS AND RANK IN TERMS OF AREA GROWN AND YIELDS, 2016

Country	Area of cane grown ha	% of total	Rank in terms of area grown	Cane yields tonnes ha^{-1}	Rank in terms of yields ha^{-1}
Malawi	27,087	0.1%	56	108	4
Zambia	41,695	0.1%	46	103	5
Kenya	86,876	0.3%	30	80	13
Australia	447,204	1.5%	9	77	19
Brazil	10,226,205	35.4%	1	75	20
India	4,950,000	17.1%	2	70	25
Uganda	54,911	0.2%	39	68	26
South Africa	246,937	0.9%	17	61	36
Indonesia	472,693	1.6%	8	57	39
Ethiopia	31,237	0.1%	51	45	48
Tanzania	108,487	0.4%	23	28	59
Total	**16,693,332**	**57.8%**	-	**Mean =70**	-

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

Sugar yield depends on cane tonnage, cane sugar content of the cane and cane quality. It is important that the cane is harvested at the most suitable moment when the economic optimum of recoverable sugar is reached. Cane tonnage at harvest can vary between 40-150 tonnes ha^{-1} or more, which depends particularly on the length of the growing period and whether it is a plant or a ratoon crop. Cane yields produced under rainfed conditions vary greatly. Good yields[46] in the humid tropics of a totally rainfed crop can be in the range of 70 to 100 tonnes ha^{-1}, and in the dry tropics and subtropics with irrigation, 110 to 150 tonnes ha^{-1}.

Toward maturity, vegetative growth is reduced and sugar content of the cane increases greatly. Sugar content at harvest is usually 10-12% of the cane fresh weight, but under experimental conditions 18% or more can be achieved. Sugar content seems to decrease slightly with increased cane yields. Luxurious growth should be avoided during cane ripening, achieved by low temperature, low nitrogen level and restricted water supply. Cane yields of SSGs are often considerably lower than those achieved by mill estates and large commercial growers for reasons indicated earlier.

Robust data on SSG yield levels compared with large scale production is difficult to obtain. However, data from a study in Malawi[47] shows yield levels of 65 tonnes ha^{-1} declining to 52 tonnes ha^{-1} for a fourth ratoon crop. These are approximately 60% of the national average. The study concluded that in order to sustain good yields and revenue streams, the industry needs to develop professional standards, have ability to regulate and invest in emerging farmers' associations. In South Africa, The South African Cane Growers' Association[48] has on many occasions demonstrated the margins between production costs and the financial returns, and hence productivity has been tight. SSGs in particular have been faced with low and declining productivity with yield levels of individual growers showing wide variation[49].

Financial models have used a cane yield of 50 tonnes ha^{-1} the base for SSGs under rainfed conditions. Under such conditions four ratoon crops can be expected with a 5% reduction in yield for each ratoon crop after which the cane will be replanted.

5.3. Cane Prices

The price of sugar cane shows high variability both between countries and between years, the lows being in the years 2000-2008 and then peaking in 2012-13, before dropping to their current levels[50]. Prices fell by more than 30% in 2014 but are now expected to average slightly above 2% per year going forwards[51]. Annex 6 shows this variation for ten cane producing countries, for which data is available. This is summarised in the table below.

46 FAO, 2018. http://www.fao.org/land-water/databases-and-software/crop-information/sugarcane/en/

47 Stephen Atkins,(2015). Smallholder Sugarcane Production in Malawi: An analysis of outgrower participation in the country's sugar industry. Research symposium.

48 https://shukela.co.za/2017/09/20/sa-canegrowers-cost-survey/

49 Woodhouse, Phil and James, Paul (2017). A farm survey of small-scale sugarcane growers in Nkomazi, Mpumalanga Province, South Africa. GDI Working Paper 2017-018. Manchester: The University of Manchester.

50 http://www.fao.org/faostat/en/#data/PP/visualize

51 OECD/FAO (2016), "Sugar", in OECD-FAO Agricultural Outlook 2016-2025, OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/agr_outlook-2016-9-en

TABLE 8: CANE PRICE AND RANGE WITH 2016-17 PRICE (USD PER TONNE)

Country	Range Low 2000-08	Range High 2012-13	Current 2016-17
Australia	20	45	36
Brazil	10	32	20
Ethiopia	50	125	125
Kenya	25	45	32
India	14	20	20
Mexico	30	50	37
Philippines	40	65	64
South Africa	30	50	40
United States	30	50	38
Mean	**28**	**54**	**46**

Financial models have used a cane farm gate price of USD 40 per tonne.

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

This section describes the qualitative impact of resilience, risk, mitigation and productivity

Key features of the 19 CSA approaches to sustainable cane production are given below.

- ***Reducing or eliminating soil erosion***, extending the number of times that sugarcane 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 sugarcane crop residues after harvesting as a mulch or ground cover
- ***Further reducing the use of inorganic fertiliser*** through utilisation of mill waste products, including filter cake (rich in phosphorus) and *vinasse* (rich in potassium, organic matter and other nutrients).
- ***Reducing the use of agrochemicals*** through biological control, introducing natural enemies to fight pests and advanced genetic enhancement programs.
- ***The reduction or elimination of pre-harvest cane field burning*** to reduce local air pollution, improve air quality and provide biomass for reduced tillage and mulching.
- ***Protecting and recover land alongside streams and riverbanks***, thus improving biodiversity.

The impact[52,53] of these practices, lies in four areas varying according to agro-climatic and market conditions. These are cumulative, but dependent on the deployment as integrated packages.

[52] 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

[53] 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)

- ***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 cane production, sequestering carbon both in the soil and in increased biomass, and N20 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.

Detail of the impact of each of these components are shown qualitatively (- no effect, + some effect, ++ intermediate effect and +++ large effect) in Annex 5, with resilience and productivity further demonstrated in the figure below. This emphasises the importance of higher agro-climatic potential and good markets in achieving higher productivity.

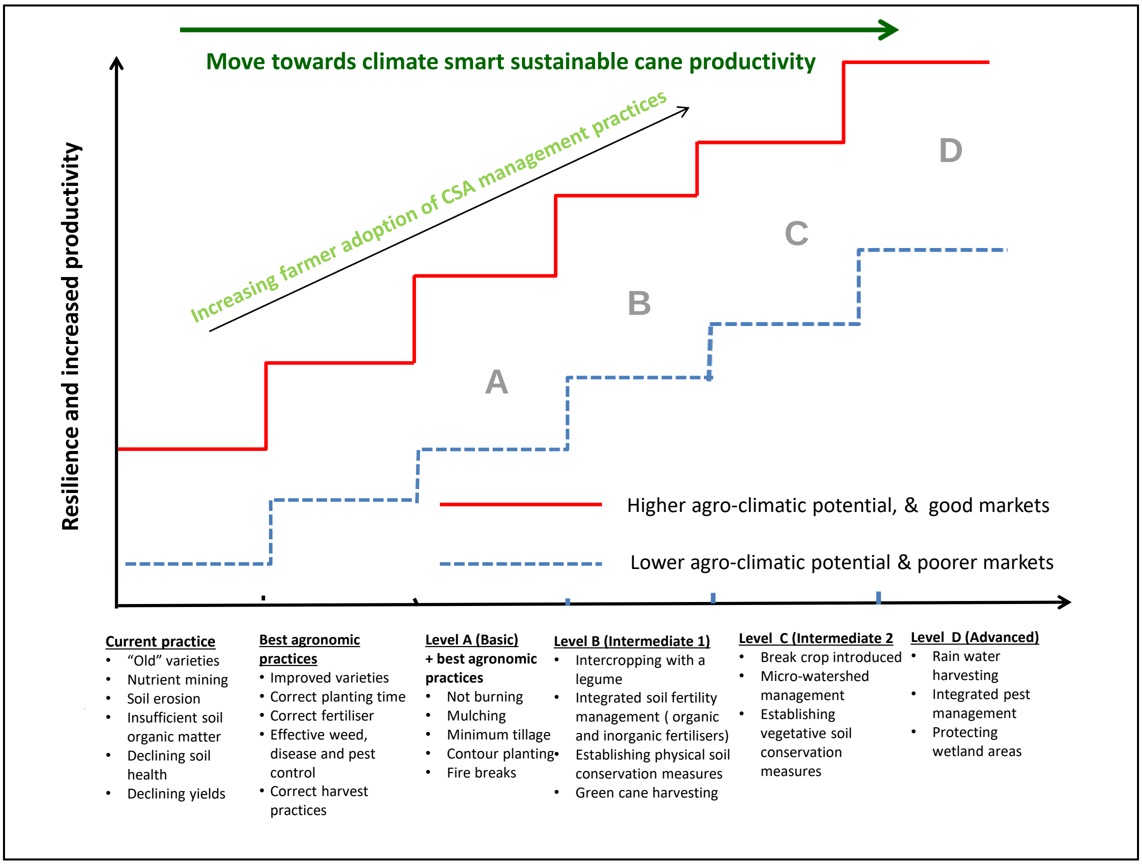

FIGURE 6: TOWARDS CLIMATE SMART SUSTAINED CANE PRODUCTION[54]

[54] 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 Cane Practices

Estimates of the yield increases through use of the 19 CSA sugar cane practices are difficult to quantify individually as greatest benefit will occur with an integration of their use alongside other best agronomic practices and this is how studies are typically carried out. As such, we do not have the ability to isolate the impact of each individual measure. Additionally, these will be location specific dependent on agro-climatic conditions, and increased yields can be achieved alongside a reduction in the costs particularly land preparation and fertiliser, although increased labour can be expected, unless mechanisation suitable for SSGs is also introduced.

Yields will increase over time as soil organic matter builds, soil health is restored and soil conservation measures become effective. Progressive yield level, based on research and practical experience in Australia[55], Brazil[56] and South Africa[57], can occur from a base of 50 tonnes ha^{-1} by 5-20% up to 53-62 tonnes ha^{-1} and up to 70-120 tonnes ha^{-1}. These will be highest where the impact effects of CSA practices are greatest, where soil health is poor and yield levels are declining, often on steeper slopes with poor soil conservation practices and under rainfed conditions. This means that adoption of CSA level practices in addition to best agronomic ones could result in a doubling of yields under favourable rainfed conditions from a base of 50 tonnes ha^{-1} to over 100 tonnes ha-1 over a period of time. Under irrigation, yield levels would be substantially higher.

Level	CSA practice	Increase from Base case[1]	tonnes ha^{-1}	Yield expected
Level A - Basic level	1. Plant 50 trees 2. Membership of a farmer group or association 3. Not burning crop residues 4. Mulching 5. Minimum tillage 6. Planting on the contour / ridges on shallower soils 7. Fire breaks	5-20%	2.5-12	53-62
Level B Intermediate 1	8. Plant additional 50 trees 9. Intercropping in first year 10. ISFM 11. Introducing physical soil conservation measures 12. Green cane harvesting	5-20%	2.5-12	65-84
Level C Intermediate 2	13. Plant additional 50 trees 14. Break crop(s) 15. Micro-watershed management and expanding soil conservation measures 16. Introducing vegetative soil conservation measures	5-20%	2.5-12	68-100
Level D Advanced level	17. Plant additional 50 trees 18. Rain water harvesting	5-20%	2.5-12	71-120

[55] Sugar Research Australia, 2018 Sugarcane Advisors Information Kit published by Sugar Research Australia Limited. ISBN: 978-0-949678-29-4.
[56] UNICA, 2018. Best practices. The Brazilian Sugarcane Industry Association) and the Brazilian Trade and Investment Promotion Agency https://sugarcane.org/best-pratices/
[57] SASRI, various dates. Sugar cane information Sheets. South African Sugar Research Industry.

19. Integrated pest management programme
20. Protecting wetland areas

FIGURE 7: QUANTIFICATION OF THE IMPACT OF CSA PRACTICE ON YIELD LEVELS OVER TIME

[1]Yields will increase over a period of time from a base of 50 tonnes ha^{-1} as the soil organic matter builds, soil health is improved and soil conservation measures become effective. It will be greater on steeper slopes, especially on areas without irrigation

Variation can be expected dependent on agro-climatic conditions, market opportunity and most importantly farmer capacity. Where agro-climatic conditions are less favourable increases in yield from 50 to over 70 tonnes ha^{-1} can be expected and where they are most favourable from 50 to well over 100 tonnes ha^{-1}, especially where irrigation is available.

5.6. Cost Increases and Reductions Through Use of CSA Cane Practices

Estimates indicate that considerable cost savings can be made over a period of time, for: fertiliser 30-50%; water requirements for irrigated cane -30%; fuel consumption for land preparation and planting -60%; and pesticide applications -20%[58]. However, to realise these benefits an increase in labour requirement is often required. Availability of labour and its opportunity cost will be important factor in the adoption or not of CSA practices. Where labour costs are high appropriate mechanisation becomes another important factor.

[58] Brian Sims and Josef Kienzle, 2015. *Mechanization of Conservation Agriculture for Smallholders: Issues and Options for Sustainable Intensification*. Environments 2015, 2, 139-166; ISSN 2076-3298. www.mdpi.com/journal/environments

TABLE 9: QUANTIFICATION OF THE IMPACT OF CSA PRACTICE ON INPUT COSTS AND LABOUR REQUIREMENTS

Climate Smart Agricultural Practice		Reduced or Additional Inputs: Inputs % of Base case	Additional Labour (days/annum)	Comment
Level A - Basic	1. Not burning crop residues	-	-1	small reduction
	2. Mulching	-	2	No increase as residues left on the surface through minimum tillage
	3. Minimum tillage	-5%	-2	reduced fuel costs for land preparation
	4. Contour planting on sloped land / ridges on shallower soils		2	Constructing ridges will be undertaken for the establishment crop and be of benefit for the ratoon crops
	5. Fire breaks	-	1	Undertaken on a seasonal basis as cane dries
	Total A	**-5%**	**2**	
Level B Intermediate 1	6. Intercropping	5%	1	Increased labour required for planting and harvesting
	7. ISFM	-5%	3	Increased labour is required for compost making and incorporation in fields, undertaken with plant crop
	8. Physical soil conservation measures on sloped land		1	Introduction but constructed to coordinate with a micro-watershed plan
	9. Green cane harvesting	-	2	Increased labour and transport costs are likely to be incurred
	Total A+B	**-5%**	**9**	
Level C Intermediate 2	10. Break crop(s)		5	Dependent on whether a green manure is incorporated or a legume crop harvested
	11. Micro-watershed management on sloped land	5%	1	Expansion of soil conservation measures in line with plan. Steeper slopes will require greater labour input
	12. Vegetative soil conservation measures		1	Integration with micro-watershed plan - likely to be on farm or field boundaries
	Total A+B+C	**0%**	**16**	
Level D Advanced level	13. Rain water harvesting on rainfed areas		2	Coordinated with micro-watershed plan
	14. Integrated pest management programme	-5%	1	IPM will reduce the cost of purchased pesticides and but require increased input of trained labour
	15. Protecting wetland areas	-	2	Additional labour may be required for wetland rehabilitation
	Total A+B+C+D	**-5%**	**21**	

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

The risks to sugar cane 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. These mean that cane yields are likely to become more unpredictable and be 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 cane growers have been able to maintain high yields and quality include a combination of good agronomic[59] and CSA practices, include : (i) introduction of new varieties using seed cane and good variety variation, (ii) replanting cane regularly with 10-20% of the area under a replant programme, (iii) fertilising both plant and ratoon fields based on results from soil analysis, (iv) liming soils to ameliorate soil acidity and aluminium toxicity, (v) green cane harvesting and fire control, (vi) sound weed and pest control, (vii) sound soil and surface water conservation practices, (viii) green manuring, (ix) minimising in-field compaction through appropriate row spacing, and (x) sound record keeping.

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

[59] Mcelligott DM, Van Antwerpen R, Ducasse G, 2014. An extension specialist's yield and gross revenue database, used to guide recommendations and improve grower profitability. Proc S Afr Sug Technol Ass (2014) 87: 372 - 393

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 sugar cane flourishes, with first plant crops being normally followed by 4-5 ratoon crops under rainfed conditions and eight or more under irrigation. Although cane does not require a special type of soil, the best are those that are more than a metre deep, are well-aerated with an optimum soil pH about 6.5. However, cane is also successfully grown on shallower soils and on slopes typically not more than 8%, requiring well-designed and maintained soil conservation measures, such as those identified as CSA.

CSA lending products can be used in any of the suitable environments especially where cane 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 reduced tillage and reducing or eliminating soil erosion through conservation measures that are coordinated through micro-watershed protection plans.

6.3. Market parameters

For many developing countries, sugar is one of the most important sources of national income. At the same time, the international sugar market is highly distorted, characterized by significant and widespread domestic support and trade distorting policies, that includes guaranteed minimum payments to growers, production and marketing controls (quotas), state-regulated retail prices, tariffs, import quotas and export subsidies[60]. Current world sugar prices retreated from a 25-year high in 2006, trending downwards as production of traditional importing countries increased, largely due to domestic support measures. Although prices are now predicted to grow slowly, the market remains susceptible to large demand swings and price volatility.

International trade in sugar is largely defined by preferential trade agreements in which producing countries enjoy access to the higher priced domestic markets of the EU or USA through preferential trade agreements. This is particularly important for many developing countries. Although pressure for reform of international sugar policy is intensifying, continued domestic support, regulated trade and uncertain future policy scenarios are likely to continue. Other factors effecting world sugar prices include the potential for expansions in production for biofuel and bio-chemicals. At the same time environmental and social issues are making producers, processors, as well as energy and food companies address sustainability.

Sugarcane accounts for some 80% of global production with developing countries producing some 70% of this[61]. Production has become increasingly concentrated with the top ten producing countries accounting for 69% of production. World sugar consumption set to grow by about 2% per year, sustained by increases in several developing countries and strong purchases made by importers aiming to increase stocks as a protection against future price instability.

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60 https://siteresources.worldbank.org/INTAFRICA/Resources/257994-1215457178567/Sugar_Profile.pdf

61 FAO, 2006. The impact of reforms to sugar sector trade policies. Trade policy technical notes No. 6. a guide to contemporary analyses http://www.fao.org/economic/est/est-commodities/sugar/en/

However, many countries are or have introduced a sugar tax on soft drinks to reduce over-consumption of sugar. These taxes have prompted the food industry and manufacturers to adapt through product reformulation or the use of alternative sweeteners.

Notwithstanding demand for sugar is projected to grow by 1.5% annually. In countries with lower consumption levels, particularly in Asia and Africa, population growth and urbanisation are expected to sustain this growth in sugar consumption, driven by increased consumption of sweetened beverages and prepared food products.

Price projections for the period 2018-2027 follow a moderate upward trend in line with inflation, but downtrend in real terms with a cane price increasing from US$ 40 per tonne to US$ 60-80 per tonne.

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 sugar cane 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 sugar 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?

Perceived profitability has been recognised as a key factor in explaining farmers' decisions to adopt or not adopt sustainable land management (SLM) technologies. Data from 363 case studies[62] conducted in a variety of countries between 1990 and 2012 show that many practices (73%) were perceived as being profitable, i.e. having a positive or at least neutral benefit cost ratio in the short term, while most (97%) were perceived to have a positive or very positive benefit cost ratio in the long term.

Additional analysis confirmed that economic factors were key determinants of land users' decisions to adopt or not adopt SLM technologies. 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.

7.3. Cost benefit analysis assumptions

Many factors in the farmer cost benefit analysis will vary according to location and agro-ecological context. Those variables used to inform this template analysis are summarised in the table below, with a cane price of US$ 40 per tonne and a labour price of US$ 2.50 per day being used.

TABLE 10: VARIABLES AFFECTING THE CSA CANE PRODUCTION PRACTICES

		Base		CSA practice lending levels							
				A		B		C		D	
		P[1]	Rs[2]	P	Rs	P	Rs	P	Rs	P	Rs
Cane yield increase	% pa	0%	0%	5%	5%	10%	10%	15%	15%	20%	20%
Decline in ratoon yield	% pa		-5%		-3%		-3%		-3%		-3%
Yield	tonnes per ha	50	48	53	51	58	56	65	63	75	73
Cane price	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	US $ per tonne	40	40	40	40	40	40	40	40	40	40
Input change	%	0%	0%	-10%	-10%	-5%	-5%	-5%	-5%	-20%	-20%
	US $ per ha	1470	330	1397	314	1397	314	1397	314	1176	264
Labour change	%	0%	0%	3%	3%	12%	14%	20%	26%	27%	34%
	days per ha	80	62	82	64	89	71	96	78	101	83

[1]P= Plant crop, [2]Rs=Four Ratoon crops

[62] 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

7.4. Results

The key output of this exercise is a base case gross margin analysis and a farmer cost benefit analysis model for small scale sugar growers adopting climate-smart and sustainable land management measures required under the proposed climate-smart credit product.

Results from the analysis are shown in below. This demonstrates, in a generalised case, 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 always need to be adopted for specific use-cases.

Sugar farmer gross margin analysis

TABLE 11: GROSS MARGIN ANALYSIS

				Year/season	0	1	2	3	4	
Base level		**Units**		**Base case**	**Plant**	**Ratoon 1**	**Ratoon 2**	**Ratoon 3**	**Ratoon 4**	**Total**
Income	Yield	t/ha			50	47.50	45.13	42.87	40.73	226
	Value	US$/t			40	40	40	40	40	200
Gross income					**2,000**	**1,900**	**1,805**	**1,715**	**1,629**	**9,049**
Input costs			**Qty/ha**	**Price/unit (US$)**						
Land preparation	Contractor	lump sum	1	100	100	100	100	100	100	500
Fertiliser	Muriate of Potash (Planting)	50 kg bag	8	40	320	-	-	-	-	320
	Muriate of Potash (Ratoon)	50 kg bag	2	40	-	80	80	80	80	320
	Diammonium Phosphate	50 kg bag	2	42	84	84	84	84	84	420
	Urea	50 kg bag	2	33	66	66	66	66	66	330
	Sub total				***570***	***330***	***330***	***330***	***330***	***1,890***
Planting	Seed cane	t	10	80	800	-	-	-	-	
	Transport	per t	10	10	100	-	-	-	-	
	Sub total				***900***	***-***	***-***	***-***	***-***	***900***
Harvest	Haulage	per t	50	10	500	500	500	500	500	2,500
	Sub total				***500***	***500***	***500***	***500***	***500***	***2,500***
TOTAL INPUT COSTS					**1,970**	**930**	**930**	**930**	**930**	**5,690**
Margin over inputs before labour, loan repayments or levies		**US $ per ha**			**30**	**970**	**875**	**785**	**699**	**3,359**
Labour costs	Fertiliser application	days	2	2.5	5	5	5	5	5	25
	Cane planting	days	18	2.5	45	45	45	45	45	225
	Tree planting and maintenace	days	0	2.5	-	-	-	-	-	-
	Weeding, roguing and pest control	days	25	2.5	63	63	63	63	63	313
	Cutting cane	days	27	2.5	68	68	68	68	68	338
	Loading	days	10	2.5	25	25	25	25	25	125
	Sub total		***82***		***205***	***205***	***205***	***205***	***205***	***1,025***
Total variable costs					**2,175**	**1,135**	**1,135**	**1,135**	**1,135**	**6,715**
Margin over inputs and labour costs before loan repayments or levies		**US$/ha**			**(175)**	**765**	**670**	**580**	**494**	**2,334**
Total labour input		days			82	82	82	82	82	410
Returns to labour		US$/ha			30	970	875	785	699	3359
Returns to labour		**US$/day**			**0.4**	**11.8**	**10.7**	**9.6**	**8.5**	**8.2**

Cost benefit ratios

TABLE 12: COST BENEFIT RATIOS

		Year						
		0	**1**	**2**	**3**	**4**		
		Plant	**Ratoon 1**	**Ratoon 2**	**Ratoon 3**	**Ratoon 4**	**Total**	**Cost Benefit Ratio**
Base	Gross Margin	(175)	765	670	580	494	2,334	1.00
	Discounted Gross Margin	(175)	729	608	501	406	2,069	
CSA 1	Gross Margin	(13)	937	876	817	759	3,377	1.45
	Discounted Gross Margin	(13)	893	795	706	625	3,005	
CSA 2	Gross Margin	64	1,011	946	884	824	3,729	1.61
	Discounted Gross Margin	64	962	858	764	678	3,326	
CSA 3	Gross Margin	140	1,084	1,017	952	889	4,081	1.76
	Discounted Gross Margin	140	1,032	922	822	731	3,648	
CSA 4	Gross Margin	175	1,100	1,030	962	896	4,162	1.80
	Discounted Gross Margin	175	1,047	934	831	737	3,724	

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 sugar, below are the summary outputs of the model showing improved cash position in the event of a 40% yield shock.

TABLE 13: LENDER IMPACT WITH CLIMATE-SMART LENDING

	Establishment	Ratoon 1	Ratoon 2	Ratoon 3	Ratoon 4
Yield loss scenario	40%	40%	40%	40%	40%
Number of clients	2,000	2,000	2,000	2,000	2,000
Loan book size (US$)	2,095,500	471,000	495,000	495,000	495,000
Portfolio loss with no climate-smart lending	882,000	198,000	198,000	198,000	198,000
Portfolio loss with climate-smart lending	104,775	23,550	24,750	24,750	24,750
Cost of capital w/o climate-smart lending	20%	20%	20%	20%	20%
Cost of capital w climate-smart lending	8%	8%	8%	8%	8%
Annual interest savings (US$)	251,460.00	56,520.00	59,400.00	59,400.00	59,400.00
Cash position improvement with climate-smart-lending (US$)	**1,028,685**	**230,970**	**232,650**	**232,650**	**232,650**

	Yield Loss			
Cash Position Improvement with CSL Lending (US$/10,000 clients)	10%	20%	30%	40%
	702,105	1,120,605	1,539,105	1,539,105

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$ 1,830 over 8 years.

TABLE 14: ENVIRONMENTAL COST BENEFIT ANALYSIS

	#	Benefits	Year 0	1	3	4	5	6	7
Loan 1	1	Plant 50 trees	19						
	2	Ensuring crop residues are not burnt after harvest and using firebreaks	-	-	-	-	-	-	-
	3	Mulching with crop residues	-	-	-	-	-	-	-
	4	Planting cane on the contour and on ridges on shallower soils	-	-	-	-	-	-	-
	5	Using minimum tillage	15	15	15	15	15	15	15
	6	Preventing fire-damage by making fire breaks to protect drying cane	-	-	-	-	-	-	-
Loan 2	7	Plant 50 additional trees	19						
	8	Intercropping with a legume when planting cane	81	81	81	81	81	81	81
	9	Integrated soil fertility management through use of organic material with inorganic fertilisers at or before planting	50	50	50	50	50	50	50
	10	Establishing physical soil conservation measures depending on soil type, land slope and available materials	-	-	-	-	-	-	-
	11	Introducing green cane harvesting, abandoning the use of burning before cutting	-	-	-	-	-	-	-
Loan 3	12	Plant 50 additional trees	19						
	13	Introducing a break crop after the last ratoon cane is harvested	7	7	7	7	7	7	7
	14	Micro-watershed management, expanding soil conservation measures integrated across farm or field boundaries	-	-	-	-	-	-	-
	15	Planting and managing vegetative soil conservation measures, where appropriate	-	-	-	-	-	-	-
Loan 4	16	Plant 50 additional trees	19						
	17	Establishing rain water harvesting from run-off areas, where appropriate	-	-	-	-	-	-	-
	18	Introducing an Integrated pest management programme	100	100	100	100	100	100	100
	19	Protecting wetland areas by planting or protecting suitable tree and/or grass species	170	170	170	170	170	170	170
		Total Benefits (US$/ha)	479	424	424	424	424	424	424
		Loan 1 Labour	(2.50)	(2.50)	(2.50)	(2.50)	(2.50)	(2.50)	(2.50)
		Loan 2 Labour	20.00	20.00	20.00	20.00	20.00	20.00	20.00
		Loan 3 Labour	17.50	17.50	17.50	17.50	17.50	17.50	17.50
		Loan 4 Labour	12.50	12.50	12.50	12.50	12.50	12.50	12.50
		Loan discounts	52.40	11.80	11.80	11.80	11.80	52.40	
		Total Costs (US$/ha)	**99.90**	**59.30**	**59.30**	**59.30**	**59.30**	**99.90**	**47.50**
		Net Benefits (US$/ha)	**379.33**	**364.20**	**364.20**	**364.20**	**364.20**	**323.60**	**376.00**
		Discounted Net Benefits (US$/ha)	**379.3**	**331.1**	**273.6**	**248.8**	**226.1**	**182.7**	**192.9**
		NPV (US$/ha)	**1,834.6**						

ANNEX 1: AREA AND AVERAGE CANE YIELDS FOR CANE SUGAR PRODUCING COUNTRIES

Country	Area ha	% of total	Tonnes of cane	% of total	Av yield tonnes ha^{-1}
Brazil	10,226,205	51.4%	768,678,382	36.0%	75
India	4,950,000	24.9%	348,448,000	16.3%	70
China	3,344,514	16.8%	245,723,679	11.5%	73
Thailand	1,336,575	6.7%	87,468,496	4.1%	65
Pakistan	1,130,820	5.7%	65,450,704	3.1%	58
Mexico	781,054	3.9%	56,446,821	2.6%	72
Indonesia	472,693	2.4%	27,158,830	1.3%	57
Australia	447,204	2.2%	34,403,004	1.6%	77
Cuba	442,307	2.2%	18,890,972	0.9%	43
Colombia	416,626	2.1%	36,951,213	1.7%	89
Philippines	410,104	2.1%	22,370,546	1.0%	55
United States of America	370,530	1.9%	29,926,210	1.4%	81
Argentina	331,699	1.7%	21,990,823	1.0%	66
Guatemala	259,850	1.3%	33,533,403	1.6%	129
Viet Nam	256,322	1.3%	16,313,145	0.8%	64
South Africa	246,937	1.2%	15,074,610	0.7%	61
Myanmar	163,650	0.8%	10,437,058	0.5%	64
Bolivia	152,306	0.8%	6,910,805	0.3%	45
Egypt	137,011	0.7%	15,760,418	0.7%	115
Cameroon	135,984	0.7%	1,288,732	0.1%	9
Paraguay	120,000	0.6%	6,708,000	0.3%	56
Tanzania	108,487	0.5%	2,994,127	0.1%	28
Dominican Republic	106,810	0.5%	4717490	0.2%	44
Ecuador	104,661	0.5%	8,661,609	0.4%	83
Bangladesh	98,357	0.5%	4,207,592	0.2%	43
Iran	95,785	0.5%	7,687,593	0.4%	80
Madagascar	94,157	0.5%	3,005,641	0.1%	32
Peru	87,696	0.4%	9,832,526	0.5%	112
Kenya	86,876	0.4%	7,094,619	0.3%	82
Nigeria	82,586	0.4%	1,337,572	0.1%	16
Nepal	80,931	0.4%	4,346,754	0.2%	54
El Salvador	79,103	0.4%	7,202,141	0.3%	91
Nicaragua	74,130	0.4%	6,815,147	0.3%	92
Sudan	69,564	0.3%	5,525,059	0.3%	79
Costa Rica	69,030	0.3%	4,158,370	0.2%	60
Honduras	64,666	0.3%	5,355,700	0.3%	83
Eswatini (Swaziland)	57,851	0.3%	5,583,295	0.3%	97
Uganda	54,911	0.3%	3,723,019	0.2%	68
Venezuela	52,230	0.3%	3,331,252	0.2%	64

Country	Area ha	% of total	Tonnes of cane	% of total	Av yield tonnes ha^{-1}
Mauritius	51,477	0.3%	3,798,448	0.2%	74
Democratic Republic of the Congo	48,910	0.2%	2,191,333	0.1%	45
Guyana	44,311	0.2%	2,394,553	0.1%	54
Zimbabwe	43,500	0.2%	3,483,000	0.2%	80
Mozambique	42,311	0.2%	2,761,505	0.1%	65
Zambia	41,695	0.2%	4,285,839	0.2%	103
Panama	37,995	0.2%	2,419,638	0.1%	64
Fiji	36,705	0.2%	1,556,692	0.1%	42
Lao People's Democratic Republic	36,180	0.2%	2,019,000	0.1%	56
Belize	33,964	0.2%	1,457,656	0.1%	43
Ethiopia	31,237	0.2%	1,410,312	0.1%	45
Japan	28,901	0.1%	1,574,000	0.1%	54
Cambodia	27,387	0.1%	610,878	0.0%	22
Malawi	27,087	0.1%	2,915,406	0.1%	108
Liberia	26,781	0.1%	272,804	0.0%	10
Jamaica	26,255	0.1%	1,422,432	0.1%	54
Cote d'Ivoire	25,205	0.1%	1,982,661	0.1%	79
Reunion	24,239	0.1%	1,820,106	0.1%	75
Haiti	23,184	0.1%	1,472,712	0.1%	64
Congo	20,132	0.1%	687,365	0.0%	34
Central African Republic	18,466	0.1%	103,002	0.0%	6
Sri Lanka	16,751	0.1%	747,907	0.0%	45
Angola	14,255	0.1%	556,094	0.0%	39
Rwanda	11,030	0.1%	93,823	0.0%	9
Guadeloupe	10,776	0.1%	687,849	0.0%	64
Morocco	10,434	0.1%	426,503	0.0%	41
Uruguay	7,600	0.0%	367,700	0.0%	48
Papua New Guinea	6,999	0.0%	217,866	0.0%	31
Ghana	6,122	0.0%	152,136	0.0%	25
China, Taiwan Province of	5,917	0.0%	395,800	0.0%	67
Senegal	5,902	0.0%	696,992	0.0%	118
Niger	5,840	0.0%	216,037	0.0%	37
Somalia	5,731	0.0%	210,620	0.0%	37
Guinea	5,683	0.0%	304,975	0.0%	54
Mali	5,035	0.0%	365,119	0.0%	73
Burkina Faso	4,823	0.0%	484,872	0.0%	101
Gabon	4,645	0.0%	286,466	0.0%	62
Chad	4,433	0.0%	455,986	0.0%	103
Martinique	4,057	0.0%	197,042	0.0%	49
Suriname	3,130	0.0%	125,286	0.0%	40
Burundi	2,998	0.0%	218,115	0.0%	73

Country	Area ha	% of total	Tonnes of cane	% of total	Av yield tonnes ha^{-1}
Bahamas	2,308	0.0%	57,602	0.0%	25
Barbados	1,733	0.0%	83,369	0.0%	48
Afghanistan	1,333	0.0%	17,364	0.0%	13
Cabo Verde	1,296	0.0%	28,375	0.0%	22
Sierra Leone	1,107	0.0%	77,269	0.0%	70
Saint Vincent and the Grenadines	732	0.0%	17,871	0.0%	24
Benin	598	0.0%	12,017	0.0%	20
Iraq	584	0.0%	11,670	0.0%	20
Bhutan	467	0.0%	14,600	0.0%	31
Guinea-Bissau	259	0.0%	6,864	0.0%	27
Dominica	244	0.0%	4855	0.0%	20
Grenada	162	0.0%	7,273	0.0%	45
French Guiana	104	0.0%	6,095	0.0%	59
Malaysia	88	0.0%	5,714	0.0%	65
Portugal	62	0.0%	5,429	0.0%	88
Oman	51	0.0%	1,186	0.0%	23
French Polynesia	40	0.0%	3,443	0.0%	86
American Samoa	32	0.0%	31	0.0%	1
Spain	9	0.0%	394	0.0%	44
Lebanon	3	0.0%	97	0.0%	32
Samoa	1	0.0%	12	0.0%	12
Wallis and Futuna Islands	1	0.0%	20	0.0%	20
	19,892,613	100.0%	2,136,385,377	Mean	56

ANNEX 2: SUGAR INDUSTRY COUNTRY PROFILES

Australia[63]

The sugar milling industry is one of Australia's largest and most important rural industries. It is the third largest exporter of sugar after Brazil and Thailand employing 16,000 people. 380,000 hectares are grown on 4,000 cane farms delivering to 24 mills owned by 8 separate milling companies. Key products are raw sugar (refined into white, brown, golden syrup), molasses (used for cattle feed), bagasse (used to generate steam and electricity), mill mud (organic fertiliser usually spread on farms) and mulch (used for landscaping).

33 million tonnes of sugarcane is crushed annually and 3.7 million tonnes of raw sugar produced. Around 80% of raw sugar is exported with most refined sugar being sold domestically. Asia has become a major focus for exports with key markets being South Korea, Indonesia, Japan and Malaysia. The industry is continually looking to diversification opportunities supported with an annual investment of $24 million in research.

Ethiopia[64]

The Tate-owned Ethiopian Sugar Corporation" came into existence on October, replacing the former Ethiopian Sugar Development Agency. In 2014-15 The Ethiopian Sugar industry included five sugar mills with a capacity to produce 33,000 tonnes of sugar annually. The government has identified sugar production as one of the cornerstones for increasing the country's competitive advantage in the agro-processing subsector. By 2020, it is expected to have 10 new sugar factories under construction On completion, Ethiopia's annual refined sugar production will be 600,000 tons

The land presently under cane is 95,000 ha including 15, 000 outgrowers in 75 sugar associations. There are plans to extend the area under irrigation for out growers to boost the supply of cane

Indonesia[65]

Indonesia currently has 63 sugar mills owned by 18 companies. The majority of these factories are old because of underinvestment and have low rates of productivity. Indonesian sugar consumption is around three million tonnes per year, while national sugar production varies from 2.5–3.0 million tonnes per year resulting in a shortfall of 300–500,000 tonnes. Many issues continue to plague the sugar industry, ranging from aging factories, reduced sugarcane fields, lack of good varieties, farm inefficiency, poor adoption of technology, slow pace of product diversification and low productivity due to a flood of cheap imported sugar due to poor market regulation. Lack of adequate research and development support to the industry also contributes to low productivity, loss of technical efficiency and low sugar recovery. The challenge of cheaply imported sugar serves to highlight the scale of demand for the commodity, placing Indonesia among the world's largest buyers, particularly by the country's food and beverage manufacturing sector.

Bright prospects for investment in the national sugar industry are evident from growing interests of the private sector to invest in the industry. The government also plans to revitalize existing sugar units, expand cane area and setup new sugar units in collaboration with the private sector to realize the plan of self-sufficiency.

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[63] Australian Milling Council, 2018. Industry Overview. https://asmc.com.au/industry-overview/
[64] Ethiopian Government. http://www.ethiopiansugar.com/index.php/en/
[65] Aris ToharismanTriantarti, 2016: *An Overview of Sugar Sector in Indonesia.* November 2016, Sugar Tech 18(6). DOI: 10.1007/s12355-016-0490-6. https://www.researchgate.net/publication/309709072

Kenya[66]

The sugar industry plays a significant role in Kenya's economy, contributing about 15 percent to the country's agricultural GDP. The sector consists of more than 250,000 smallholder farmers, who supply over 92 percent of the sugarcane processed by sugar companies, while the remainder is supplied by factory-owned nucleus estates. An estimated 25 percent of the country's population depends directly or indirectly on the sugar industry for their livelihood. Kenya's 11 sugar factories have an annual production capacity of about 600,000 tonnes of sugar against the annual consumption of 800,000 tonnes. Sugarcane yield stands at an average of 60 tonnes of sugar cane per hectare compared to the global an average of 63 tonnes per hectare. The sector has not been vibrant for considerable time due to low cane production coupled with poor mill management[67]. The much anticipated privatization of sugar mills has not taken place and they continue to be burdened by obsolete milling technology and debts leading to poor services to farmers[68]. Consequently, privately owned mills have encroached some of areas that were previously zoned-off for the state-owned mills to provide alternative cane marketing outlets. Local sugar production is also limited by poor crop husbandry practices, low access to inputs, poor transport infrastructure, and delayed payments to farmers with some reports of malnutrition and poverty in sugar growing areas. Consequently farmers have diverted to other cropping enterprises to earn a living. Kenya could be self-sufficient in sugar production but imports sugar from neighbouring countries. Kenya's Sugar Directorate indicates that locally produced sugar remains uncompetitive with a cost of production at about $600 USD per tonne and higher than anywhere else in the Common Market for Eastern and Southern Africa (COMESA). Local production meets about 60% of total consumption with the shortfall offset by imports, mainly from the COMESA region, but also India, Mauritius, Egypt, and Thailand.

Malawi[69]

Sugar contributes about 10% of Malawi's GDP, and about 35% of the country's agricultural sector. Sugar contributed 9% of export earnings in 2013. The industry directly employs 11,552 people (including seasonal and non-permanent workers) and supports an estimated 3,434 people as out-growers. Sugar cane production was 2.92 million tonnes In 2016 and has been growing at an average annual rate of 7.49 %. All sugar is produced by Illovo Sugar's two mills. The company owns two estates one of 13,300 ha and one of 20,925 ha south

Major constraints have included out of season rainfall affecting cane quality negatively resulting in interruptions in cane supply which in turn, contributes to poor factory performance and land availability affecting cane expansion.

South Africa[70]

The South African sugar industry is one of the world's leading competitive producers of high quality sugar and makes an important contribution to employment, particularly in rural areas, to sustainable development and to the national economy. It is a diverse industry combining the agricultural activities of sugarcane cultivation with the manufacture of raw and refined sugar, syrups, specialised sugars and a range of by-products. The cane growing sector comprises approximately 22 500 registered sugarcane growers with sugar manufactured by six milling companies with 14 sugar mills. The industry produces an estimated average of 2.2 million tons of sugar per season, some 60% being marketed in the Southern African Customs Union, the remainder being exported to markets in Africa, Asia and the Middle East.

Small-scale sugarcane growers form the majority of cane growers, although there has recently been a decline in numbers. Their contribution to the sustainability and long-term growth of the South African sugarcane industry is regarded as invaluable and impacts on the long term viability of the whole industry. SSGs are faced with challenges

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66 USDA, 2017. Kenya Annual Sugar Report, 2017. USDA Foreign Agricultural Service Global Information network

67 Kenya Sugar production, 2017. http://www.farmlinkkenya.com/sugarcane-farming/

68 Top Farmer, 2017. Untold Story: Why Kenya's sugar industry is in a mess. http://topfarmer.co.ke/untold-story-why-kenyas-sugar-industry-is-in-a-mess/. TopFarmer -June 22, 2018

69 MITC, 2016. Malawi sugar production and consumption. Malawi Investment and Trade Centre, https://mitc.mw/trade/index.php/sugar-production-and-consumption.html accessed 29 November 2017.

70 South African Sugar Association, 2018. Industry Overview. http://www.sasa.org.za/sugar_industry/IndustryOverview.aspx accessed 28th November 2018

such as the lack of capital or credit; low and declining productivity of crop land; lack of management capacity and regulatory systems; lack of farmer capacity (technical, business, institutional); high costs of inputs and transportation and inadequate irrigation infrastructure[71].

Zambia[72]

There are three sugar companies with the market being dominated Zambia Sugar Plc., which contributes about 92.5% of the total sugar production in Zambia. Sugarcane is grown largely under irrigation in the Northern and Southern parts of the country. Miller owned estates contribute about sixty percent of the total sugarcane production, with forty percent coming from independent farmers and SSG outgrower schemes. 2016/17 estimates of the sugar cane crop are 3,250,745 tonnes with sugar production estimated to be 388,405 tonnes[73]. Exports are mainly to Africa and the European Union. Sugar imports are minimal.

Zambia is one of the lowest cost producers of sugar globally and growth in the sugar industry holds prospects for economic diversification and employment creation. However it is constrained by high transaction costs including high fuel, electricity, transportation and distribution costs. Water rights and insecurity associated with customary land tenure have emerged as major issues requiring attention to enhance investment in the sector. The situation is aggravated by lack of a well-articulated sugar policy to provide guidance for sector development. This includes water rights and land tenure security for establishment of sugar plantations, as well as policy on bio-fuels as well and export strategy to reduce dependence on EU markets and explore alternative regional markets

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[71] Hurly KM, Sibiya TG, Nicholson R and King M, 2015. Roadmap for small-scale grower sustainability. Proceedings of South African Sugar Technology Association, (2015) 88: 318 – 336.

[72] Thomson Kalinda and Brian Chisanga, 2013. Sugar Value Chain in Zambia: An Assessment of the Growth Opportunities and Challenges. Asian Journal of Agricultural Sciences 6(1): 6-15, 2014 1. https://www.researchgate.net/publication/264713328_Sugar_Value_Chain_in_Zambia_An_Assessment_of_the_Growth_Opportunities_and_Challenges_1 [accessed Nov 29 2018]

[73] USDA, 2017. Zambia supply and demand for-sugar. https://www.fas.usda.gov/data/zambia-supply-and-demand-sugar-Zambia

Annex 3: Best sugar cane management practices for sustainable production

Practices[74,75,7677]		Sugar cane crop		Practice detail	Environmental benefits
		Plant	Ratoon		
Land preparation	Land preparation on the contour	+	-	Land preparation on contour, rather than up and down the slope	Reduction in soil erosion due to rainfall run-off especially in high intensity storms. Severe erosion will result in large crop losses
	Minimum or zero tillage	+	-	Crop residues left on surface, burning discouraged	Reduced soil erosion, due to both rainfall run-off and winds, as well as improved soil moisture content
Crop diversification	Break crops after ratoon removal and cane re-establishment	+	-	Green manure or legume crop which can be harvested or incorporated in soil. This should be for at least one year and could be longer if land is available	Improved soil fertility through legume nodulation and atmospheric N capture, and additional biomass building soil organic matter, as well as improved pest control, reducing the need for agro-chemicals
	Intercropping in the year of establishment	+	-	Legume intercrop in alternative rows during first year	
Agronomic practices	Improved varieties (for yield, sugar content, disease control and pest resistance)	+	-	Such practices can be regarded as good crop husbandry and should normally be used	Following 'best' recommended practices will ensure that high yields will be obtained ensuring that environmental benefits are captured
	Plantlet use following in-vitrio production rather than cane stems	+	-		
	Planting at the correct time	+	-		
	Row planting on the contour	+	-		
	Effective weeding by hand, mechanically or with herbicides	+	+		
	Integrated pest management	+	+	Plant suitable species adjacent to cane fields.	Reduced pest damage and cost saving in reducing or eliminating the need for agro-chemical pesticides and possible misuse by SSGs with dangers to human health.
Soil fertility management	Organic and inorganic input	+	+	Integrated soil fertility management (ISFM) practices involve the use of a combination of organic and inorganic fertilisers. Ideally soil analysis should be undertaken to ensure no micro-nutrients are limiting and soil pH is acceptable	Improved soil health through an increase in soil organic matter and CO_2 capture and hence a reduction in the application of inorganic fertilisers and consequent cost saving.
	Green manures as a breakcrop	+	-		
	Incorporation of sugar milling bi-products	+	-		
	Compost/manure use	+	-		
	Inorganic inputs (NPK) and trace elements	+	+		
	Split application of Nitrogen fertiliser	+	+		
	Lime on acid soils	+	-		

74 Mcelligott DM, Van Antwerpen R, Ducasse G, 2014. An extension specialist's yield and gross revenue database, which is used to guide recommendations and improve grower profitability. Proc S Afr Sug Technol Ass (2014) 87: 372 - 393

75 Sugar Research Australia, 2018. The Sugarcane Advisors Information Kit. ISBN: 978-0-949678-29-4

76 UNICA, 2018. Best practices. The Brazilian Sugarcane Industry Association and the Brazilian Trade and Investment Promotion Agency https://sugarcane.org/best-pratices/

77 SASRI, various. Sugar cane, information Sheets. South African Sugar Research Industry

	Fertiliser banding	+	+		
Soil & water management	Level earth contours	+	-	The exact soil conservation measures will depend on the soil type, land slope, and available materials	Reduced soil erosion due to rainfall run-off especially in high intensity storms.
	Cane planted on ridges on shallow soils	+	-		
	Grass strips on contour on sloping lands	-	-		
	Stone bunds on contour on sloping lands	+	-		
	Fanya Juus on contour on sloping land	+	-		
	Micro-watershed management	+	-	It will be important that neighbouring farmers collaborate when considering alternative structures	Reduced soil erosion across the micro-watershed due to safe rainfall run off
	Mulching used with reduced or zero tillage	+	+	Use of cane residues and other biomass material	Reduction in soil erosion due to both rainfall and wind and increase in soil moisture holding capacity that allows the cane to better withstand drought periods as well as higher temperatures.
	Wetland protection (not planting cane)	+	+	Replanting suitable tree species may be required if wetlands have been cultivated with cane for some time	Unsuitable or marginal land is not used for cane production resulting in increased bio-diversity and reduced soil erosion in those areas where run-off rainfall collects
	Rain water harvesting from run-off areas	+	+	Capturing rainfall run-off and channelling it safely into cane fields Different methods can be used depending on circumstances	Reduced soil erosion due to high intensity rainfall events. Increased soil moisture available to the cane especially important due to periods of drought
	Irrigation	+	+	Alternatives can be considered depending on water and equipment availability and cost	The need for irrigation is reduced by the overall improvement in soil health
Agroforestry practices	Trees on contour	-	-	The only realistic agroforestry practices are planting suitable varieties planted on farm or field boundaries as hedgerows using biomass for livestock feed, building, firewood or crop mulching purposes	Although agro-forestry systems are suitable for many crops, this is not the case with cane. Notwithstanding agro-forestry will increase biomass availability that can be used in ISFM as well as making tree products available to SSGs.
	Alley cropping	-	-		
	Boundary trees	+	+		
	Fertiliser trees in the field	-	-		
	Shade trees	-	-		
Harvest practices	Fire control	+	+	Fire breaks to protect drying crop	Reduced CO2 and increased carbon sequestration
	Green cane harvesting	+	+	Fire use before cutting cane abandoned with crop residues used as a mulch	

[1] + Suitable for use, - cannot be used or unsuitable

ANNEX 4: CLIMATE SMART MANAGEMENT PRACTICES FOR SUGAR CANE

Practice		Benefit	Challenges/costs
Level A Basic	1. Not burning crop residues	• Crop residues used as mulch will protect the soil against rain drop action, consequent rain-water run-off and soil erosion.	• Control of some pests such as Eldana spp may require periodic burning.
	2. Mulching	• They will also reduce soil moisture evaporation from the soil surface; reduce soil temperatures as well contributing to an increase in soil organic matter. This is an integral part of Conservation Agriculture or CA.	
	3. Minimum tillage		• A reduction in land preparation costs is achieved compared with conventional ploughing.
	4. Planting on the contour / ridges on shallower soils*	• Yields are likely to increase from 5% - 50% over a number of years.	• Constructing ridges undertaken for the establishment crop will be of benefit for subsequent ratoon crops.
	5. Fire breaks	• Will prevent run-away fires as the cane dries. This is a risk prevention strategy that could result in a 100% yield benefit.	• This would be undertaken on a seasonal basis.
Level B Intermediate 1	6. Intercropping with a legume in the plant crop	• Designed to utilise the unused interow providing an additional crop as well as adding to soil N.	• Additional labour required for planting and harvesting.
	7. ISFM	• Designed to increase soil organic matter incorporating carbon and improving soil health. As with CA, the benefits will increase as soil organic content builds.	• Increased labour is required for compost making and incorporation in fields, undertaken with establishment crop.
	8. Physical soil conservation measures especially on slopes over 2%	• Designed to prevent soil erosion and consequent decline in soil health.	• Some measures would be initiated but constructed to coordinate with a micro-watershed plan.
	9. Green cane harvesting	• Intended to prevent the loss of crop residues for mulching in the subsequent ratoon crop Linked to the use of CA.	• Increased labour and transport costs are likely to be incurred.
Level C Intermediate 2	10. Break crop(s), green manure or legume	• An important means of improving soil health as well as reducing disease and pest problems. This will result in loss of cane land for duration of the break, but yield increases in the subsequent crop can be over 80% and 20% in the ratoon crops. Yield from an	• Dependent on whether a green manure is grown or a legume crop harvested.

Practice		Benefit	Challenges/costs
		alternative crop should compensate for loss of the cane crop.	
	11. Micro-watershed management	• This allows for extending and integrating soil conservation measures across farm or field boundaries for safe water run-off into uncropped natural waterways along natural drainage lines. Yiled benefits will be greater on steeper slopes	• Requires coordination and integration with adjoin fields. The steeper the slopes will require greater labour input.
	12. Vegetative soil conservation measures	• The use of carefully managed hedge-rows or trees species on the contour may be option on steep slopes, although competition with cane may be an issue. Such measures should be considered on field or farm boundaries or across contours on steep slopes The increase will be greater on steeper slopes	• Requires coordination and integration with adjoin fields. The stepper the slopes will require greater labour input.
Level D Advanced	13. Rain water harvesting especially on rainfed cane	• Involves collection of rainfall from run-off areas and channelled into cane fields to increase soil moisture availability, increasing yields in affected areas.	• Requires coordination with a micro-watershed plan.
	14. Integrated pest management programme	• IPM uses multiple pest management tactics to prevent economically damaging out-breaks while reducing risks to human health and the environment.	• IPM will reduce the cost of purchased pesticides and but require increased input of trained labour.
	15. Protecting wetland areas	• Wetlands in cane growing areas are areas of high biodiversity as well as being areas where run-off water from cane-lands naturally collect. They require special protection and may be protected by law. Protection or removal from cultivation may require introduction of suitable tree or grass species. This may require some land to be taken out of cultivation. This is likely to be beneficial as such areas are prone to waterlogging.	• Additional labour may be required for wetland rehabilitation.

ANNEX 5: THE IMPACT OF CSA SUGAR CANE PRACTICES

1. The impact of CSA practice on the resilience of natural resource uses

Climate smart agricultural 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
Level A - Basic level	1.	Membership of a farmer group or association		intended to promote farmer to farmer expansion and adoption of best practice						
	2.	Not burning crop residues	+	-	+++	+++	+++	+++	+++	+++
	3.	Mulching	+++	+	+++	+++	+++	+++	+++	+++
	4.	Minimum tillage	+++	+++	+++	+++	+++	+++	+++	+++
	5.	Planting on the contour / ridges on shallower soils*	-	-	+++	+	+	+	-	++
	6.	Fire breaks	++	++	++	++	++	++	++	++
Level B Intermediate 1	7.	Intercropping	+	+	++	+++	++	++	++	++
	8.	ISFM	+++	+	+++	+++	+++	+++	+++	+++
	9.	Physical soil conservation measures*	-	+	+	+	++	+	+	+
	10.	Green cane harvesting	-	++	++	++	++	++	++	++
Level C Intermediate 2	11.	Break crop(s)	+++	++	++	+++	++	+++	+++	++
	12.	Micro-watershed management*	+	++	+++	++	++	+	++	++
	13.	Vegetative soil conservation measures	+++	++	++	++	+	+	+	++
Level D Advanced level	14.	Rain water harvesting**	+	++	+	-	++	+	-	++
	15.	Integrated pest management programme	+++	-	-	-	-	+	-	-
	16.	Protecting wetland areas	+++	+++	+	-	+	-	-	++

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

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

2. CSA sugar cane practices impact on risks associated with climate change

Climate smart agricultural practice			Increased temperature	Intra-seasonal droughts	In season droughts	Shortened growing season	Increased rainfall intensity	Unpredictable seasons
Level A - Basic level	1.	Membership of a farmer group or association	Intended to promote farmer to farmer expansion and adoption of best practice					
	2.	Not burning crop residues	+	+	+	+	+	+
	3.	Mulching	+++	+++	+++	+++	+++	++
	4.	Minimum tillage	+++	+++	+++	+++	+++	++
	5.	Planting on the contour / ridges on shallower soils*	-	-	-	-	+++	+++
	6.	Fire breaks	++	++	++	++	++	++
Level B Intermediate 1	7.	Intercropping	++	+	+	++	++	-
	8.	ISFM	++	++	++	++	++	++
	9.	Physical soil conservation measures*	-	+	+	+	+++	+++
	10.	Green cane harvesting	++	++	++	++	++	++
Level C Intermediate 2	11.	Break crop(s)	++	++	++	++	++	++
	12.	Micro-watershed management*	-	+	+	+	+++	+++
	13.	Vegetative soil conservation measures	+	+	+	+	++	++
Level D Advanced level	14.	Rain water harvesting**	-	++	+++	+++	-	+
	15.	Integrated pest management programme	+	+	+	+	+	+
	16.	Protecting wetland areas	+	++	++	+	++	++

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

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

3. The impact of sugar cane 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
Level A - Basic level	1.	Membership of a farmer group or association	Intended to promote farmer to farmer extension and adoption of best practice					
	2.	Not burning crop residues	+	-	++	++	-	-
	3.	Mulching	+	-	+++	+++	+	-
	4.	Minimum tillage	+	++	+++	+++	+	-
	5.	Planting on the contour / ridges on shallower soils*	+	-	+	+	+	-
	6.	Fire breaks	+	++	+++	+++	+	-
Level B Intermediate 1	7.	Intercropping	++	++	+	-	-	-
	8.	ISFM	+	+	+++	++	+	-
	9.	Physical soil conservation measures*	+++	-	-	-	-	-
	10.	Green cane harvesting	-	+	+++	+++	-	-
Level C Intermediate 2	11.	Break crop(s)	++	++	+++	+++	+	-
	12.	Micro-watershed management*	++	-	-	-	-	-
	13.	Vegetative soil conservation measures	++	-	++	++	-	-
Level D Advanced level	14.	Rain water harvesting**	+	-	-	++	-	-
	15.	Integrated pest management programme	-	+++	+	++	+	-
	16.	Protecting wetland areas	+++	-	+	+	-	-

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

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

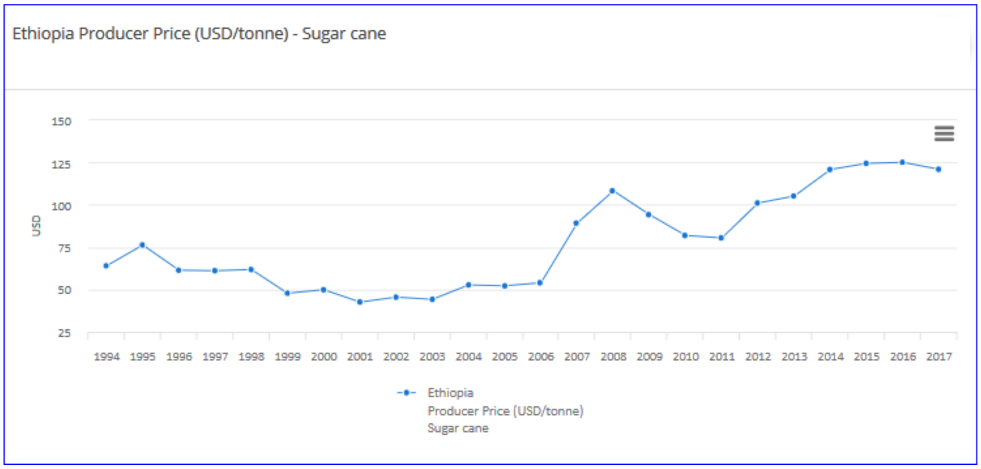
4. The impact of CSA practice impact on productivity

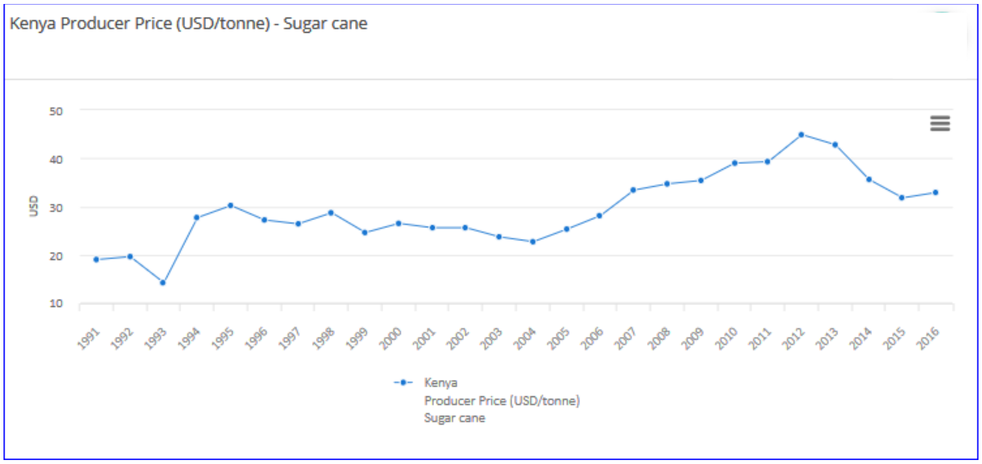
Climate smart agricultural practice			Yield	Yield variability	Labour	Income
Level A - Basic level	1.	Membership of a farmer group or association	Intended to promote farmer to farmer extension and adoption of best practice			
	2.	Not burning crop residues	+++	+++	-	+++
	3.	Mulching	+++	+++	-	+++
	4.	Minimum tillage	+++	+++	+++	+++
	5.	Planting on the contour / ridges on shallower soils*	+++	+++	+++	+++
	6.	Fire breaks	+++	+++	+++	+++
Level B Intermediate 1	7.	Intercropping	+++	+++	+++	+++
	8.	ISFM	+++	+++	+++	+++
	9.	Physical soil conservation measures*	+++	+++	+++	+++
	10.	Green cane harvesting	+++	+++	-	+++
Level C Intermediate 2	11.	Break crop(s)	+++	+++	++	+++
	12.	Micro-watershed management*	++	++	++	++
	13.	Vegetative soil conservation measures	+	+	+	+
Level D Advanced level	14.	Rain water harvesting**	+++	+++	+++	+++
	15.	Integrated pest management programme	+++	+++	+++	+++
	16.	Protecting wetland areas	+	+	+	+

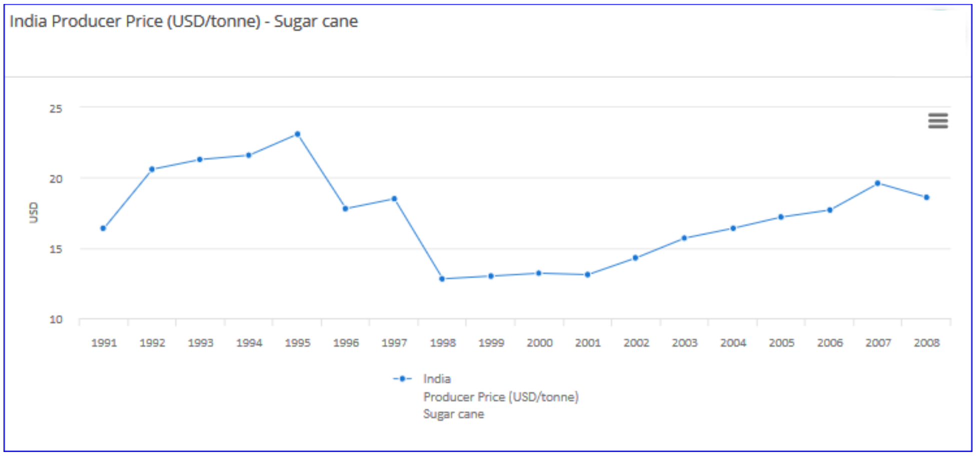
* greatest on steeper slopes
** especially on areas without irrigation

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

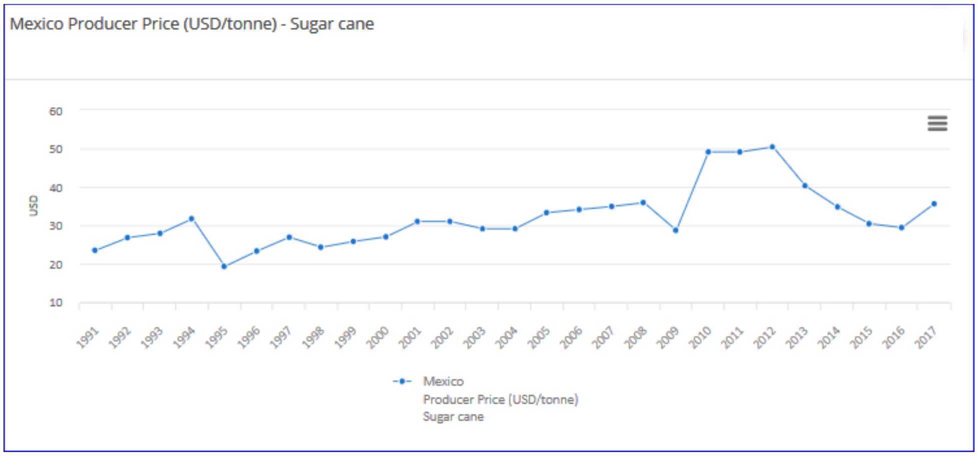
ANNEX 6: SUGAR CANE PRICES[78]

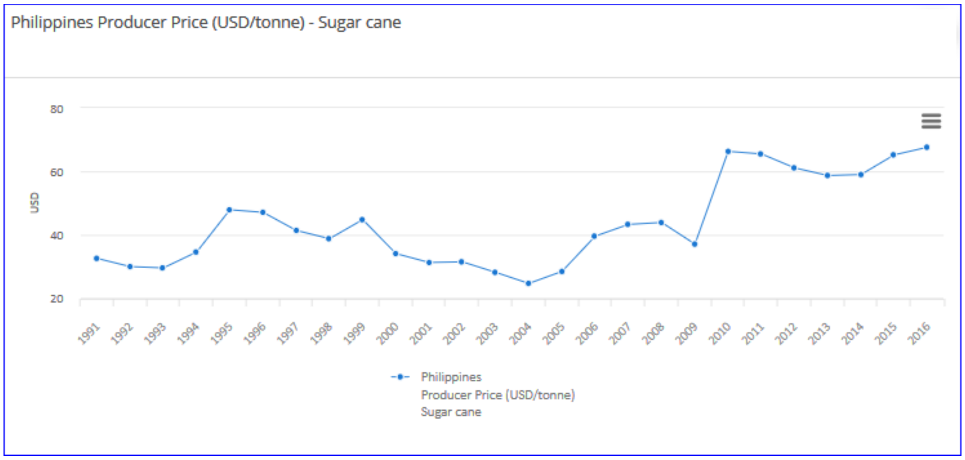


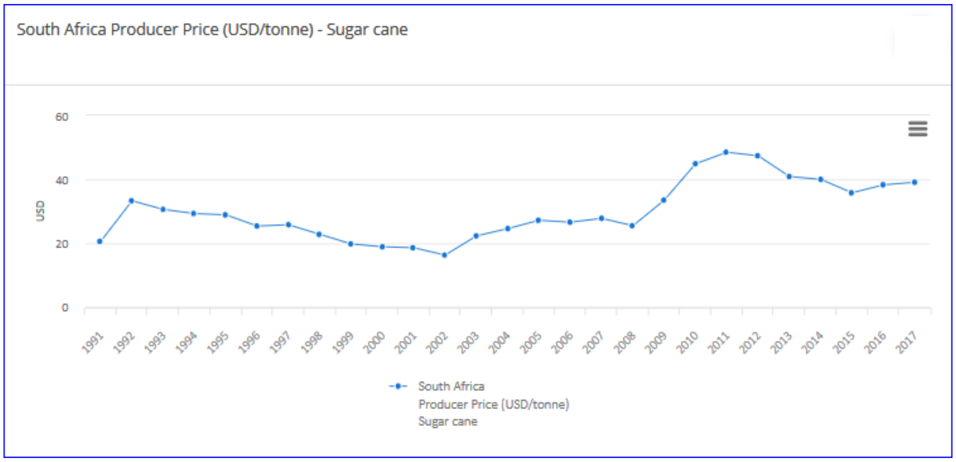


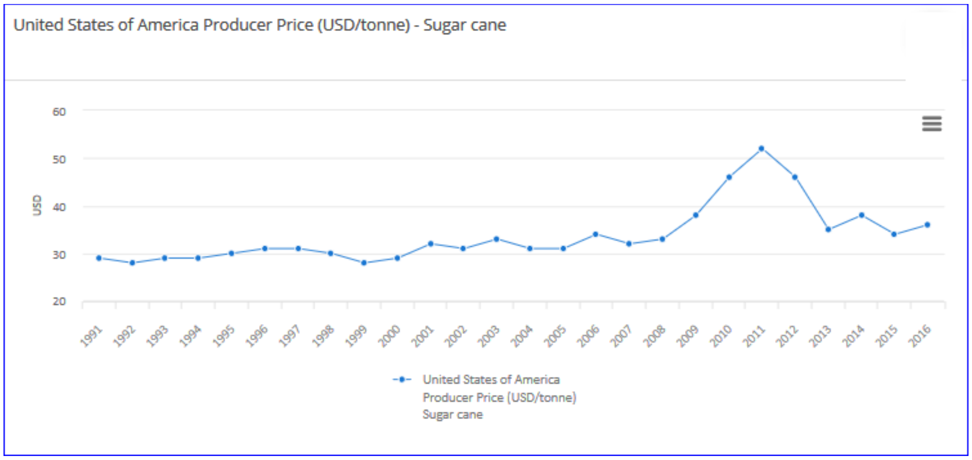


78 FAO, 2018 FAOSTAT. http://www.fao.org/faostat/en/#data/QC


Mexico Producer Price (USD/tonne) - Sugar cane
USD
60
50
40
30
20
10
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Mexico
Producer Price (USD/tonne)
Sugar cane


Philippines Producer Price (USD/tonne) - Sugar cane
USD
80
60
40
20
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
Philippines
Producer Price (USD/tonne)
Sugar cane


South Africa Producer Price (USD/tonne) - Sugar cane
USD
60
40
20
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
South Africa
Producer Price (USD/tonne)
Sugar cane


United States of America Producer Price (USD/tonne) - Sugar cane
60
50
40
30
20
USD
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
United States of America
Producer Price (USD/tonne)
Sugar cane