TEMPLATE POTATO CLIMATE-SMART CREDIT PRODUCT

F3 Life

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1. Executive summary

1.1. Introduction

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

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 potato product and related models which can be easily adapted for use with specific application.

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

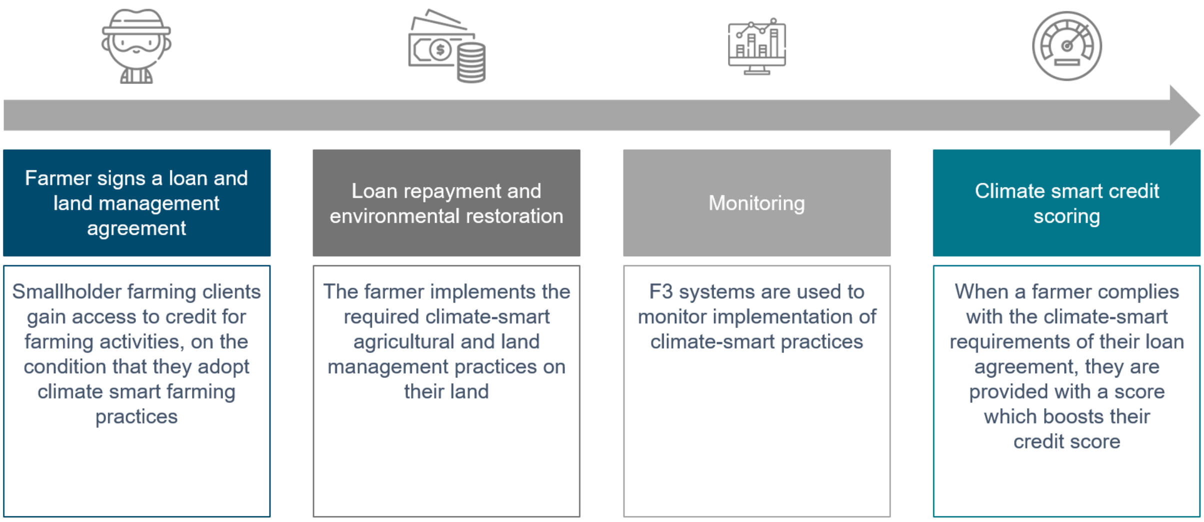

FIGURE 1: CLIMATE-SMART LENDING PROCESS

Potato (*Solanum tuberosum L.*), sometimes referred to as Irish or round potatoes, in contrast to sweet potatoes are the third most important food crop in the world after rice and wheat in terms of human consumption. They are used for a variety of purposes, not only as a vegetable, with also processed into food products. They can grow from sea level up to 4,700 meters above sea level from southern Chile to Greenland. The broad, fertile highlands of East, Central, West, and Southern Africa have an ideal a temperate climate, providing ideal growing conditions for potato.

1.2. Climate risks to potato production

Land traditionally suitable for potato cultivation is decreasing due to insect and disease pressures from warming climates, as cultivation is forced to move to elevations, where centuries-old varieties and farming practices are often no longer tenable. This is due to declining soil fertility and soil erosion, compounded by changing rainfall patterns and temperature changes.

1.3. Potato production

Understanding potato management practices and growth stages is important in devising strategies and CSA interventions which will impact on climate change and improve yields. These include but are not limited to (i) crop rotation, (ii) use of improved varieties, (iii) improved land preparation and planting, (iv) soil fertility practices, (v) weed management, (vi) plant protection, (vii) improved harvesting and storage.

1.4. Potato value chain

The potato value chain includes researchers, agri-input manufacturers and supply organisations, seed producers, farmers, traders, processors, wholesalers and retailers through to shops and restaurants. Government, often the Ministry of Agriculture or other state bodies, is responsible for policy and the regulatory requirements for creating an enabling environment for production and marketing.

1.5. Challenges faced by small scale potato growers

Common challenges to potato production in developing countries include: (i) limited access to good quality seeds[1]; (ii) declining soil fertility and yields; (iii) heavy reliance on fungicides; (iv) increasing production costs, (v) low profitability compounded by volatile markets. Improved agronomic production practices are urgently required especially in view of changing climate conditions. Unfortunately, small scale growers often have limited information on best practice and market prices, and lack the finance to purchase the necessary agricultural inputs to improve productivity.

1.6. Climate smart agriculture practices

These include the need to use (i) varieties adapted to drier, warmer and/or cooler conditions with resistance to pests and diseases; (ii) integrated soil fertility management practices, through increased use of crop rotations, composts and manures, and cover crops integrated with the use of inorganic fertilisers, (iii) integrated soil and water conservation and drainage measures using contour barriers or terracing especially on steeper slopes, using grasses and trees on the terraces combined with rainwater harvesting techniques and improved irrigation, when water is available; (iv) agroforestry involving the planting of trees and hedges to mitigate wind and water damage and improve soil fertility, including protection of areas of high biodiversity, and importantly (v) integrated pest and disease management, through improved scouting and biological control methods.

1.7. The potato climate smart credit product

The integrated approach required for SSGs to derive optimum benefit from CSA potato practices, starting with an area of 0.03 ha, this being equivalent to 1/32nd of one ha. This is a "Learner Level", where CSA practices can be tried, tested and learnt from, before proceeding to progressively larger areas. These would be increased from 0.03 ha to 0.06 ha, 0.13 ha, 0.25 ha, 0.5 ha, 0.75 ha and then one ha. The reason for having very small learner and starter levels is that these will not only support the learning process of individual growers, but would be available for demonstration, learning and if necessary, modification through experience by relevant stakeholders. Seven practices have been identified under the potato climate-smart credit product, which can be monitored with targets for each are based on those required for one ha and proportionately scaled down for smaller areas. These targets can be adjusted according to locally-specific agro-climatic conditions and based on recommendations from local potato research organisations or extension agencies.

1 Fajardo, J., N. Lutaladio, L. Larinde, C. Rosell, I. Barker, W. Roca, and E. Chujoy. 2010. Quality declared planting material—Protocols and standards for vegetatively propagated crops. FAO Plant Production and Protection Paper 195. Rome. 126 p.

		0.03ha	0.06ha	0.13ha	0.25ha	0.5ha	0.75ha	1ha
Contractual Requirements	Plant Trees	8 trees	16 trees	31 trees	53 trees	125 trees	188 trees	250 trees
	Rainwater Harvesting Ditches	0	0	0	1	2	3	4
	Grass reinforcement of terraces	13m	25m	50m	100m	200m	300m	400m
	Contour Terracing	13m	25m	50m	100m	200m	300m	400m
	Crop Rotation	0.03ha	0.06	0.13ha	0.25ha	0.5ha	0.75ha	1ha
	Manure / Compost Spreading	0.03ha	0.06ha	0.13ha	0.25ha	0.5ha	0.75ha	1ha
		Loan 1	**Loan 2**	**Loan 3**	**Loan 4**	**Loan 5**	**Loan 6**	**Loan 7**
Non-Contractual Requirements	Improved Varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties
	Integrated Pest Management	Training	Training	Training	Training	Training	Training	Training

FIGURE 2: CLIMATE-SMART CREDIT PRODUCT FOR SMALL SCALE POTATO FARMERS

1.8. Present and projected yield Levels

FAO data from 2017 show that more than 150 countries grew more than 25 million ha of potatoes producing 486 million tonnes at a median yield of 18 tonnes per ha, but with a wide range of 1-48 tonnes per ha. African countries contributed 6% of the total area and 3% of the total yield with an median yield of 11 tonnes per ha, with average yield levels

The International Potato Centre (CIP) has recently pledged to improve the livelihoods smallholder households in potato-growing regions of Africa by the use of high-quality seed and expect farmers to increase potato yields to 15 tonnes per ha, with incomes of at least US $800 per ha per season[2].

1.9. Potato prices

Average prices in 2016 for selected African countries for which data is available show a median of USD 377 per tonne, with a range of USD 184-624 per tonne. Annual potato prices have shown a rising if variable trend with highs of up to USD 600 per tonne in 2008 but currently ranging from around USD 200 in Ethiopia to nearly USD 400 per tonne in Kenya.

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

The impact of these practices lies in four areas varying according to agro-climatic and market conditions. Their impact will be cumulative, but dependent on deployment as integrated packages. This includes (i) improving the resilience of natural resource use, (ii) reducing the risks associated with climate change, (iii) mitigating the effects of some of the causes of climate change and increasing productivity.

1.11. Farmer cost-benefit analysis

A key output of this exercise are two gross margin and farmer cost benefit analysis models for two scenarios of small scale potato growers adopting climate-smart and sustainable land management measures required under the proposed climate-smart credit product. These are:

- Firstly for ware potatoes with and without CSA practices.
- Secondly, for seed potatoes with and without CSA practices.

These demonstrate, in generalised cases, the positive financial return to climate-smart and sustainable land-management measures required under the potato climate-smart credit product. This conclusion may not apply in all cases, and the model will need to be adapted for specific use-cases. Results are summarised in the Table below:

2 https://cipotato.org/crops/potato/

TABLE 1: RESULTS SUMMARY

	Scenario	Yields (Y10)	Gross margin (Y10)	Labour required (Y10)	Returns to labour (Y10)	Returns to labour (Y10)	Benefit cost ratio
		tonnes per ha	USD per ha	days per ha	USD per ha	USD per day	over 10 years
Ware potatoes	Ware potatoes without CSA practices	8	803	139	1,150	8.3	-
	Ware potatoes with CSA practices	13	2,564	178	3,009	16.9	1.9
Seed potatoes	Seed potatoes without CSA practices	6	843	123	1,150	9.3	-
	seed potatoeswith CSA pactices	10	2577	173	3,009	17.4	1.8
						Discount rate =	10%

1.12. Potato "lender financial impact model"

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

TABLE 2: CLIMATE SMART LENDING LENDER CASH POSITIONS

	Loan 1	Loan 2	Loan 3	Loan 4	Loan 5	Loan 6	Loan 7
Yield loss scenario	30%	30%	30%	30%	30%	30%	30%
Number of clients	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Loan book size (US$)	9,891,000	9,891,000	9,891,000	9,891,000	9,891,000	9,891,000	9,891,000
Portfolio loss with no climate-smart lending	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**
Portfolio loss with climate-smart lending	**(2,126,859)**	**(1,866,992)**	**(1,659,098)**	**(1,489,002)**	**(1,347,256)**	**(1,227,318)**	**(1,124,513)**
Savings due to CSA practices	(314,359)	(54,492)	153,402	323,498	465,244	585,182	687,987
Cost of capital w/o climate-smart lending	20%	20%	20%	20%	20%	20%	20%
Cost of capital w climate-smart lending	8%	8%	8%	8%	8%	8%	8%
Annual interest savings (US$)	1,186,920.00	1,186,920.00	1,186,920.00	1,186,920.00	1,186,920.00	1,186,920.00	1,186,920.00
Cash position improvement with climate-smart-lending (US$)	**872,561**	**1,132,428**	**1,340,322**	**1,510,418**	**1,652,164**	**1,772,102**	**1,874,907**

1.13. Potato "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 578 over 7 years.

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2. AN INTRODUCTION TO POTATOES AND CLIMATE RISKS TO PRODUCTION

2.1. Introduction[3]

Potato (*Solanum tuberosum L.)*, sometimes referred to as Irish or round potatoes, in contrast to sweet potatoes, are the third most important food crop in the world after rice and wheat in terms of human consumption. There are over 4,000 edible varieties of potato, mostly found in the Andes of South America. More than a billion people worldwide eat potatoes and global crop production exceeds 300 million tonnes. They are an excellent, low-fat source of carbohydrates. Boiled, they have more protein than maize.

They can be vegetative propagated from in-vitrio plantlets and mini tubers through to certified seed potatoes or tubers. A new plant will produce 5-20 new tubers, which are genetic clones of the mother plant. Potato plants also produce flowers and berries that contain botanical seeds, which can be planted to produce new tubers, but will be genetically different from the mother plant and not recommended as a source of seed tubers. Potatoes can grow from sea level up to 4,700 meters above sea level from southern Chile to Greenland. The broad, fertile highlands of East, Central, West, and Southern Africa have an ideal a temperate climate with often dependable rains, providing ideal growing conditions for potato.

One hectare of potato can yield 2-4 times the food quantity of grain crops. They produce more food per unit of water than other major crops and are up to seven times more efficient in using water than cereals. They are produced in over 150 countries worldwide and are important in food security for millions of people across South America, Africa, and Asia. They are used for a variety of purposes, not only as a vegetable, with less than 50% being consumed fresh, the rest being processed into potato food products and food ingredients, fed to cattle, pigs and chickens, processed into starch for industry and re-used as seed tubers for growing next season's potato crop.

2.2. Climate risks to potato production

Land traditionally suitable for potato cultivation is decreasing due to insect and disease pressures from warming climates, as cultivation is forced to move to elevations, where centuries-old varieties and farming practices are often no longer tenable. This is due to declining soil fertility and soil erosion, compounded by changing rainfall patterns and temperature changes[4].

Key problems related to climate change include:

- Changes in the timing of seasons
- Increasing drought both between and within seasons
- Heavy rains leading to soil erosion and waterlogged growing conditions
- Shortened growing season with unreliable rains due to earlier onset of cold weather
- Increased temperatures during the day
- Increased incidence of hail.

As agro-climatic conditions change and soil health declines, productivity and yields also decline. Consequently, there is strong farmer pressure to increase incomes by expanding into new areas5. As agriculture encroaches onto non-farmland, forested mid- and high-altitude regions are lost with

3 https://cipotato.org/crops/potato/ accessed 20th March 2019-
4 ibid
5 Waithaka, M.M., P.K. Thornton, M. Herrero, K.D. Shepherd, J.J. Stoorvogel, B. Salasya, N. Ndiwa, et al. 2005. System Prototyping and Impact Assessment for Sustainable Alternatives in Mixed Farming Systems in High-Potential Areas of Eastern Africa. Final Program Report to the Ecoregional Fund to Support Methodological Initiatives.

consequential disruption to the carbon sinks that these forests represent, with wildlife habitats and biodiversity being seriously threatened.

2.3. Potato production

Understanding potato management practices and growth stages is important in devising strategies and CSA interventions which will impact on climate change and improve yields. Key management practices include:

#	Description[6][7]
Crop rotation	Crop rotation is critical to avoid accumulation of pest and diseases both in the soil and crop as well as improving soil health/fertility and diversifying food supply to reduce the risk of a single crop. Without a suitable crop rotation poor quality potatoes will be produced. This includes good field hygiene and removal of plant volunteers in the following crop. Ideally growers should have enough land to allow for rotation of at least 3-4 seasons with crops not related to potato and 4-5 seasons for seed potato producers.
Seed and Varieties	There are many different varieties with different growing periods suitable for table and further processing. Local tastes and the market usually determining those best to grow. Seed and ware potatoes are distinct commodities that need to be treated differently, although in many developing countries, the two are regarded as identical, as it is often difficult to distinguish them especially in local markets. For instance, seed potatoes sold in markets may be ware potatoes sold as seed. Consequently, buyers are often reluctant to pay the premium prices needed to justify the extra costs associated with the production of seed potatoes. Seed potatoes are bulky and often the long distances from seed producers to farmers make seed expensive. Local multiplication encourages the use of quality seed, as farmers are likely to see the value from neighbours. If growers use home-grown seed they should purchase a portion of new certified or multiplier seed annually.
Land preparation and planting	Potatoes require loose soil to maximise growth and yield. Hence the crop usually involves land preparation to 30 cm and intensive soil tillage during the cropping period. Planting down the slope can result in high runoff and soil loss and therefore, they should be planted along the contour. Runoff and soil loss can also be high after harvesting especially when the land is left bare without any ground cover, leaving the soil exposed to different forms of erosion. Potato tubers are planted in rows 75 cm apart and 25 - 30 cm within rows depending on tuber size. This is reduced for potatoes grown for seed to encourage individual plants to produce more tubers of a smaller size. 2000 kg, about 40,000 tubers are required to plant one ha. This typically requires 360 m^2 of land and 200 kg of certified or multiplier seed to produce seed potatoes for one ha.

6 Feed the Future Kenya Accelerated Value Chain Development (AVCD) project. 2018. Model learning farm for potato producers. Guide for ware potato farmers training. International Potato Centre. Lima (Peru). 25p.
7 Feed the Future Kenya Accelerated Value Chain Development (AVCD) project. 2018. Manual for local seed potato multipliers. Improving access to quality seed by smallholder farmers. International Potato Centre. Lima Peru). 17p.

#	Description[67]
Soil fertility practices	Proper nutrition is crucial in determining potato yield and quality, as well as the plant's ability to withstand pest, environmental, and other stresses. Ideally fertilizer and manure application should be based on soil analysis results and recommendations. Common fertilizer combinations include Di-ammonium Phosphate (DAP), NPK 17:17:17, NPK 23:23:0, depending on soil analysis. A general recommendation is 500 Kg DAP per ha. Mixing of fertiliser and soil is desirable to prevent scorching of the sprouts, together with decomposed manure or compost used at rates of 3-10 tonnes per hectare, depending on availability. Leguminous cover crops provide vegetative cover for soils susceptible to erosion and can be used in association with potatoes to protect soils from erosion, improve soil fertility and structure, as well as preventing nutrient leaching and providing a source of nitrogen and reduce weeds and soil nematodes. Often these can be planted immediately after the potatoes are harvested, which also gives protection to the soil.
Growth	Potatoes have five key stages of development: emergence after planting when sprouts develop from eyes on the tubers; a vegetative growth stage when leaves and branch stems develop above the ground and roots and stolons below the ground; tuber initiation at early flowering; tuber expansion as nutrients move from the leaves to the tubers, when leaves start turning yellow; vines turning yellow and losing their leaves, when tuber growth slows and vines eventually die. Tuber dry matter reaches a maximum and tuber skins set.
Weed management	Weeds can be controlled when ridging or hilling is done, four weeks after emergence and again 4- 6 weeks later. If weeds are not controlled, crop yields will be severely reduced. It is also important to control weeds after harvest and in adjoining areas to avoid a build-up in pest populations in fields not cropped to potatoes.

#	Description[67]
Plant Protection	Disease problems include late blight, bacterial wilt, viruses and other emerging diseases such as blackleg (*Dickeya* spp) and soil nematodes). Late blight is the most important disease, caused by the fungus *Phytophthora infestans*, causing crop failure by infecting plants from tuber up until harvest. Severe infections occur at times of high rainfall, high humidity and low temperatures. The disease damages leaves, stems and tubers. If not controlled, infected plants will die within 2-3 days. It spreads very rapidly via air, soil, water and seed. Key practices in late blight management are use of resistant varieties and application of fungicides. Bacterial wilt is extremely dangerous, especially in regions where potatoes are cultivated intensively. Leaves become yellow, the plant wilts and dies. Management requires: using healthy seed; rotating crops; planting in soils free from bacterial wilt; removing infected plant debris before planting and clearing weeds while plants are growing and at harvesting time; using composted organic fertilizer not infected with bacterial wilt; digging channels that allow irrigated water to flow freely from the field; using water not contaminated with bacterial wilt in irrigated crops; cleaning the field by burying infected plants and tubers throughout the season; and importantly cleaning farming tools after use. Viral diseases develop from one generation to the next primarily due to farmers basing seed potato selection on small tubers. Generally, viral diseases lead to smaller tubers being produced and consequently, when tubers selected for seed, most are already infected. Viruses can be controlled by using virus free seed, destroying plants infected with viral diseases; controlling insects such as such as aphids, thrips, mites and whiteflies that spread viral disease. When home-grown seed is used, they should be selected from healthy plants. Post-harvest field sanitation is an important part of controlling various pests and diseases, by removing sources of contamination for the next crop. Pests include: Colorado potato beetle (*Leptinotarsa decemlineata*) a serious pest with strong resistance to insecticides. Potato tuber moth, most commonly *Phthorimaea operculella*, is the most damaging pest of planted and stored potatoes in warm, dry areas. Leafminer fly (*Liriomyza huidobrensis*) common in areas where insecticides are used intensively. Cyst nematodes (*Globodera pallida* and *G. rostochiensis*) are serious soil pests in temperate regions and highland areas.
Harvesting	Potato foliage should be cut 10-14 days before harvesting. This hardens tubers preventing disease spreading from plant stems to tubers. Tubers should also be

#	Description[67]
	left in the field to allow soil to dry and fall off, prevent subsequent rot, while in store. Tubers should then be sorted.
Yields	Attainable yields are 25–35 t/ha, but are often in the range 4-10 t/ha, far below their potential
Storage	Produce can be sold while still in the field, if prices are high but usually storage is required in order to sell when prices are higher. If so after harvest tubers should be stored in a storage area considering temperature, humidity and air circulation. Temperature: If stored for a long time, lower temperatures (2°C - 5°C) are required to prevent sprouting. In the case of seed potatoes storage at higher temperature is desirable to accelerate sprouting. Humidity: Overly humid conditions will increase the risk of disease, condensation and rotting. Tubers will become damp and sprout easily. If too low tubers will shrink and lose weight. Air circulation: Ventilation is necessary to ensure a clean and even flow of air and to regulate humidity. Storage systems for seed potatoes require a Diffused Light Store (DLS) while ware potato require a cool and dark facility

2.4. Potato value chain

The potato value chain includes researchers, agri-input manufacturers and supply organisations, seed producers, farmers, traders, processors, wholesalers and retailers through to shops and restaurants. A typical potato value chain is shown below, with Government often the Ministry of Agriculture or other state body being responsible for policy and the regulatory requirements for creating an enabling environment for production and marketing.

TABLE 3: TYPICAL POTATO VALUE CHAIN

Improved varieties, land management & agronomic practices	Agri-Input acquisition & production advice	Potato production (ware potatoes)	Transport and marketing	Processing	Marketing and consumption
− Researchers	**Production advice** − Extension agents (Govt & NGO) − Grower Associations − Cooperatives − Other farmers **Potato seed production** − Research stations − Certified seed producers − Seed multipliers **Fertilisers / pesticides** − Agri-input producers − Agro-dealers	− Large Scale Farmers − Small scale growers − Community organisations − Farmers' groups or cooperatives	**Transport** − Transporters − Farmers' groups or cooperatives **Marketing** − Local markets (fresh or cooked) − Collectors/traders − Directly to supermarkets or processors (contract farming)	**Crisp manufacture** −Local processors	− Wholesalers − Supermarkets − Small retailers − Restaurants − Consumers

	– Coops **Production credit** – Micro-finance institutions, NGOs, Coops – Banks, Agri-banks				

Seed and ware potatoes are distinct commodities that need to be treated differently from planting to harvesting and then storage. Unfortunately, in many developing countries these two commodities are largely regarded as identical as it is often difficult to distinguish seed tubers from ware potatoes. Consequently, potential buyers of seed potatoes are reluctant to pay premium prices needed to justify the extra costs associated with the production of quality materials. A typical value chain for seed potatoes is shown in the table above.

TABLE 4: TYPICAL SEED POTATO VALUE CHAIN

Research		Seed growers		Farmers	Consumers
In vitrio plantlets	Mini potato tubers	Certified seed	Seed multipliers	Ware potatoes	

2.5. Challenges faced by small scale potato growers

Most potato farming occurs under rain-fed conditions. Consequently, the major cropping seasons follow the rainy seasons. For instance in Ethiopia, Kenya and Uganda two seasons for potato cultivation are possible during the short and long rans. At the same time limited off-season production occurs at higher altitudes or in valley bottoms or drained wetlands. This is supported by residual moisture in rich organic soil or drainage water coming from the surrounding hills. Also, out-of-season irrigated potato production occurs where water is available[8].

In the same countries, typical potato field sizes were 0.3 ha (Kenya), 0.25 ha (Uganda) and 0.2-0.4 ha (Ethiopia), representing 40%, 25% and 6-34% of the total farm size in each country. Other crops typically grown on the same farms included cereals (maize, sorghum, tef, wheat), legumes (beans, peas, broad beans) bananas and sweet potatoes[9]. The study showed that potato is a dual-purpose crop in the three countries, grown as both a household staple and a source of cash income. Few farmers purchased seed potatoes, relying on their own or a neighbour's produce or purchased in the local market. FYM and fertiliser application was also low (table below).

TABLE 5: PERCENTAGE FARMERS USING FYM AND FERTILISER AND AVERAGE AMOUNTS APPLIED:[10]

	FYM		Fertiliser		
	Farmers using FYM (%)	FYM applied (kg/ha)	Farmers using fertiliser	N applied (kg/ha)	P applied (kg/ha)
Kenya	45	4.3	88	43	100
Uganda	18	2.2	5	38	47
Ethiopia	26	3.0	57	30	33

In many developing countries farmers tend to grow potatoes in very close rotation and sometimes continual mono-cropping. As a result, diseases accumulate, soil fertility declines, soil loss increases and yields decline, further reducing incomes. Often farmers have few alternatives for other high-value cash crops and limited knowledge of good agronomic practices, which could boost potato yields and marketability. The same study shows that family and hired labour make up 44% of the costs of production, seed 24%, fertiliser and manure 12% and fungicides (5%).

8 Peter R. Gildemacher &Wachira Kaguongo & Oscar Ortiz & Agajie Tesfaye & Gebremedhin Woldegiorgis & William W. Wagoire & Rogers Kakuhenzire & Peter M. Kinyae & Moses Nyongesa & Paul C. Struik & Cees Leeuwis. 2009. Improving Potato Production in Kenya, Uganda and Ethiopia: A System Diagnosis. Potato Research (2009) 52:173–205. DOI 10.1007/s11540-009-9127-4
9 Ibid
10 Ibid

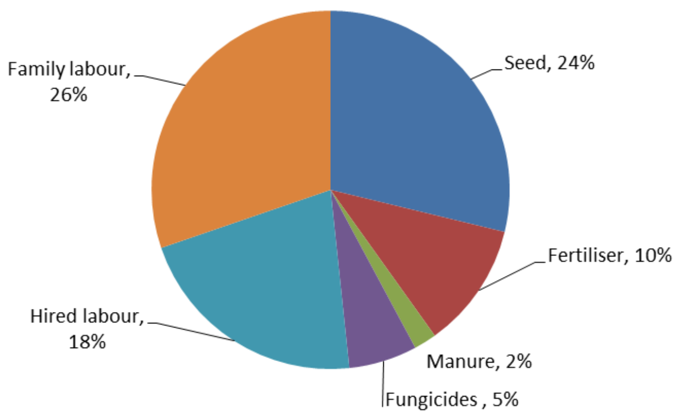


FIGURE 3: PERCENTAGE COSTS OF POTATO PRODUCTION

Common challenges to potato production in developing countries include:

- **Limited access to good quality seeds** -A major bottleneck to increasing productivity is limited access to quality seed, which reduces yields, food availability, and famers' incomes. Typically, farmers use small-sized and unmarketable ware potatoes for planting. This is generally low quality and sourced from their own fields or markets. Diseases often accumulate and are spread in farmer-saved seed stocks. Farmers' limited awareness of how to select quality seed is compounded by poor access to varieties with traits such as drought, heat, and disease tolerance and bio-fortification with essential micronutrients, lack of knowledge of good agricultural practices for potato, and minimal capacity to store tubers. Although seed certification standards exist, many national policies do not recognize practical quality standards, such as Quality Declared Planting Material (QDPM). This further limits access to quality seed[11].
- **Declining soil fertility** - Many potato farmers are faced with declining soil fertility. With increasing prices for inorganic fertilisers, a growing number of farmers started using the fertiliser designed for potato on other staple crops, rather than their potatoes.
- **Reliance on fungicides** – Since potato production is often dominated by short rotations and mono-cropping systems, disease incidence is high and use of fungicides is often essential to obtain any yield. High costs, as well as the health risks, are concerns.
- **Increasing production costs** - Costs for fertilizers, chemical pesticides, irrigation and labour have all increased in the last years. If this is matched by low potato prices on the markets, then producers make hardly any profit. Unstable potato prices are very common.
- **Low profitability -** sometimes low yields are insufficient to pay for the inputs.
- **Volatile markets** - Large price fluctuations have led to economic losses, particularly when market information is not available. Oversupply can lead very low prices, just as undersupply can lead to high prices.

Improved agronomic production practices are urgently required especially in view of changing climate conditions. Unfortunately, small scale growers often have limited information on improved agronomic practices and market prices and lack the finance to purchase the necessary agricultural inputs to improve productivity.

11 Fajardo, J., N. Lutaladio, L. Larinde, C. Rosell, I. Barker, W. Roca, and E. Chujoy. 2010. Quality declared planting material—Protocols and standards for vegetatively propagated crops. FAO Plant Production and Protection Paper 195. Rome. 126 p.

3. Climate smart agriculture strategies for potato growers

Climate-smart agriculture (CSA) contributes to the achievement of the sustainable development goals[12], through integrating three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is an approach that requires site-specific assessments to identify suitable agricultural production technologies and practices. Increasing potato production, protecting producers, consumers and the environment, requires an integrated approach encompassing a range of strategies: planting non-diseased or clean seed, rotating with other crops, breeding and using varieties with pest/disease and drought/temperature tolerance or resistance, encouraging natural pest predators, and improving soil health through integrated soil fertility management using conservation agriculture principles, where feasible[13].

The table following summarises the main climate change threats to sustainable potato production, the likely impact and six broad mitigation strategies. These include the need to establish: i) planting varieties adapted to drier, warmer and/or cooler conditions with resistance to pests and diseases, ii) integrated soil fertility management (ISFM) practices, through increased use of crop rotations, composts and manures, and cover crops integrated with the use of inorganic fertilisers, iii) integrated soil and water conservation (ISWC) and drainage measures using contour barriers or terracing especially on steeper slopes, using grasses and trees on the terraces combined with rainwater harvesting techniques and improved irrigation, when water is available, iv) agroforestry involving the planting of trees and hedges to mitigate wind and water damage and improve soil fertility, including protection of areas of high biodiversity, and importantly v) integrated pest and disease management, through improved scouting and biological control methods.

TABLE 6: CLIMATE CHANGE THREATS, IMPACT AND MITIGATION STRATEGIES

Climate change threats	Impact	Mitigation strategies
1. Changes in the timing of seasons 2. Increasing drought both between and within seasons 3. Heavy rains leading to waterlogged growing conditions 4. Shortened growing season due to earlier onset of cold weather 5. Increased temperatures during the day 6. Increased incidence of hail	– Delay in the onset of rainfall and extension of the dry season – Increased soil erosion, soil fertility loss and reduced soil moisture availability – Heat stress and arrival or increase in pests and diseases – Reduced yield and quality of potato – Declining suitability of some areas for growing potato and consequential move to other more suitable areas – Biodiversity loss	i) Planting disease and drought resistant or tolerant varieties ii) Integrated soil fertility management iii) Improved soil and water conservation practices iv) Use of Integrated pest and disease management measures v) Protection of areas of high biodiversity

3.1. Management practices for Climate Change Adaptation

12 FAO, 2013. Climate Smart Agriculture Sourcebook. ISBN 978-92-5-107720-7 (print), E-ISBN 978-92-5-107721-4 (PDF). www.fao.org/climatechange/climatesmart

13 Emilio J.Gonzalez-Sanchez, Oscar Veroz-Gonzalez, Gordon Conway, Manuel Moreno-Garcia, Amir Kassam, Saidi Mkomwag, Rafaela Ordoñez-Fernandez, Paula Triviño-Tarradas, RosaCarbonell-Bojollo, 2019. Meta-analysis on carbon sequestration through Conservation Agriculture in Africa. Soil and Tillage Research Volume 190, July 2019, Pages 22-30. https://www.sciencedirect.com/science/article/pii/S0167198718313953?via%3Dihub

As climate change alters the economics of production, potato farming communities will have to formulate different adaptation strategies. These include:

- Using potato varieties resistant or tolerant to heat stress, drought spells, weeds, pests and diseases.
- Favouring a farming system that has plant diversity and soil fertility management through the inclusion of crop rotations including green manures and cover crops.
- Stopping any unnecessary loss of nutrients for the farming system, preventing soil erosion and abandoning the burning of potato crop residues and burying diseased material.
- Minimising the period that land lays bare, in order to slow down loss of organic matter and soil moisture and soil erosion.
- Adjusting planting dates to offset moisture stress during the warm period, to prevent pest outbreaks, and to make best use of the length of the growing season.
- Minimising soil tillage in order to prevent loss of soil organic matter – a natural source of soil fertility and a means of storing water for plant uptake.
- Optimising the use of sustainable, natural fertilising sources in potato production, including nitrogen fixing crop rotations, compost and manures.
- Optimising the efficiency of additional fertilizer use where required, because of its costs and carbon fuel footprint.
- Optimising the use of pesticides because of their costs and carbon fuel footprint.
- Optimising water-use efficiency in irrigated potato, because of the irrigation water's costs and carbon fuel footprint.
- Following Conservation Agriculture (CA) principles especially with regards cereal and legume crops grown in rotation with maize.

CA is a farming system that promotes continuous no or minimum soil disturbance or tillage, maintenance of a permanent soil mulch cover, and diversification of plant species. Through these principles it enhances biodiversity and natural biological processes above and below the ground surface, so contributing to increased water and nutrient use efficiency and productivity, to more resilient cropping systems, and to improved and sustained crop production. The characteristics of CA make it one of the systems best able to contribute to climate change mitigation by reducing atmospheric greenhouse gas concentration14.

The five mitigation strategies identified in below involve important management practices, which will improve productivity as well mitigating the effects of climate change. These include:

CSA Practice	Management practices
Planting improved potato varieties	Varieties tolerant or resistant to pests and diseases and adversities of weather (drought, water logging, and warm/cold weather conditions) should be used[15].

14 Emilio J.Gonzalez-Sanchez, Oscar Veroz-Gonzalez, Gordon Conway, Manuel Moreno-Garcia, Amir Kassam, Saidi Mkomwag, Rafaela Ordoñez-Fernandez, Paula Triviño-Tarradas, RosaCarbonell-Bojollo, 2019. Meta-analysis on carbon sequestration through Conservation Agriculture in Africa. Soil and Tillage Research Volume 190, July 2019, Pages 22-30. https://www.sciencedirect.com/science/article/pii/S0167198718313953?via%3Dihub

15 https://cipotato.org/programs/seed-potato-for-africa/

CSA Practice	Management practices
Integrated soil fertility management (ISFM)	Improvement of soil organic matter content: Inorganic fertilisers can improve soil fertility through adding nutrients to the soil. However, they do not improve soil organic matter content, microorganisms or soil structure. Adding organic matter in the form of compost and well matured animal manure is an essential component of ISFM. It provides both nutrients, increases soil moisture holding capacity and improves the structure of the soil and will lead to a reduced need for inorganic fertilisers. This should be undertaken through applications of 3-5 tonnes per ha Crop Rotations: Rotation is critical to avoid accumulation of pest and diseases in soil and crop and to improve soil fertility and soil health. Without a suitable crop rotation, poor quality potatoes will be produced. Ideally growers should allow for rotation of at least 3-4 seasons with crops not related to potato and 4-5 seasons for seed potato producers. Typical rotations include: Potato/cover crop/legume-Maize-Maize-Legume/cover crop-then back to potato, with maize grown under a system of conservation agriculture. Green manures and cover crops: These form an integral part of both ISFM and soil and water conservation (SWC) and are described under soil and water conservation.
Soil and water conservation	Emphasis should be given to increasing the infiltration of rainwater into the soil and safe disposal from it during periods of high rainfall using the following measures: Application of manure and compost helps increase organic matter content in the soil, improving soil structure and water infiltration and water retention. Hilling up or planting on ridges aligned along the contour and not up and down the slope. Active rainwater harvesting through pits or trenches leading to wells can help to recharge groundwater levels In addition, the following should be undertaken: Contour terraces/banks planted with grass and/or trees should be established with appropriate measures for safe removal of water (micro-watershed management) especially on steeper slopes, the distance between terraces depending on the slope of the land, but typically 25 m apart. Suitable grass species such as vetiver (*Vetiver zizanioides*), napier grass (*Pennisetum purpureum*) and guinea grass (*Panicum maximum*), Bahia grass (*Paspulum notatum*) should be planted along the contour at intervals across the slope to slow down run-off of water. In addition to reducing soil erosion, the grasses can provide material for mulch or feed for livestock. Green manures and cover crops are particularly important on steep slopes. Species planted should match local climatic and soil conditions, but not compete with the potato for nutrients, water or light. Common species include: *Crotalaria*

CSA Practice	Management practices
	spp, Desmodium intortum, Canavalia ensiformis, Dolichos lablab, Medicago sativa, Mucuna pruriens and *Macroptilium atropurpureum.*
Agroforestry soil fertility trees	In areas with heavy wind and frost, agroforestry with wind breaks should be considered. Different trees are needed to break the wind, protect from strong rains, and provide shade, mulch and fodder. Grasses can be mixed or replaced with hedgerows of leguminous fodder trees such as *Leucaena diversifola, Calliandra calothyrsus, Sesbania sesban* and *Gliricidia sepium.* However, the trees need regular pruning because the potato plants do not tolerate much shade.
Protecting water sources and areas of biodiversity	If the potato area has a water-course running along the edge or within its boundary, neither potato nor other crop should be cultivated near it. Natural vegetation should be encouraged and if necessary additional protection provided by planting indigenous trees and a suitable grass. Such areas should be given protected status where possible in order to protect the biodiversity and avoid serious environmental damage, through loss of endangered or indigenous species, soil erosion and water contamination.
Integrated pest and disease management (IPM)	<u>Late blight:</u> This is the most important disease. Key management practices are: use of resistant varieties and if necessary through application of fungicides which can reduce infection and influence the formation of spores and the spread of rot on the leaves. <u>Bacterial wilt:</u> Management requires: using healthy seed; rotating crops; planting in soils free from bacterial wilt; removing infected plant debris before planting and clearing weeds while plants are growing and at harvesting time; using composted organic fertilizer not infected with bacterial wilt; digging channels that allow irrigated water to flow freely from the field; using water not contaminated with bacterial wilt to irrigate the crop; cleaning the field by burying plants and tubers infected with bacterial wilt throughout the season; cleaning farming tools after use. <u>Viral diseases</u>: Viruses can be controlled by: using virus free seed; destroying plants infected with viral diseases; controlling insects that spread viral diseases such as such as aphids, thrips, mites and whiteflies can spread viruses. Post-harvest field sanitation is an important part of controlling various pests and diseases, by removing sources of contamination for the next crop. This includes removal of plant volunteers and good field hygiene and in the following crop. Ideally growers should have enough land to allow for rotation of at least 3-4 seasons with crops not related to potato and 4-5 seasons for seed potato producers.

4. The climate smart potato credit product

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

The integrated approach required for SSGs to derive optimum benefit from CSA potato practices dictate that loans advanced should be guided by the size of the area to be planted, starting with an area of 0.03 ha, this being equivalent to 1/32nd of one ha. This can be regarded as "Learner Level", where CSA practices can be tried, tested and learnt from, before proceeding to progressively larger areas. These would be increased from 0.03 ha to 0.06 ha, 0.13 ha, 0.25 ha, 0.5 ha, 0.75 ha and then one ha, a total of seven levels as detailed on on the next page. The reason for having very small learner and starter levels is that these will not only support the learning process of individual growers, but would be available for demonstration, learning and if necessary modification through experience by relevant stakeholders.

A number of practices have been identified under the potato climate-smart credit product, which can be monitored. Targets for each are based on those required for one ha and proportionately scaled down for smaller areas. Rainwater harvesting structures can be introduced at the 0.25 ha level, since their construction will be opportunity driven and may not be possible on very small areas. They should also form part of a micro-watershed plan where contours/terraces and drainage lines from adjoining fields are linked to feed into natural watercourses. These can then be protected through afforestation or reforestation with indigenous trees and suitable grass species. Ideally they should also be given protected status.

Although use of integrated pest and disease management practices should be initiated from the onset, they should be provided through training rather than setting specific targets.

It should be noted that these targets can be adjusted according to locally-specific agro-climatic conditions and based on recommendations from local potato research organisations or extension agencies.

TABLE 7: PRACTICES REQUIRED UNDER THE POTATO CLIMATE-SMART CREDIT PRODUCT

					CSA requirements per ha						
					Loan 1	Loan 2	Loan 3	Loan 4	Loan 5	Loan 6	Loan 7
			units	No. per ha	0.03	0.06	0.13	0.25	0.5	0.75	1
Plant improved potato varieties on suitable land	1	Varieties tolerant or resistant to adversities of weather (drought, water logging, warm/cold weather conditions) and pests and diseases	tonnes	2	0	0	0	1	1	2	2
Integrated soil fertility management	2	Improvement of soil organic matter content through applications of compost, crop residues, cattle manure (3-5 tonnes per ha) leading to a reduction in inorganic fertiliser applications	100 kg piles of manure or similar	40	1	3	5	10	20	30	40
		Ensuring appropriate crop rotations are followed. These should include cereals (maize or sorghum), legumes (soya beans, beans, groundnuts, broad beans)or a fallow period growing a leguminous cover crop as a green manure with residues used for mulching	-	0	0	0	0	0	0	0	0
Soil and water conservation	3	Establish contour terraces/banks planted with grass and/or trees with appropriate measures for safe removal of water (micro-watershed management)	metres	400	13	25	50	100	200	300	400
	4	Establishing vegetative matter (such as Napier, Guatemala or vetiver grass grown on contour terraces)	sq. metres	400	13	25	50	100	200	300	400
	5	Rain water harvesting ditches incorporated in the micro-watershed plan	No.	4	0	0	0	1	2	3	4
		Irrigation during dry spells where feasible	-	-	-	-	-	-	-	-	-
Agroforestry	6	Establish trees for windbreaks, mulching, improving soil fertility and erosion control	seedlings per unit of land	50	2	3	6	13	25	38	50
	7	Afforestation, reforestation and establishment of trees on field boundaries, surrounding water courses, around homes and areas surrounding cotton fields.	-	200	6	13	25	50	100	150	200
Integrated pest and disease management		Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment			Integrated pest and disease management practices would be initiated from the onset, provided through training rather than setting specific targets.						

		0.03ha	0.06ha	0.13ha	0.25ha	0.5ha	0.75ha	1ha
Contractual Requirements	Plant Trees	8 trees	16 trees	31 trees	53 trees	125 trees	188 trees	250 trees
	Rainwater Harvesting Ditches	0	0	0	1	2	3	4
	Grass reinforcement of terraces	13m	25m	50m	100m	200m	300m	400m
	Contour Terracing	13m	25m	50m	100m	200m	300m	400m
	Crop Rotation	0.03ha	0.06	0.13ha	0.25ha	0.5ha	0.75ha	1ha
	Manure / Compost Spreading	0.03ha	0.06ha	0.13ha	0.25ha	0.5ha	0.75ha	1ha
		Loan 1	**Loan 2**	**Loan 3**	**Loan 4**	**Loan 5**	**Loan 6**	**Loan 7**
Non-Contractual Requirements	Improved Varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties	Improved varieties
	Integrated Pest Management	Training	Training	Training	Training	Training	Training	Training

FIGURE 4: CSL POTATO PRODUCT

5. Yield and mitigation benefits

5.1. Introduction

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

5.2. Present Areas grown and yield levels16

FAO data from 2017 shows that more than 25 million ha of potatoes were grown globally producing 486 m tonnes from more than 150 countries. Median yields were 18 tonnes per ha, but with a wide range of 1-48 tonnes per ha. Detail for individual countries is shown in Annex 1 with range yields summarised in below**Error! Reference source not found.**.

FIGURE 5: POTATO YIELD RANGE, 2017 (TONNES PER HA)

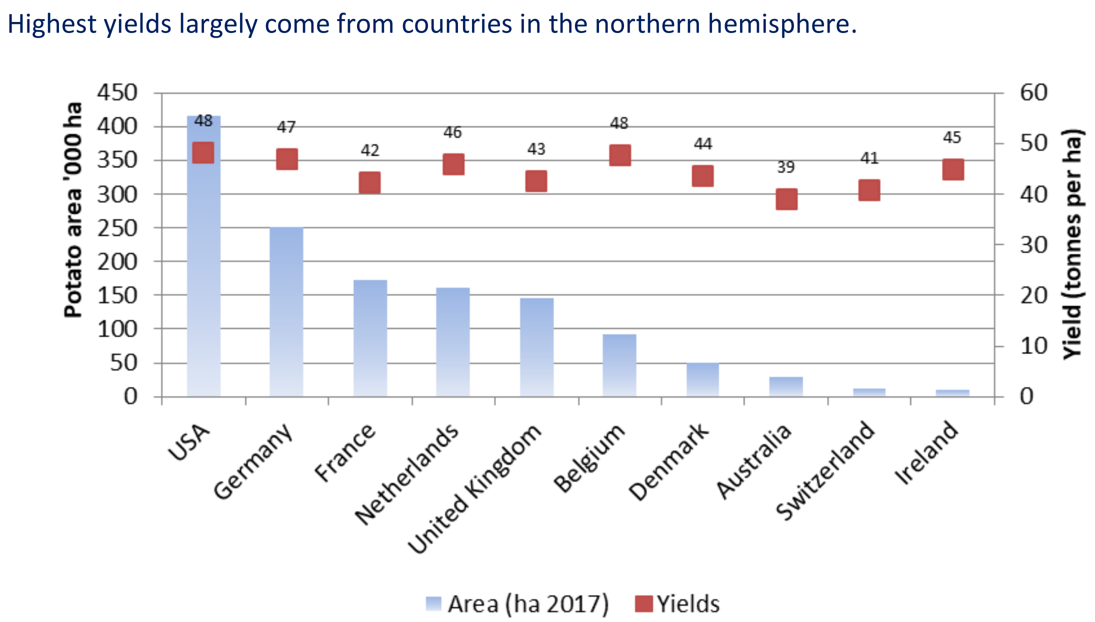


FIGURE 6: POTATO AREAS AND MEAN PER HA YIELDS FOR SELECTED HIGH YIELD COUNTRIES, 2017F

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

Africa countries contributed 6% of the total area and 3% of the total yield with a median yield of 11 tonnes per ha and a range of 1-36 tonnes per ha. Detail for a number of countries is shown in the figure below.

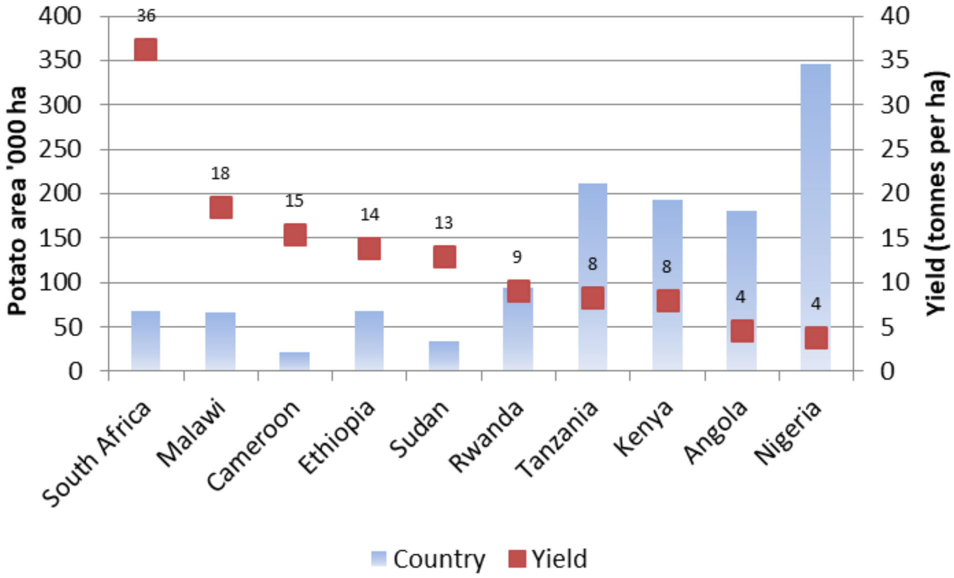


FIGURE 7: POTATO AREAS AND MEAN PER HA YIELDS FOR SELECTED SUB SAHARAN AFRICAN COUNTRIES, 2017

5.3. Potato Prices

Average prices in 2016 for selected African countries for which data is available show a median of USD 377 per tonne, with a range of USD 184-624 per tonne[17].

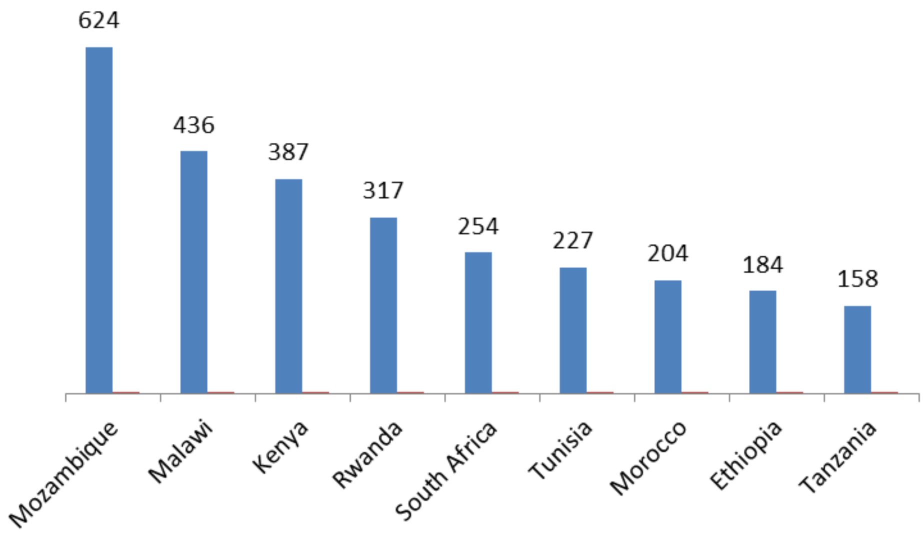


FIGURE 8: AVERAGE ANNUAL POTATO PRICE FROM SELECTED AFRICAN COUNTRIES - 2016 (USD PER TONNE)

Annual potato prices have shown a rising if variable trend with highs of nearly USD 600 per tonne in 2008 in Kenya and currently ranging from around USD 200 in Ethiopia to nearly USD 400 per tonne in Kenya[18].

17 FAOSTAT, 2017, http://www.fao.org/faostat/en/#data/PP accessed 24th March 2019
18 Ibid

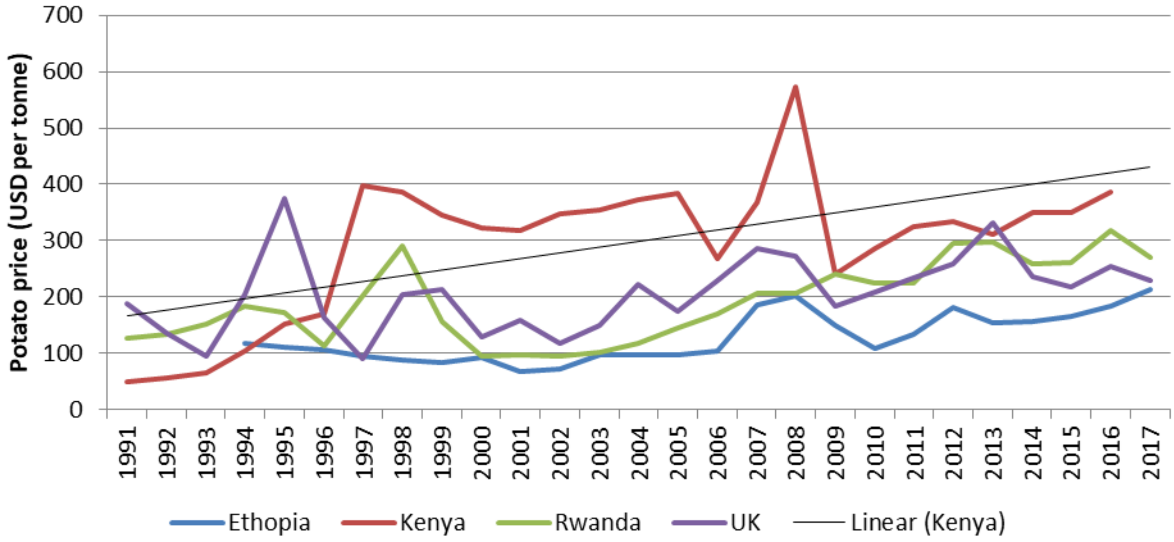


FIGURE 9: SEED POTATO PRICES FROM SELECTED COUNTRIES - 1991-2017 (USD PER TONNE)

The Impact of Sustainable Land-Management and Climate Smart Practices

Key features of the CSA approaches for sustainable potato production five strategy areas:

- Planting improved varieties tolerant to the adversities of drought, weather conditions and pests and diseases.
- Improving soil health through integrated soil fertility management practices, including use of appropriate crop rotations, application of composts and manures combining this with mulching and use of green manure cover crops. This will over time reduce the requirements or need for inorganic fertilisers.
- Improving soil and water conservation thus reducing or eliminating soil erosion and improving control of rainwater run-off, through the establishment of contour terraces on which grass and / or trees are planted. In addition rainwater harvesting and irrigation where available will increase soil moisture facilitating longer growing periods.
- Establishing trees, windbreaks, mulching, and erosion control within potato fields and on field boundaries. At the same time afforestation, reforestation and establishment of indigenous trees in areas adjoining water course and low lying areas will increase biodiversity as well as providing further protection against soil erosion and flooding.
- Introducing integrated pest and disease management practices to prevent economically damaging out-breaks, while reducing risks to human health and the environment
- The impact19,20 of these practices, lies in four areas varying according to agro-climatic and market conditions. Their impact will be cumulative, but dependent on deployment as integrated packages.
- Improving the resilience of natural resource use. This includes increasing farm level biodiversity; increasing groundwater availability, reducing soil erosion, increasing availability of plant nutrients from the soil, increasing both infiltration of water into the soil and improving run-off

19 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

20 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)

control measures, 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 potato 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.

Details of the impact of each of these components are shown qualitatively (- no effect, + some effect, ++ intermediate effect and +++ large effect) in

Annex , with that on productivity shown in below**Error! Reference source not found.**.

TABLE 8: IMPACT OF CSA POTATO PRACTICES ON PRODUCTIVITY

Climate smart agricultural practice			Yield	Yield variability	Labour	Income
Plant improved potato varieties on suitable land	1	Varieties tolerant or resistant to adversities of weather (drought, water logging, warm/cold weather conditions) and pests and diseases	+++	+++	-	+++
Integrated soil fertility management	2	Improvement of soil organic matter content through applications of compost,crop residues, cattle manure (3-5 tonnes per ha) leading to a reduction in inorganic fertiliser applications	++	++	++	++
	-	Ensuring appropriate crop rotations are followed. These should include cereals (maize or sorghum), legumes (soya beans, beans, groundnuts, broad beans)or a fallow period growing a leguminous cover crop as a green manure with residues used for mulching	++	++	++	++
Soil and water conservation	3	Establish contour terraces/banks planted with grass and/or trees with appropriate measures for safe removal of water (micro-watershed management)	++	++	++	++
	4	Establishing vegetative matter (such as Napier, Guatemala or vetiver grass grown on contour terraces)	++	++	++	++
	5	Rain water harvesting ditches incorporated in the micro-watershed plan	++	++	++	++
Agro-forestry	6	Establish trees for windbreaks, mulching, improving soil fertility and erosion control	++	++	++	++
	7	Afforestation, reforestation and establishment of trees on field boundaries, surrounding water courses, around homes and areas surrounding cotton fields.	++	++	++	+++
Integrated pest and disease management	-	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	+++	+++	++	++

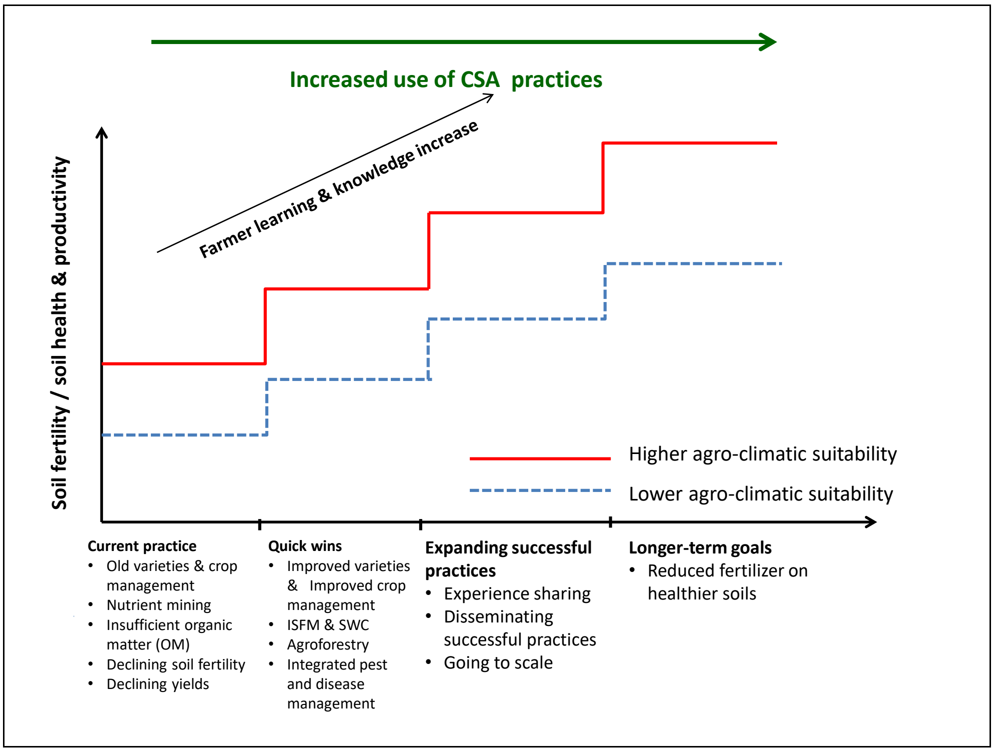
** greatest on steeper slopes*
*** especially on areas without irrigation*

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

5.4. Yields Increases through Adoption of CSA Potato Practices

Yields will increase over time as soil health is restored, soil organic matter builds and soil and water conservation measures become effective. This is likely to involve a step-wise process through farmer learning and knowledge increase, but also dependent on agro-climatic potential below.

FIGURE 10: STEP WISE PRODUCTIVITY YIELD IN RESPONSIVE AND LESS RESPONSIVE SOILS[21]



Yield increase estimates through the adoption of CSA potato production practices are difficult to quantify and depend on existing base yields. They will also be location specific, dependent on local agro-climatic conditions, but can be achieved alongside a reduction in costs particularly for inorganic fertiliser and chemical applications in the control of pests and diseases, although an increase in labour will be required. Variation can be expected dependent on agro-climatic conditions, market opportunity and most importantly farmer capacity.

Ware potato yields will increase over a period of time from a base of around 5 tonne per ha, up to and exceeding ten tonnes per ha and could be substantially higher, as improved seed is consistently used, soil health is improved, soil organic matter builds and soil conservation measures become effective. The impact will be greatest where soil health is presently poor and yield levels are already declining, often on steeper slopes with poor soil and water conservation practices and under rainfed conditions. Unfortunately no reliable data exists of how individual CSA practices contribute to yield increases, although the table below**Error! Reference source not found.** provides quantification i n percentage terms.

The International Potato centre (CIP) has recently pledged to improve the livelihoods of at least 600,000 smallholder households in potato-growing regions of Africa by the use of high-quality seed of robust, market-preferred and bio-fortified varieties. They expect farmers to increase potato yields to 15 tonnes per ha, with incomes of at least US $800 per ha per season. In addition, multiplier effects are expected to benefit an additional three million households. CIP's initiative is intended to exploit the crop's largely untapped potential, creating entrepreneurial opportunities along the seed value chain, with a special focus on women and youth farmers. The approach includes testing and

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

implementing methodologies to generate innovations on large-scale production and use of quality seed, through effective linkages among value chain actors, particularly private companies[22].

TABLE 9: QUANTIFICATION OF THE IMPACT OF CSA PRACTICE ON POTATO YIELD LEVELS OVER TIME

Climate smart agricultural practice			% yield increase	Agronomic reasons for benefit
New varieties	1	Varieties tolerant or resistant to adversities of weather (drought, water logging, warm/cold weather conditions) and pests and diseases	20%	Great genetic potential with resistance /tolerance to drought as well as pests and diseases
Integrated soil fertility management	2	Improvement of soil organic matter content through applications of compost, cotton residues, cattle manure (3-5 tonnes per ha) leading to a reduction in inorganic fertiliser applications	20%	Improving soil organic matter content increases soil moisture holding capacity, improves soil health allowing a reduction in time of the need for inorganic fertiliser
	-	Ensuring appropriate crop rotations are followed. These should include cereals (maize or sorghum), legumes (soya beans, beans, groundnuts, broad beans)or a fallow period growing a leguminous cover crop as a green manure with residues used for mulching		Introducing a break between potato crops prevents a build up of pests and diseases. Use of a legume crop improves soil nitrogen, and reduced tillage protects the soil from soil erosion and soil moisture evaporation.
Soil and water conservation	3	Establish contour terraces/banks planted with grass and/or trees with appropriate measures for safe removal of water (micro-watershed management)	20%	Reduced soil erosion and consequential increase in soil fertility, Stabilisation of contour banks and use as mulch material
	4	Establishing vegetative matter (such as Napier, Guatemala or vetiver grass grown on contour terraces)		Protect the soil against raindrop action, soil erosion and reduce soil temperature
	5	Rain water harvesting ditches incorporated in the micro-watershed plan		Harvest and store rain water to increase soil moisture availability for the crop
Agroforestry	6	Establish trees for windbreaks, mulching, improving soil fertility and erosion control	20%	The provision of shade, windbreaks, mulching, and erosion control
	7	Afforestation, reforestation and establishment of trees on field boundaries, surrounding water courses, around homes and areas surrounding fields.		This will support IPM through build up of natural predators of cotton pests
Integrated pest and disease management	-	Use of multiple pest and disease management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	20%	Biological control will help reduce the costs of using purchased pesticides
		Total	100%	over a ten year period

Note: Although % increases are attributed to each CSA practice, integration/coordination of all practices at the same time is required to derive full impact

5.5. Cost Increases and Reductions through Use of CSA Potato Practices

The table below provides quantification of the cost increases associated with the CSA practices. These have been determined on a per ha basis and scaled down for the smaller areas, these being 0.03, 0.06, 0.12, 0.25, 0.5, 0.75 and one ha.

Research indicates that cost savings should be possible by adopting CSA practices, mainly by applying less inorganic fertiliser, a 20-100% reduction, as soil health improves through application of manures, composts and mulching materials; and pesticide applications, a 20-100% reduction as integrated pest management methods are utilised[23].

The table below**Error! Reference source not found.** quantifies the impact of the CSA practice the a dditional labour requirements in both days and cost per ha, again scaled down for the smaller areas.

22 https://cipotato.org/crops/potato/

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

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

TABLE 10: QUANTIFICATION OF THE IMPACT OF CSA PRACTICE ON POTATO INPUT COSTS

						Labour requirement (days)								Labour costs (USD)						
						Loan 1	**Loan 2**	**Loan 3**	**Loan 4**	**Loan 5**	**Loan 6**	**Loan 7**		**Loan 1**	**Loan 2**	**Loan 3**	**Loan 4**	**Loan 5**	**Loan 6**	**Loan 7**
			units	No. per ha	**Days per ha**	**0.03**	**0.06**	**0.13**	**0.25**	**0.5**	**0.75**	**1**	Costs per day	**0.0**	**0.1**	**0.1**	**0.25**	**0.5**	**0.75**	**1**
Plant improved potato varieties on suitable land	1	Varieties tolerant or resistant to adversities of weather (drought, water logging, warm/cold weather conditions) and pests and diseases	tonnes	2	**10**	0.3	0.6	1.3	2.5	5.0	7.5	10.0	2.5	1	2	3	6	13	19	25
Integrated soil fertility management	2	Improvement of soil organic matter content through applications of compost, crop residues, cattle manure (3-5 tonnes per ha) leading to a reduction in inorganic fertiliser applications	100 kg piles of manure or similar	40	5	0.2	0.3	0.6	1.3	2.5	3.8	5.0	2.5	0.4	0.8	1.6	3.1	6.3	9.4	12.5
		Ensuring appropriate crop rotations are followed. These should include cereals (maize or sorghum), legumes (soya beans, beans, groundnuts, broad beans)or a fallow period growing a leguminous cover crop as a green manure with residues used for mulching	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Soil and water conservation	3	Establish contour terraces/banks planted with grass and/or trees with appropriate measures for safe removal of water (micro-watershed management)	metres	400	20	1	1	3	5	10	15	20	2.5	2	3	6	13	25	38	50
	4	Establishing vegetative matter (such as Napier, Guatemala or vetiver grass grown on contour terraces)	sq. metres	400	5	0	0	1	1	3	4	5	2.5	0	1	2	3	6	9	13
	5	Rain water harvesting ditches incorporated in the micro-watershed plan	No.	4	8	0	0	0	2	4	6	8	2.5	0	0	0	5	10	15	20
		Irrigation during dry spells where feasible	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	
Agroforestry	6	Establish trees for windbreaks, mulching, improving soil fertility and erosion control	seedlings per unit of land	50	5	0.2	0.3	0.6	1.3	2.5	3.8	5	2.5	0	1	2	3	6	9	13
	7	Afforestation, reforestation and establishment of trees on field boundaries, surrounding water courses, around homes and areas surrounding cotton fields.	-	200	20	0.6	1.3	2.5	5.0	10.0	15.0	20	2.5	2	3	6	13	25	38	50
Integrated pest and disease management		Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	-	-	5	0.0	0.0	0	0	0	0	0	2.5	0.0	0.0	0.0	0	0	0	0
					Total	**2**	**4**	**8**	**18**	**37**	**55**	**73**	**Total**	**5.1**	**10.2**	**20.3**	**46**	**91**	**137**	**183**

TABLE 11: QUANTIFICATION OF THE IMPACT OF CSA PRACTICE ON POTATO LABOUR REQUIREMENTS

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

The risks to potato associated with climate change and associated weather shocks include increased droughts both between and within growing seasons and consequently shortened growing seasons; increased rainfall intensity; increased temperatures and more unpredictable seasons.

These mean that potato 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.

6. Agro-climatic and market parameters for CSA lending

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 management conditions where potatoes flourish. Growth of potato is temperature-dependent, with potato bushes not growing when temperatures are either too low or too high, regardless of other climatic factors.

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

6.3. Market parameters

CSA lending for SSGs could be deployed in all those potato growing areas, where SSGs make an important contribution to total production.

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 potato production under the terms of a climate-smart credit product. The purpose of this is to firstly demonstrate that the terms of a climate-smart credit product will be beneficial for a small scale potato grower, and secondly to provide a cost benefit analysis model template for creation of climate-smart credit products in specific contexts.

7.2. Why undertake cost benefit analysis?

Ecologically sustainable potato production is possible by applying best practices of agronomy and crop protection. These include planting of, drought and disease resistant varieties, improving soil health through application of organic and inorganic fertilizers to maintain optimum soil quality and crop nutrient levels, soil and water conservation measures, including using agroforestry to plant trees to reduce crop losses due to biotic stress factors, and using integrated pest management techniques. Full commitment of all stakeholders in the Potato Sector will be required in helping to ensure economic and social sustainability of potato production.

Perceived profitability has been recognised as a key factor in explaining farmers' decisions to adopt or not adopt sustainable land management (SLM) technologies[24]. 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 a farmer cost benefit analysis will vary according to location, agro-ecological and economic context, as well as farmer perceptions of the advantages and disadvantages of each. Those variables used to inform this template analysis are summarised in the table below, with a potato farm gate price of USD 300 per tonne, together with an opportunity price for labour of US$ 2.50 per day. The tables below following set out the variables affecting base-line and CSA output and input prices for both seed and ware potatoes.

24 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

TABLE 12: VARIABLES AFFECTING THE BASE-LINE WARE AND SEED POTATO PRODUCTION PRACTICES

Base Case Outputs	Unit	No.	Value per kg	Source
Ware potato yield	tonnes/ha	8	300	Report Section 3.1 and 3.2
Seed potato yield	tonnes/ha	6	400	

Base Case Inputs	Unit	No.	Cost/unit (USD)	
Seed	tonnes/ha	2	400	Report Section 1.3 and 1.7
Fertiliser (DAP)*	50 kg bag/ha	10	35	
Pesticides -when used	ha	1	100	

* https://africafertilizer.org/local-prices/

Base case labour requirments	Unit	No	USD / day	
Land preparation	days/ha	10		Report Section3.6
Planting and fertilising/manuring	days/ha	20		
Weeding and ridging	days/ha	40		
Pest and disease control	days/ha	5		
Harvesting and transport	days/tonne	4		
Storage and sale	days/tonne	4		
	Typical opportunity cost		2.5	

Discount Rate =	10%

TABLE 13: VARIABLES AFFECTING THE CSA WARE AND SEED POTATO PRODUCTION PRACTICES

CSA Practice Outputs		Unit	#	Value per kg
Increasedware potato yields		% base case per year	5%	300
Increased seed potato yields		% base case per year	5%	400

CSA additional input costs	Year	Units	No.	Cost (USD)
Green manure cover crops (seed) Y1	Y1	kg/ha	5	5.00
Planting grass on contour terraces (plant materials) Y1	Y1	kg/ha	10	5.00
Agroforestry shade trees (seedlings) Y1	Y1	trees/ha	250	0.50
CSA Input cost savings (non organic only)	**Y1-10**	% of base case per yea	3%	

CSA additional labour costs (non organic and organic)		Unit	No.	USD / day
ISFM compost /manure making, transport and spreading	Y1-Y10	days/ha	10	
SWC contour terraces contruction	Y1	days/ha	20	
SWC contour terraces maintenance	Y2-Y10	days/ha	5	
SWC incorporate green manure crop	Y1-Y10	days/ha	5	
SWC rain water harvesting construction	Y1	days/ha	8	
SWC rain water harvesting maintenance	Y2-10	days/ha	1	
Agroforestry trees (establishment)	Y1	days/ha	25	
Agroforestry trees (maintenance)	Y2-10	days/ha	3	
		Typical opportunity cost		2.5

Results

The key output of this exercise are two gross margin and farmer cost benefit analysis models for small scale potato growers adopting climate-smart and sustainable land management measures required under the proposed climate-smart credit product. These are

- Firstly, for ware potatoes
- Secondly, for seed potatoes

Results from the analysis are shown in the following two sets of comparative tables. These demonstrate, in generalised cases, the positive financial return to climate-smart and sustainable land-management measures required under the potato climate-smart credit product. This conclusion may not apply in all cases, and the model will need to be adapted for specific use-cases.

Scenario 1: Potato production using inorganic fertiliser and integrated pest management strategies incorporating chemical control measures and all CSA practices adopted

The table belo shows a base situation where the grower is not using CSA practices. This is compared with potato using CSA practices. Results are presented over a single year reflecting the additional input required by CSA although it can be expected that fertiliser and IPM chemical use will decrease over time.

TABLE 14: POTATO GROSS MARGIN ANALYSIS - BASE CASE, WARE POTATOES WITHOUT CSA PRACTICES

	#		Units	Qty/ha	Price/unit USD	Y1-Y10
Income	Yield		tonnes per ha			8
	Value		USD/tonne			300
Gross Income			**USD per ha**			**2,400**
Input costs						
	Seed potatoes		tonnes/ha	2	400	800
	Fertiliser					
		DAP	kg/ha	10	35.0	350
	Pesticides (typical cost)		per ha	1	100	100
			sub-total			**1,250**
Margin over input costs before labour costs, loan repayments or levies			**USD / ha**			**1,150**
Labour costs	Land preparation		days	10	2.50	25
	Planting and fertilising		days	20	2.50	50
	Weeding /ridging		days	40	2.50	100
	Pest and disease control		days	5	2.50	13
	Harvesting and transport		days/tonne	32	2.50	80
	Storage and sale		days/tonne	32	2.50	80
			sub-total	**139**		**348**
Total variable costs			**USD per ha**			**1,598**
Gross Margin over inputs and labour costs before loan repayments or le			**USD per ha**			**803**
Total labour input			**days**			**139**
Returns to labour			**USD /ha**			**1,150**
Returns to labour			**USD/ day**			**8.3**

TABLE 15: POTATO GROSS MARGIN ANALYSIS – WARE POTATOES WITH CSA PRACTICES

		Units	Qty/ha		Price/unit USD	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Income	Yield	kg/ha	5%	increase over base pa		8	9	9	10	10	11	11	12	12	13
	Value	USD/kg				300	300	300	300	300	300	300	300	300	300
Gross Income		**USD per ha**				**2,520**	**2,646**	**2,778**	**2,917**	**3,063**	**3,216**	**3,377**	**3,546**	**3,723**	**3,909**
Input costs	Base costs	USD per ha				1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250
	Savings on base input costs		3% per year		-	-38	-75	-113	-150	-188	-225	-263	-300	-338	-375
	Additional costs														
	SWC (plant grass on contour) Y1 only	kg/ha	10		5.00	50									
	SWC (cover crops)	kg/ha	5		5.00	25	25	25	25	25	25	25	25	25	25
	Agroforestry (trees) Y1 only	seedlings	250		0.50	125									
		sub-total				**1,413**	**1,200**	**1,163**	**1,125**	**1,088**	**1,050**	**1,013**	**975**	**938**	**900**
Margin over input costs before labour costs, loan repayments or lev		**USD / ha**				**1,108**	**1,446**	**1,616**	**1,792**	**1,976**	**2,166**	**2,365**	**2,571**	**2,786**	**3,009**
			Y1	Y2-Y10	USD/day										
Labour costs	Base costs	days	139	139	2.5	348	348	348	348	348	348	348	348	348	348
	Additional costs														
	ISFM (compost making , transport and spreading)	days	10	10	2.5	25	25	25	25	25	25	25	25	25	25
	SWC (contour/ terraces) Y1 construction	days	20	-	2.5	50									
	SWC (contour/ terraces) Y2-Y10 maintenance	days	-	5	2.5		13	13	13	13	13	13	13	13	13
	SWC rainwater harvesting Y1 construction	days	8	-	2.5	3									
	SWC rainwater harvesting Y2-19 maintence	days	-	1	2.5		3	3	3	3	3	3	3	3	3
	Agroforestry (trees)Y1 estblishment]	days	25	-	2.5	63									
	Agroforestry (trees) Y2-10 maintenance	days	-	3	2.5		8	8	8	8	8	8	8	8	8
	Additional harvesting and transport	USD			2.5	4	8	13	17	22	27	33	38	44	50
	Additional storage and sale	USD			2.5	4	8	13	17	22	27	33	38	44	50
		sub-total			-	**492**	**403**	**408**	**412**	**417**	**422**	**428**	**433**	**439**	**445**
Total variable costs		**USD per ha**				**1,904**	**1,603**	**1,570**	**1,537**	**1,505**	**1,472**	**1,440**	**1,408**	**1,377**	**1,345**
Gross Margin over inputs and labour costs before loan repayments		**USD per ha**				**616**	**1,043**	**1,208**	**1,380**	**1,558**	**1,744**	**1,937**	**2,138**	**2,347**	**2,564**
Total labour input		**days**				**197**	**161**	**163**	**165**	**167**	**169**	**171**	**173**	**176**	**178**
Returns to labour		**USD /ha**				**1,108**	**1,446**	**1,616**	**1,792**	**1,976**	**2,166**	**2,365**	**2,571**	**2,786**	**3,009**
Returns to labour		**USD/ day**				**5.6**	**9.0**	**9.9**	**10.9**	**11.8**	**12.8**	**13.8**	**14.8**	**15.9**	**16.9**

Scenario 2: Potato production using no inorganic fertiliser or chemical pest and disease control measures. This compares the situation without, and with CSA practices.

TABLE 16: POTATO GROSS MARGIN ANALYSIS – SEED POTATOES WITHOUT CSA PRACTICES

	#		Units	Qty/ha	Price/unit USD	Y1-Y10
Income	Yield		tonnes/ha			6
	Value		USD/tonne			400
Gross Income			**USD per ha**			**2,400**
Input costs						
	Seed		tonnes/ha	2	400	800
	Fertiliser	Urea	kg/ha	10	35	350
		Phosphate	kg/ha			
		Potash	kg/ha			
	Herbicides and pesticides (typical cost)		per ha	1	100	100
			sub-total			**1,250**
Margin over input costs before labour costs, loan repayments or levies			**USD / ha**			**1,150**
Labour costs	Land preparation		days	10	2.50	25
	Planting		days	20	2.50	50
	Weeding		days	40	2.50	100
	Pest and disease control		days	5	2.50	13
	Harvesting and transport		days/tonne	24	2.50	60
	Storage and sale		days/tonne	24	2.50	60
			sub-total	**123**		**308**
Total variable costs			**USD per ha**			**1,558**
GrossMargin over inputs and labour costs before loan repayments or levies			**USD per ha**			**843**
Total labour input			**days**			**123**
Returns to labour			**USD /ha**			**1,150**
Returns to labour			**USD/ day**			**9.3**

TABLE 17: POTATO GROSS MARGIN ANALYSIS – ORGANIC WITH CSA PRACTICES

CSA ware potoes															
					Price/unit										
		Units	Qty/ha		USD	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Income	Yield	kg/ha	5%	increase over base pa		8	9	9	10	10	11	11	12	12	13
	Value	USD/kg				300	300	300	300	300	300	300	300	300	300
Gross Income		**USD per ha**				**2,520**	**2,646**	**2,778**	**2,917**	**3,063**	**3,216**	**3,377**	**3,546**	**3,723**	**3,909**
Input costs	Base costs	USD per ha				1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250
	Savings on base input costs		3% per year		-	-38	-75	-113	-150	-188	-225	-263	-300	-338	-375
	Additional costs														
	SWC (plant grass on contour) Y1 only	kg/ha	10		5.00	50									
	SWC (cover crops)	kg/ha	5		5.00	25	25	25	25	25	25	25	25	25	25
	Agroforestry (trees) Y1 only	seedlings	250		0.50	125									
		sub-total				**1,413**	**1,200**	**1,163**	**1,125**	**1,088**	**1,050**	**1,013**	**975**	**938**	**900**
Margin over input costs before labour costs, loan repayments or le		**USD / ha**				**1,108**	**1,446**	**1,616**	**1,792**	**1,976**	**2,166**	**2,365**	**2,571**	**2,786**	**3,009**
			Y1	Y2-Y10	USD/day										
Labour costs	Base costs	days	139	139	2.5	348	348	348	348	348	348	348	348	348	348
	Additional costs														
	ISFM (compost making , transport and spreading)	days	10	10	2.5	25	25	25	25	25	25	25	25	25	25
	SWC (contour/ terraces) Y1 construction	days	20	-	2.5	50									
	SWC (contour/ terraces) Y2-Y10 maintenance	days	-	5	2.5		13	13	13	13	13	13	13	13	13
	SWC rainwater harvesting Y1 construction	days	8	-	2.5	3									
	SWC rainwater harvesting Y2-19 maintence	days	-	1	2.5		3	3	3	3	3	3	3	3	3
	Agroforestry (trees)Y1 estblishment]	days	25	-	2.5	63									
	Agroforestry (trees) Y2-10 maintenance	days	-	3	2.5		8	8	8	8	8	8	8	8	8
	Additional harvesting and transport	USD			2.5	4	8	13	17	22	27	33	38	44	50
	Additional storage and sale	USD			2.5	4	8	13	17	22	27	33	38	44	50
		sub-total			-	**492**	**403**	**408**	**412**	**417**	**422**	**428**	**433**	**439**	**445**
Total variable costs		**USD per ha**				**1,904**	**1,603**	**1,570**	**1,537**	**1,505**	**1,472**	**1,440**	**1,408**	**1,377**	**1,345**
Gross Margin over inputs and labour costs before loan repayments		**USD per ha**				**616**	**1,043**	**1,208**	**1,380**	**1,558**	**1,744**	**1,937**	**2,138**	**2,347**	**2,564**
Total labour input		**days**				**197**	**161**	**163**	**165**	**167**	**169**	**171**	**173**	**176**	**178**
Returns to labour		**USD /ha**				**1,108**	**1,446**	**1,616**	**1,792**	**1,976**	**2,166**	**2,365**	**2,571**	**2,786**	**3,009**
Returns to labour		**USD/ day**				**5.6**	**9.0**	**9.9**	**10.9**	**11.8**	**12.8**	**13.8**	**14.8**	**15.9**	**16.9**

Results are summarised below:

TABLE 18: RESULTS SUMMARY

	Scenario	Yields (Y10)	Gross margin (Y10)	Labour required (Y10)	Returns to labour (Y10)	Returns to labour (Y10)	Benefit cost ratio
		tonnes per ha	USD per ha	days per ha	USD per ha	USD per day	over 10 years
Ware potatoes	Ware potatoes without CSA practices	8	803	139	1,150	8.3	-
	Ware potatoes with CSA practices	13	2,564	178	3,009	16.9	1.9
Seed potatoes	Seed potatoes without CSA practices	6	843	123	1,150	9.3	-
	seed potatoeswith CSA pactices	10	2577	173	3,009	17.4	1.8

Discount rate = 10%

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 tea, below are the summary outputs of the model showing improved cash position in the event of a 30% yield shock. The model projects both (i) reduced savings on portfolio losses over time, and (ii) savings due to improvements in cost of capital due to the environmental return.

TABLE 19: LENDER FINANCIAL IMPACT ANALYSIS

	Loan 1	**Loan 2**	**Loan 3**	**Loan 4**	**Loan 5**	**Loan 6**	**Loan 7**
Yield loss scenario	30%	30%	30%	30%	30%	30%	30%
Number of clients	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Loan book size (US$)	9,891,000	9,891,000	9,891,000	9,891,000	9,891,000	9,891,000	9,891,000
Portfolio loss with no climate-smart lending	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**	**(1,812,500)**
Portfolio loss with climate-smart lending	**(2,126,859)**	**(1,866,992)**	**(1,659,098)**	**(1,489,002)**	**(1,347,256)**	**(1,227,318)**	**(1,124,513)**
Savings due to CSA practices	(314,359)	(54,492)	153,402	323,498	465,244	585,182	687,987
Cost of capital w/o climate-smart lending	20%	20%	20%	20%	20%	20%	20%
Cost of capital w climate-smart lending	8%	8%	8%	8%	8%	8%	8%
Annual interest savings (US$)	1,186,920.00	1,186,920.00	1,186,920.00	1,186,920.00	1,186,920.00	1,186,920.00	1,186,920.00
Cash position improvement with climate-smart-lending (US$)	**872,561**	**1,132,428**	**1,340,322**	**1,510,418**	**1,652,164**	**1,772,102**	**1,874,907**

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$ 580 over 7 years. Please note that as a template, this model uses dummy variables ahead of a site specific analysis and excludes farmer benefits which would be included in a full public cost benefit structure methodology.

#		Year						
#	**Benefits**	0	1	2	3	4	5	6
1	Plant trees	13	13	13	13	13	13	13
2	Rainwater harvesting structures	40	40	40	40	40	40	40
3	Crop rotation	30	30	30	30	30	30	30
4	Contour terracing	40	40	40	40	40	40	40
5	Manure and compost spreading	24	24	24	24	24	24	24
6	Introducing an Integrated pest management programme	14	14	14	14	14	14	14
	Total Benefits (US$/ha)	161	161	161	161	161	161	161
	Additional Labour Costs	(163.00)	50.00	(363.00)	125.00	125.00	200.00	237.00
	Loan discounts	49.45	49.45	49.45	49.45	49.45	49.45	49.45
	Total Costs (US$/ha)	**(113.55)**	**99.45**	**(313.55)**	**174.45**	**174.45**	**249.45**	**286.45**
	Net Benefits (US$/ha)	**274.77**	**61.77**	**474.77**	**(13.23)**	**(13.23)**	**(88.23)**	**(125.23)**
	Discounted Net Benefits (US$/ha)	**274.8**	**56.2**	**392.4**	**(9.9)**	**(9.0)**	**(54.8)**	**(70.7)**
	NPV (US$/ha)	**578.9**						

ANNEX 1: AREA AND AVERAGE CANE YIELDS FOR POTATO PRODUCING COUNTRIES – 2016-1725

Country	Area (ha)	Yield tonnes	Yields (t/ha)
USA	415,010	20,017,350	48
Germany	250,500	11,720,000	47
France	173,486	7,342,203	42
Netherlands	160,791	7,391,881	46
United Kingdom	146,000	6,218,000	43
Belgium	92,855	4,416,665	48
Denmark	49,700	2,171,000	44
Australia	28,372	1,105,194	39
Switzerland	11,276	458,900	41
Ireland	9,200	412,400	45
Palestine	1,565	56,912	36
South Africa	67,746	2,450,541	36
Uzbekistan	78,251	2,793,689	36
Sweden	24,570	852,500	35
United Arab Emirates	143	4,921	34
Israel	15,264	522,424	34
Luxembourg	622	21,284	34
Turkey	142,851	4,800,000	34
Argentina	75,975	2,454,001	32
Iran	160,902	5,102,342	32
Zambia	1,004	31,750	32
Spain	70,878	2,239,470	32
Brazil	118,030	3,656,846	31
Algeria	148,692	4,606,403	31
Morocco	64,293	1,924,871	30
Czechia	23,418	688,970	29
Niger	5,650	165,743	29
Japan	73,483	2,150,917	29
Bahrain	1	29	29
Mexico	59,256	1,715,499	29
Finland	21,200	611,900	29
Greece	18,800	536,000	29
Austria	22,991	653,400	28
El Salvador	581	16,333	28
Jordan	4,008	111,753	28
Poland	329,323	9,171,733	28
Iraq	9,610	266,794	28
Italy	48,571	1,346,936	28
Saint Kitts and Nevis	3	82	27

25 FAOSTAT, 2018. Statistical data base. Food and Agriculture Organisation of the United Nations, Rome, Italy. http://www.fao.org/faostat/en/#data/PP/ accessed 20th March 2019

Country	Area (ha)	Yield tonnes	Yields (t/ha)
Norway	11,655	314,500	27
Oman	585	15,737	27
Egypt	163,939	4,325,478	26
Chile	54,082	1,426,479	26
Guatemala	21,156	545,759	26
Costa Rica	3,218	82,827	26
Cyprus	5,258	135,083	26
Saudi Arabia	18,755	476,418	25
Lebanon	15,246	384,259	25
Albania	9,948	249,804	25
China, Taiwan	2,336	58,580	25
Republic of Korea	24,852	614,033	25
Hungary	16,364	402,853	25
Panama	1,205	29,417	24
Bermuda	41	1,000	24
Slovenia	3,165	77,076	24
Belarus	275,997	6,414,755	23
Lao	70	1,585	23
Pakistan	183,961	4,142,399	23
Senegal	5,284	118,783	22
India	2,179,000	48,605,000	22
Cuba	6,765	147,044	22
Portugal	23,735	515,030	22
Armenia	25,311	547,420	22
Mali	11,750	251,558	21
Turkmenistan	15,243	314,116	21
Bangladesh	499,725	10,215,957	20
Slovakia	7,450	149,705	20
Mauritius	710	14,124	20
Uruguay	4,584	90,772	20
Syria	31,046	613,434	20
Libya	17,790	349,478	20
Kazakhstan	182,895	3,551,114	19
Tajikistan	40,615	782,892	19
Latvia	21,500	408,300	19
Colombia	149,060	2,819,026	19
Malawi	66,604	1,226,603	18
Romania	171,390	3,116,910	18
Venezuela	11,000	200,000	18
Bulgaria	12,806	227,815	18
Nicaragua	3,404	59,699	18
China	5,767,481	99,205,580	17
Mozambique	14,951	255,139	17
Kyrgyzstan	83,033	1,416,011	17
Montenegro	1,620	27,500	17

Country	Area (ha)	Yield tonnes	Yields (t/ha)
Zimbabwe	3,915	66,359	17
Estonia	5,388	91,182	17
Ukraine	1,323,200	22,208,220	17
Lesotho	7,386	123,857	17
Jamaica	1,039	17,148	17
Sri Lanka	4,457	73,358	16
Tunisia	25,590	420,000	16
Thailand	7,749	126,671	16
Honduras	1,644	26,764	16
Afghanistan	32,116	513,194	16
Croatia	9,833	156,089	16
Russian Federation	1,889,208	29,589,976	16
Azerbaijan	58,772	913,899	16
Indonesia	75,611	1,164,743	15
Peru	310,400	4,776,294	15
Cameroon	20,500	315,000	15
Serbia	38,472	589,241	15
Myanmar	32,703	499,933	15
Yemen	16,631	251,590	15
Philippines	7,793	117,637	15
Iceland	600	9,000	15
Comoros	40	598	15
Viet Nam	20,480	303,675	15
Paraguay	260	3,760	14
Faroe Islands	105	1,494	14
Nepal	194,115	2,691,037	14
Ethiopia	67,591	932,701	14
Belize	98	1,308	13
North Macedonia	13,436	178,951	13
Canada	342,218	4,410,829	13
Sudan	33,000	425,000	13
Ecuador	29,532	377,243	13
Haiti	3,044	38,723	13
Malta	700	8,740	12
Lithuania	19,351	237,045	12
Namibia	1,404	17,030	12
Fiji	23	270	12
Korea	157,569	1,770,000	11
Bhutan	5,192	57,223	11
Qatar	3	32	11
Guinea	5,616	59,012	11
Moldova	20,000	197,000	10
Chad	4,216	41,499	10
Bosnia and Herzegovina	34,941	337,137	10
French Polynesia	60	569	9

Country	Area (ha)	Yield tonnes	Yields (t/ha)
Cabo Verde	307	2,864	9
Georgia	19,700	180,100	9
Rwanda	93,991	846,184	9
New Caledonia	208	1,841	9
Congo	666	5,711	9
Tanzania	211,927	1,749,213	8
Benin	87	708	8
Mongolia	15,148	121,808	8
Kenya	192,341	1,519,870	8
Burundi	21,205	150,527	7
Bolivia	182,675	1,174,744	6
Mauritania	386	2,327	6
Madagascar	39,285	235,406	6
Papua New Guinea	232	1,287	6
Reunion	1,104	5,984	5
Montserrat	40	213	5
D R Congo	22,339	103,484	5
Angola	180,104	807,310	4
Uganda	39,300	165,000	4
Nigeria	345,246	1,284,368	4
Eswatini	4,037	8,449	2
Burkina Faso	710	1,411	2
Timor-Leste	1,115	1,192	1
Eritrea	148	139	1
Central African Republic	1,780	1,341	1
Total/mean	25,056,682	486,794,200	20

Annex 2: Potato producing country profiles: Kenya, Rwanda, Ethiopia

Kenya[26].

Potato is one of the most consumed produce in Kenya, coming second to Maize. It acts as a staple food crop as well as cash crop for many rural and semi urban dwellers playing an important role in improving national food security and income generation for those involved in its value chain development.

Potato is grown in Kenya by approximately 800,000 small scale farmers on 120,000 hectares with yields of 4-8 tons per hectare. Most small scale famers have less than 1 hectare[27]. The most favourable climatic conditions are found in areas with a yearly rainfall of between 850 mm and 1200 mm, at altitudes between 1 500 m and 2 800 m above sea level. These areas are situated mainly in the Central, Rift Valley and Eastern provinces of Kenya[28].The crop is mostly grown in the highland areas where maize has low competitive advantage with over 70% of the potatoes being grown in areas 2,100 M above sea level. Consumption has been increasing with increasing urbanization and growth of the fast food industry. Some 60% of the produce grown and traded by urban traders is used by restaurants and street market stalls

Production is bi-modal produced twice a year following the rainfall pattern. Around July to August period, potatoes are usually in high volumes and fetch low prices while in December, April and May they are usually in low supply fetching higher prices for farmers involved. Per capita annual consumption is estimated to be 10-15 kg, compared with 100 kg in Western Europe and 150–200 kg in Eastern Europe. The average yield achieved by the small-scale farmer is approximately 4-5 tons per hectare. Large-scale farmers generally achieve higher yields, approximately 10-14 tons per hectare. Efficient husbandry and the use of improved planting material could increase average yields to 16–20 tons per hectare with yields of up to 40 tons per hectare being achieved.

Survey results show that the average household farm sizes are less than 2.4 hectares with most farmers allocating some 25% of their farms to potatoes. The crop is produced both for food and cash by 90% of respondents in all districts. Cultivar preferences are mostly dictated by availability of markets, yield potential and taste.

Due to continuous production of potatoes in the same piece of land, soil degradation has been inevitable. Fertilizer application has been below the recommended rates with the most common being Di-Ammonium Phosphate. Only about 1% of the planted area has recorded use of certified seed. Other constraints that have affected productivity of potatoes include diseases such as brown rot and late blight, lack of crop rotation, poor storage facilities and lack of enough capital for capital intensive production.

Rwanda[29]

Rwanda is the second largest producer of potatoes in East Afrca after Kenya and third largest in SSA. The crop has a short growth cycles and can easily be integrated into existing agricultural systems, and stored relatively easily. It has excellent nutritional content and is a good source of dietary energy and micronutrients. Notwithstanding, potato production in Rwanda is faced with various

26 Jane Muthoni1,2, Hussein Shimelis1 & Rob Melis1, Potato Production in Kenya: Farming Systems and Production Constraints, 2013. Journal of Agricultural Science; Vol. 5, No. 5; 2013. ISSN 1916-9752 E-ISSN 1916-9760. Published by Canadian Center of Science and Education 182

27https://mfarm.co.ke/blog/post/potato-production-in-kenya

28

29 https://cipotato.org/media/seed-potato-in-rwanda/

constraints among which pests and diseases, limited land sizes, and high production costs (for pesticides and seeds

Most of potato sector consists of small family farms that intercrop potato with beans and maize, and yields average almost 6-8 tonnes per hectare. The potato underpins Rwanda's food security. Annual consumption is high at 125 kg per person, making potato the country's second most important source of calorie intake after cassava. Currently, Rwanda has over 70,000 potato farmers grouped in 30 cooperatives .   Potato farmers face many challenges including low quality seed, pests and diseases which lead to low productivity and limited expansion of the crop. The country requires some 120,000 tonnes of quality seed potatoes per year but only 25 per cent of the demand is met.

Ethiopia[30]

Among African countries, Ethiopia has possibly the greatest potential for potato production with 70 percent of its arable land - mainly in highland areas above 1 500 m - suitable for potato. Since the highlands are also home to almost 90 percent of Ethiopia's population, the potato could play a key role in ensuring national food security. At present, potatoes are still widely regarded as a secondary crop, and annual per capita consumption is estimated at just 5 kg. However, potato growing is expanding steadily:

30 Peter Rein Gildemacher, Wachira Kaguongo, Oscar Ortiz, C. Leeuwis , 2009. Improving Potato Production in Kenya, Uganda and Ethiopia: A System Diagnosis. Potato Research 52(2):173-205. DOI: 10.1007/s11540-009-9127-4. https://www.researchgate.net/publication/226264414_Improving_Potato_Production_in_Kenya_Uganda_and_Ethiopia_A_System_Diagnosis

Annex 3: The impact of CSA potato management practices[31]

1. Improving the resilience of natural resource use (farm level biodiversity, groundwater availability, soil erosion, plant available nutrients, infiltration of water into the soil, soil microbial diversity soil aggregation and soil water holding capacity)
2. Reducing the risks associated with climate change (increased temperature, intra-seasonal droughts, in season droughts, shortened growing season, increased rainfall intensity and unpredictable seasons)
3. Mitigating the effects of some of the causes of climate change (change in land use, emission from inputs, carbon sequestered in the soil, carbon sequestered in biomass, N_20 emissions, and CH^4 emissions)
4. Increasing productivity (yield, yield variability, labour and income)
5. Quantification of the impact of CSA practice on productivity (farmer benefits and costs)

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

CSA practice			Farm level biodiversity	Groundwater availability	Soil erosion	Plant available nutrients	Infiltration of water into the soil	Soil microbial diversity	Soil aggregation	Soil water holding capacity
Improved varieties	1	Varieties tolerant or resistant to adversities of weather (drought, water logging, warm/cold weather conditions) and pests and diseases	-	-	-	-	-	-	-	-
Integrated soil fertility management	2	Improvement of soil organic matter content through applications of compost, crop residues, cattle manure (3-5 tonnes per ha) leading to a reduction in inorganic fertiliser applications	+	++	++	+++	+++	+++	+++	+++
	-	Ensuring appropriate crop rotations are followed. These should include cereals (maize or sorghum), legumes (soya beans, beans, groundnuts, broad beans)or a fallow period growing a leguminous cover crop as a green manure with residues used for mulching	++	+	++	++	++	++	+	++
Soil and water conservation	3	Establish contour terraces/banks planted with grass and/or trees with appropriate measures for safe removal of water (micro-watershed management)	+++	+++	+++	+++	+++	+++	+++	+++
	4	Establishing vegetative matter (such as Napier, Guatemala or vetiver grass grown on contour terraces)	+	+	+++	++	++	+	-	++
	5	Rain water harvesting ditches incorporated in the micro-watershed plan	-	++	++	+	++	+	+	++
Agro-forestry	6	Establish trees for shade, windbreaks, mulching, and erosion control between fields and on field boundaries	+++	++	++	+++	+++	++	+	++
	7	Afforestation, reforestation and establishment of trees on field boundaries, surrounding water courses, around homes and areas surrounding fields.	+++	++	++	+++	+++	++	+	++
Integrated pest and disease management	-	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	+++	-	-	-	-	-	-	-

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

2. CSA potato practices impact on risks associated with climate change

CSA practice			Increased temperature	Intra-seasonal droughts	Inter-seasonal droughts	Shortened growing season	Increased rainfall intensity	Unpredictable seasons
Improved Coffee varieties	1	Varieties tolerant or resistant to adversities of weather (drought, water logging, warm/cold weather conditions) and pests and diseases	++	++	++	+++	-	++
Integrated soil fertility management	2	Improvement of soil organic matter content through applications of compost, crop residues, cattle manure (3-5 tonnes per ha) leading to a reduction in inorganic fertiliser applications	+	+	+	+	+	+
	-	Ensuring appropriate crop rotations are followed. These should include cereals (maize or sorghum), legumes (soya beans, beans, groundnuts, broad beans)or a fallow period growing a leguminous cover crop as a green manure with residues used for mulching	+	+	+	+	+	+
Soil and water conservation	3	Establish contour terraces/banks planted with grass and/or trees with appropriate measures for safe removal of water (micro-watershed management)	-	+++	+++	+++	+++	+
	4	Establishing vegetative matter (such as Napier, Guatemala or vetiver grass grown on contour terraces)	+	++	++	++	++	++
	5	Rain water harvesting ditches incorporated in the micro-watershed plan	++	++	++	++	++	++
Agro-forestry	6	Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	+++	+++	+++	+++	+++	+++
	7	Afforestation, reforestation and establishment of trees on field boundaries, surrounding water courses, around homes and areas surrounding cotton fields.	++	++	++	++	++	++
Integrated pest and disease management	-	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	-	-	-	-	-	-

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

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

3. The impact of potato CSA practices on mitigation of the factors causing climate change

Climate smart agricultural practice			Change in land use	Emission from inputs	Carbon sequestered in the soil	Carbon sequestered in biomass	N20 emissions	CH4 emissions
Improved Coffee varieties	1	Varieties tolerant or resistant to adversities of weather (drought, water logging, warm/cold weather conditions) and pests and diseases	+	-	-	-	-	-
Integrated soil fertility management	2	Improvement of soil organic matter content through applications of compost, crop residues, cattle manure (3-5 tonnes per ha) leading to a reduction in inorganic fertiliser applications	+	-	+++	+++	+	-
	-	Ensuring appropriate crop rotations are followed. These should include cereals (maize or sorghum), legumes (soya beans, beans, groundnuts, broad beans)or a fallow period growing a leguminous cover crop as a green manure with residues used for mulching	++	-	+	+	-	-
Soil and water conservation	3	Establish contour terraces/banks planted with grass and/or trees with appropriate measures for safe removal of water (micro-watershed management)	+	-	+	-	-	-
	4	Establishing vegetative matter (such as Napier, Guatemala or vetiver grass grown on contour terraces)	++	-	+	+	+	-
	5	Rain water harvesting ditches incorporated in the micro-watershed plan	-	-	++	-	+	-
Agro-forestry	6	Establish trees for shade, windbreaks, mulching, and erosion control between trees and on field boundaries	+++	-	++	+++	-	-
	7	Afforestation, reforestation and establishment of trees on field boundaries, surrounding water courses, around homes and areas surrounding cotton fields.	+++	-	++	+++	-	-
Integrated pest and disease management	-	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	+	+++	-	-	+	+

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

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

4. The impact of potato CSA practices on productivity

Climate smart agricultural practice			Yield	Yield variability	Labour	Income
Plant improved potato varieties on suitable land	1	Varieties tolerant or resistant to adversities of weather (drought, water logging, warm/cold weather conditions) and pests and diseases	+++	+++	-	+++
Integrated soil fertility management	2	Improvement of soil organic matter content through applications of compost,crop residues, cattle manure (3-5 tonnes per ha) leading to a reduction in inorganic fertiliser applications	++	++	++	++
	-	Ensuring appropriate crop rotations are followed. These should include cereals (maize or sorghum), legumes (soya beans, beans, groundnuts, broad beans)or a fallow period growing a leguminous cover crop as a green manure with residues used for mulching	++	++	++	++
Soil and water conservation	3	Establish contour terraces/banks planted with grass and/or trees with appropriate measures for safe removal of water (micro-watershed management)	++	++	++	++
	4	Establishing vegetative matter (such as Napier, Guatemala or vetiver grass grown on contour terraces)	++	++	++	++
	5	Rain water harvesting ditches incorporated in the micro-watershed plan	++	++	++	++
Agro-forestry	6	Establish trees for windbreaks, mulching, improving soil fertility and erosion control	++	++	++	++
	7	Afforestation, reforestation and establishment of trees on field boundaries, surrounding water courses, around homes and areas surrounding cotton fields.	++	++	++	+++
Integrated pest and disease management	-	Use of multiple pest management tactics to prevent economically damaging out-breaks, while reducing risks to human health and the environment	+++	+++	++	++

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

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