WHITE PAPER

Financing Agriculture for Carbon Offset and Food Security in East Africa

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Contents

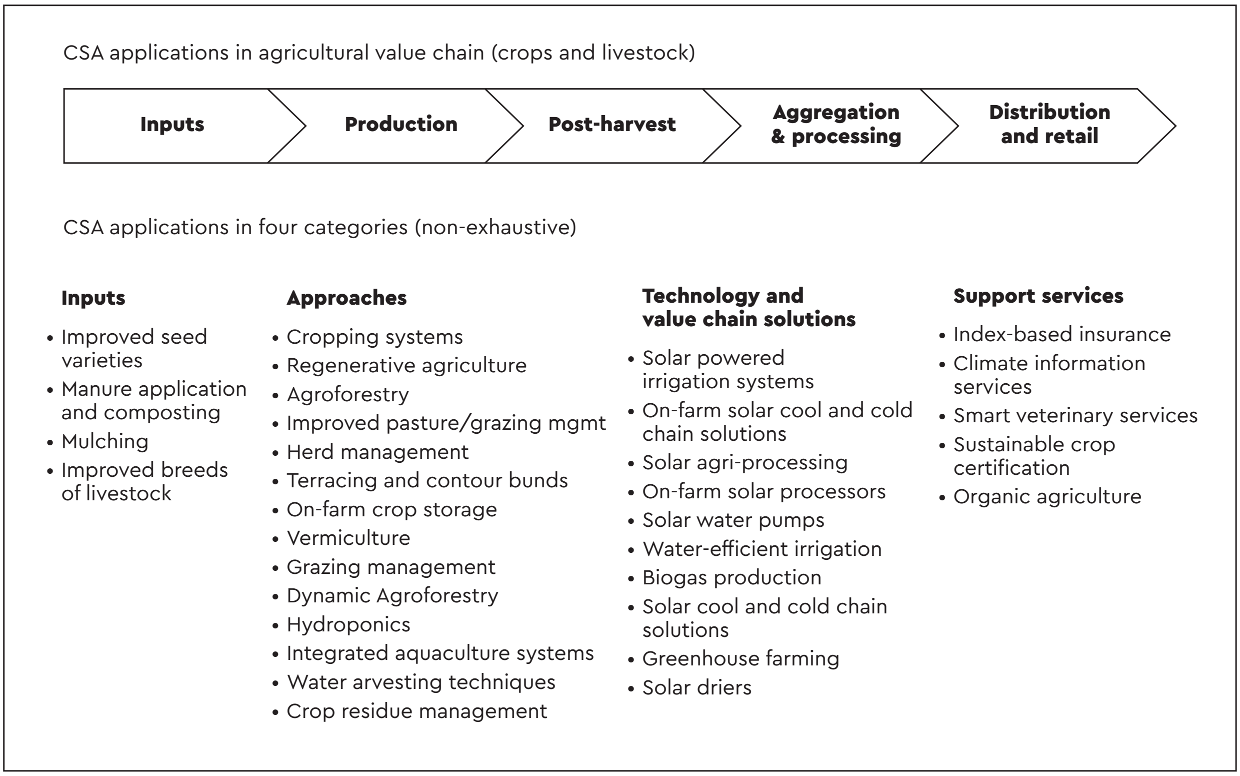
1. Introduction

Agriculture is a major contributor to the national economies of East African countries, contributing between **21% and 42%** of gross domestic product (GDP) and employing approximately **63% of the labor force**. Dominated by **smallholder farmers** – who produce up to 90% of the region's food – this sector is facing unprecedented pressure from **climate change**, environmental degradation, and economic vulnerability.[1] Climate-smart agriculture (CSA), defined as practices that sustainably increase productivity and resilience while reducing or removing GHGs is gaining prominence as a strategy to adapt farming to climate pressures. CSA integrates improved practices (e.g., conservation agriculture), technologies (e.g., solar based drip irrigation), inputs (e.g., improved seeds), and services (e.g., weather-index insurance), tailored to specific agro-ecological zones. To scale CSA, an enabling policy environment and strengthened collaboration between public, private, and development actors are essential. Linking CSA with climate finance and carbon markets is seen as a way to encourage low-emission farming. For example, policies now consider blended public–private finance and green bonds to support sustainable crop production (though such instruments remain nascent in East Africa).[2]

1 Adhikari, U., Nejadhashemi, A. P., & Woznicki, S. A. (2015). Climate change and eastern Africa: a review of impact on major crops. Food and energy security, 4(2), 110–132.

2 Enabling Climate Smart Agriculture across East Africa,FAO(2010). https://www.kas.de/documents/282730/14348058/Climate+Smart+Agriculture+in+East+Africa+_Policy+Brief.pdf/5e027e66-f9cd-fcd7-8c8d-e7752398ab2a?version=1.0

Figure 1 : East African CSA Applications Taxonomy



Source: [2] Enabling Climate Smart Agriculture across East Africa, FAO (2010)

2. Agricultural Financing in East Africa

Access to finance is a fundamental enabler of agricultural development, particularly for smallholder farmers in East Africa. However, these farmers face persistent constraints in accessing credit, including high transaction costs, lack of collateral, and low financial literacy (Khan et al., 2024). These barriers hinder productivity, adoption of improved practices, and resilience to climate shocks.

To address these challenges, various financing models have been implemented across the region. Microfinance institutions, government subsidies, and input credit schemes—such as Kenya's Agricultural Finance Corporation and Ethiopia's input credit programs—have shown mixed levels of success (Havemann et al., 2022). Despite these efforts, most current financial models are not explicitly aligned with climate-smart agriculture (CSA) or carbon mitigation goals.[3]

In recent years, blended finance—which combines public and private capital—has

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3 All Donors to East Africa for Climate Adaptation during 2009–2018. Aid Atlas. Visualise international development finance.

gained traction as a promising approach to de-risk investments in sustainable agriculture. Instruments such as trade credit guarantees, first-loss coverage, and performance-based incentives help lower the cost and risk for lenders, making it easier for smallholders and agribusinesses to access capital.A notable example is the African Development Bank's $500 million facility, designed to mobilize $10 billion in financing for smallholders and agribusinesses across Africa. This initiative targets the continent's estimated $75 billion annual agricultural financing gap and aims to increase investment flows through blended instruments and risk-sharing mechanisms.[4]

Additionally, emerging climate finance mechanisms—including green bonds, ESG-focused funds, and sustainable investment platforms—offer new opportunities to support low-emission, resilient agricultural systems. However, uptake in East Africa remains limited, highlighting the need for stronger policy alignment, awareness, and capacity building to integrate CSA and carbon goals into financial models.[5]

In summary, while financing tools are expanding in East Africa, there is a critical need to better align them with climate-smart objectives to ensure that capital flows support both productivity and sustainability.

3. Staple Crop Production and Food Security

Staple crops – especially maize, potato, and wheat – are central to food security in East Africa. Maize is the **dominant food staple** for millions, while potato is a key highland crop rich in calories and micronutrients.[6] Wheat consumption is rising but most supply is imported, making countries vulnerable to global price shocks. For example, in Kenya agriculture contributes ~34% of GDP and supports ~70% of the rural population, yet staple yields remain well below potential. In Kenya's potato sector, per capita consumption is **~25 kg/year** (~2.3 million tons total) and the government targets production of 2.5 million tons. Actual yields are only 7–10 t/ha, far below the 30–40 t/ha agronomic potential. The yield gap is attributed to

4 Bridging the Gap: IFAD's Role in Climate Finance for Smallholder Farmers – COP28. https://www.ifad.org/en/w/remarks/bridging-the-gap-ifad-s-role-in-climate-finance-for-smallholder-farmers-cop28-statement?

5 How effective is climate finance in assisting farmers in low- and middle-income countries adapt to climate change? https://www.sei.org/features/how-effective-is-climate-finance-in-assisting-farmers-in-low-and-middle-income-countries-adapt-to-climate-change/?

6 Adhikari, Umesh, A. Pouyan Nejadhashemi, and Sean A. Woznicki. "Climate change and eastern Africa: a review of impact on major crops." Food and energy security 4.2 (2015): 110–132. https://doi.org/10.1002/fes3.61

poor-quality seed, **suboptimal agronomy, and postharvest losses**. National strategies therefore emphasize certified seed distribution, fertilizer use, and mechanization.[7] Similarly, maize smallholders typically achieve 2–4 t/ha (depending on inputs and rain), and wheat even less, underscoring food insecurity. Hence, improving yields through sustainable intensification (e.g. better varieties, soil fertility, irrigation) is expected to boost food availability without expanding cropland (FAO).[8]

4. GHG Emissions and Sustainable Agricultural Practices

Agricultural systems contribute a substantial share of greenhouse gases. Globally, land use change and agriculture emit ~24% of total anthropogenic GHGs[9]. However, Agriculture also offers mitigation opportunities: practices that increase soil C sequestration (e.g. agroforestry, cover crops) or reduce emissions (e.g. fertilizer optimization) are key. By combining productivity gains with emissions controls, CSA practices can deliver "triple wins" (higher output, climate resilience, and lower GHG). For instance, diversifying crops with **legume rotations or agroforestry** can improve soil N and C stocks. Drip irrigation or rainwater harvesting can boost efficiency. In the rice system, alternate wetting/draining (AWD) and SRI demonstrate how improved water management cuts methane while sustaining yields. In maize/wheat systems, integrated soil fertility management (combining organic manures with optimized mineral fertilizer) can maintain yields with less N_2O per unit yield.[10]

Rice grown under the System of Rice Intensification (SRI) can yield ~8 t/ha and emit ~3,500 kg CO_2e/ha (paddy basis), i.e.~0.42 kg CO_2e per kg of paddy. By contrast, conventional flooded rice can emit much more; water- and fertilizer-management practices (AWD irrigation, intermittent drying, optimized N rates) have been shown to cut methane and overall GHG by ~40–60% in some trials.[11]

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7 The national potato strategy. Signed-Strategy-2021–2025.pdf

8 Agrifood systems and land-related emissions Global, regional and country trends, 2001–2021. FAOSTAT Analytical Brief 73. https://openknowledge.fao.org/server/api/core/bitstreams/487c7f4e-91ff-4d23-b1e4-f72dd867e939/content

9 IPCC. (2019). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, eds E. Calvo Buendia, K. Tanabe, A. Kranjc, J. Baasansuren, M. Fukuda, S. Ngarize, et al. (IPCC).

10 Frontiers. Greenhouse gas emissions in irrigated paddy rice as influenced by crop management practices and nitrogen fertilization rates in eastern Tanzania. https://doi.org/10.3389/fsufs.2022.868479

11 Smallholder cropping systems contribute limited greenhouse gas fluxes in upper Eastern Kenya. https://doi.org/10.1016/j.nbsj.2023.100098

Maize and wheat fields emit mainly nitrous oxide (N_2O) from fertilizers and modest amounts of CO_2. Yield- scaled field emissions for maize are relatively low (on the order of 0.1–0.2 kg CO_2e per kg grain in recent Kenyan trials)[12] given moderate application of N fertilizers. Wheat, often grown in highlands with fewer inputs, likely has comparable or slightly higher intensity than maize. In any case, more efficient fertilizer use (e.g. precision or organic amendments) can reduce per-ton GHG from these cereals.[13]

Potatoes – a major tropical root crop – have an intermediate carbon footprint. East African studies estimate potato emissions around 0.16–0.25 kg CO_2e per kg tuber. (For example, one modeling of the Kenyan potato sector finds ~0.20 kg CO_2e/kg.) Emissions sources include fertilizer N_2O, diesel fuel for land prep, and indirect emissions embodied in seed potatoes. Despite being less than rice on a per-kg basis, potato's relatively high yield means per-hectare emissions can still be significant (multiple tons CO_2e per ha)[12]. Nonetheless, a compelling illustration from recent potato case studies by **Soethoudt, H., & Castelein, B. (2021)**, has compared the current smallholder practice (home-saved seed, low inputs), switching to climate-smart potato systems (certified seed, balanced NPK and micronutrients, mechanized planting/harvest, and reduced losses) unveiling that the later roughly doubles to triples yields while halving GHG per unit.

In one analysis, baseline smallholder yields (~8.3 t/ha) increased to ~21.6 t/ha under an intensified scenario. At the same time, on-farm and handling losses dropped dramatically, and lifecycle emissions fell from about 263 to 128 kg CO_2e per ton of marketable potato (a 51% reduction)[12]. In other words, CSA potato farming delivered ~2.6× more edible yield and 50% lower emissions per ton.[13]

The study models four practical scenarios – ranging from traditional practices to fully mechanized systems using certified seeds – and applies a novel backward calculation method to assess their impacts.

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12 Policy Brief: For a Climate Smart Potato Sector in Kenya. https://www.wur.nl/nl/show/policy-brief-for-a-climate-smart-potato-sector-in-kenya.htm

13 Food Loss-Reducing Intervention Strategies for Potato Smallholders in Kenya – A Positive Business Case with Reduced Greenhouse Gas Emissions Food Loss-Reducing Intervention Strategies for Potato Smallholders in Kenya – A Positive Business Case with Reduced Greenhouse Gas Emissions

Intervention Scenarios – Four farming scenarios were evaluated:

- **Scenario 1 (Reference):** Manual labor, home-saved seeds, minimal inputs.
- **Scenario 2:** Certified seed, increased DAP fertilizer and plant protection.
- **Scenario 3:** Clean seed, partial mechanization, increased DAP fertilizer and crop protection.
- **Scenario 4:** Certified seed, full mechanization (ploughing, planting, harvesting), appropriate NPK fertilizer, and intensive plant protection.

Key results

Metric	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Yield (t/ha)	8.3	16.1	17.8	21.6
GHG Emissions (kg CO_2-eq/ton)	263	195	195	128
Food Loss (kg/ton)	257	257	257	75
Profit (USD/ton)	$16.40	$25.42	–	$91.79
Acreage Required	0.22 ha	0.12 ha	–	0.07 ha

- **Scenario 4** yielded the most benefits across all indicators: higher yield, lowest greenhouse gas emissions, significantly reduced food loss, and the highest profit.
- **Scenario 2 and 3** also showed substantial improvements over the reference scenario.

Similar potential exists for cereals: e.g. hybrid maize varieties and split-N fertilizer scheduling can lift maize yields 2× with marginal N_2O increase. In summary, sustainable intensification practices (cover cropping, soil conservation, input efficiency, climate-adapted varieties, etc.) can greatly improve the GHG intensity of East African farming while strengthening food security.[14]

14 Policy Brief: For a Climate Smart Potato Sector in Kenya. https://www.wur.nl/nl/show/policy-brief-for-a-climate-smart-potato-sector-in-kenya.htm

5. Comparative Emissions and Water Use Data

In this section data from academic studies and World Bank/FAO reports are compiled for rice, maize, wheat, and potatoes in East Africa, focusing on yields, water usage, and CO_2 emissions on a per 5-acre farm basis. **(Note: 5 acres ≈ 2.02 hectares.)** Where possible, distinction is made between rainfed (dependent on rainfall) and irrigated systems, as these can differ greatly in both yield and resource use. Source data often come in per-hectare or per-ton units; we convert them to per-5-acre values for easy comparison.

Rice (Oryza sativa)

Yields: In East Africa, rice is grown in both rainfed and irrigated systems. Rainfed rice (often upland or rainfed lowland) has relatively low yields. For example, surveys in Tanzania's rainfed lowlands found average yields **~1.2 t/ha (≈2,700 kg/5 acres)** (J. Mkanthama, 2018). By contrast, irrigated paddy rice yields are much higher: many schemes achieve 4–6 t/ha (some farmers in Kenya even reach >7 t/ha under best practices (Samejima et al., 2020). A target of 3.5 t/ha was set in Tanzania's National Rice Strategy, equivalent to about 7,100–7,800 kg on 5 acres under irrigation (J. Mkanthama, 2018).

Water Usage: Rice is water intensive. Rainfed rice relies on "green" water (rainfall). Number of papers are limited but as a sample one specific paper by P. A. Mboyerwa et al., 2022 tried to access both CO2 emission and production of Rice in Tanzania using different treatment methods. Initially the research focused on the analysis per hectare, but in these documentit is tried to convert using 5-acre scale. The water usage varies significantly depending on the irrigation method. Using the System of Rice Intensification (SRI), which relies on alternate wetting and drying, estimated seasonal water use ranges from approximately **16,184 to 24,276 tons/5 acre**. In contrast, the conventional continuous flooding method demands substantially more water, around **30,345 to 50,575 tons per season/5 acre**. This indicates that SRI can reduce water consumption by 40% to 60%, potentially saving **14,000 to 26,000 tons** of water per season on a 5-acre farm.

CO_2 Emissions: GHG emissions (non-CO2) are greater in rice production systems than in other cereal cropping systems. The global warming potential of GHG emissions from rice systems is approximately four times greater than that of wheat or maize. These GHG emissions are mainly caused by methane emissions from rice cultivation. Global annual methane emissions from rice fields were estimated to be between 25 and 100 Tg, contributing 48% of total GHG emissions in global croplands (Wang, et.al, 2023). Rice production in Uganda's wetlands is not only problematic for wetland protection, it also contributes heavily to greenhouse gas emissions. Growing rice produces methane, a greenhouse gas more than 30 times as potent as carbon dioxide.[15] A Tanzania-based field study (Morogoro region) evaluated paddy rice under two systems: conventional practice (CP) and System of Rice Intensification (SRI), with varying nitrogen levels. Seasonal methane emissions ranged from 88.7 to 220.6 kg CH_4/ha, and SRI reduced methane and CO_2 by about 60% and 20%, respectively. The greenhouse gas intensity was approximately 0.42 kg CO_2 eq per kg of paddy, equating to roughly 420 kg CO_2 eq/Mg of grain—well below global extremes but contextually informative for East Africa.[16] Therefore,5-acre rice farm using SRI in Tanzania would emit approximately 6,787 kg CO_2 eq (or 6.79 tonnes CO_2 eq) per season (assuming one harvest).

Maize (Zea mays)

Yields: Maize is largely rainfed in East Africa. Yields are low relative to global averages due to limited inputs and rainfall variability. In Kenya, for instance, maize yields average ~1.5 t/ha (1500 kg/ha).[17] Other East African countries report similar rainfed yields (~1–2 t/ha), though Ethiopia has seen improvements up to ~3 t/ha in recent years. Under irrigation or improved management, maize yields can increase significantly. (Experimental stations and high-input farms can achieve >5 t/ha in East Africa **(Hengsdijk, et al,2014),** which would be ~>10,000 kg per 5 acres, but this is not the norm for smallholders.) Overall, ~3,000–4,000 kg per 5 acres is a typical rainfed maize output on small farms **(Aylward, C., et al,2015).**

Water Usage: Maize is less water-demanding than rice, but as a rainfed staple it depends on seasonal rainfall. In Kenya, the water footprint to produce 1 ton of maize is about 2,746 m^3 (mostly rainwater) Value of Water Research Report Series **(Mekonnen, et al.,2008)**. Given low yields, the water use per hectare is around 2,700–3,000 m^3/ha. On a 5-acre plot (~2 ha yielding ~3 t), this equates to roughly 8,000–9,000 m^3 of water consumed (almost entirely green water). Notably, in higher-yield systems

15 https://eastafrica.rikolto.org/en/projects/strengthening-rice-sector-climate-adaptation-and-mitigation-uganda

16 Greenhouse gas emissions in irrigated paddy rice as influenced by crop management practices and nitrogen fertilization rates in eastern Tanzania. https://doi.org/10.3389/fsufs.2022.868479

17 Rice production in Africa: Current situation and issues. International Rice Commission Newsletter Vol. 48.

water productivity improves – global average maize water footprint is ~1,100–1,300 m^3/ton **(Mekonnen, et al.,2011)**. But in East Africa's low-yield contexts the water use per ton is higher (reflecting substantial water but low output). Irrigated maize (though not common) would use blue water; one study indicates ~1,101 m^3/ton under irrigation **(Mekonnen, et al.,2008)**. If an irrigated 5-acre plot produced ~10 t, total water use might be ~11,000 m^3 (with part of that from irrigation).

CO_2 Emissions: Maize cultivation emissions come mainly from soil nitrous oxide (N_2O) due to fertilizer or manure use. In smallholder systems with minimal fertilizer, GHG emissions are relatively low per hectare. For example, applying ~50 kg N/ha might lead to ~0.3–0.5 t CO_2e/ha from N_2O (Tier-1 IPCC factors). One Kenya study found extremely low N_2O emission intensities (on the order of 0.1–0.15 g CO_2 per kg maize) under smallholder conditions essentially negligible in total (Lemarpe, et al.,2023). More generally, estimates for maize range around 0.3–0.6 kg CO_2e per kg grain in moderate input systems (Lemarpe, et al.,2023). Using ~0.5 kg/kg as a rough value, a 5-acre yield (~3,000 kg) would emit ~**1.5 t CO_2e**. High-input commercial maize can be higher – up to ~0.97 kg CO_2e per kg (nearly 1:1, due to heavy fertilizer and field emissions). But East African rainfed maize, with low inputs, likely falls in the **1–3 t CO_2e per 5 acres** range in total. (For context, Kenya's entire crop sector emits far less GHG than its livestock; maize's share is modest **(Martius et al., 2023)**. According to **Tongwane and Moeletsi (2018),** Maize yield in East Africa varies widely, often **1.5–4.5 t/ha**, meaning that GHG intensity can range from **~0.3–0.7 kg CO_2e per kg of maize**. While still below global high-input levels, these emissions are non-negligible. East African croplands – especially under rainfed systems – exhibit **moderate emission intensities**, largely driven by nitrogen use inefficiencies.

Wheat (Triticum aestivum)

Yields: Wheat in East Africa is grown primarily under rainfed conditions in highlands (e.g. Kenya's Rift Valley, Ethiopian highlands) and also under some irrigation in Sudan. Rainfed wheat yields are on the order of **1–2 t/ha** for smallholders, though large mechanized farms may achieve 3 t/ha. For instance, Eastern Africa's wheat yields average around 1.5–2.5 t/ha in many years 1500–2500 kg/ha **(Adhikari et al., 2015, Aylward et al.,2015).** This corresponds to roughly **3,000–5,000 kg per 5 acres**. (By comparison, global average wheat yield is ~3.4 t/ha, highlighting the yield gap[18].

18 Rice production in Africa: Current situation and issues. International Rice Commission Newsletter Vol. 48.

Water Usage: Wheat's water footprint in East Africa is significant but lower than rice's. Kenya-specific data show about 1,562 m^3 of water per ton of wheat produced. Most of this is rainwater in rainfed systems. So a 5-acre plot yielding ~4 t might consume on the order of 6,000+ m^3 of water (rainfall). Globally, wheat averages ~1,800 m^3/ton[19]. Under rainfed conditions, wheat's water comes entirely from green water; under irrigation (e.g. Sudan), blue water is applied. Interestingly, one study found wheat's water footprint per ton increases slightly with irrigation (due to more blue water use) – e.g. ~1,805 m^3/ton rainfed vs ~1,868 m^3/ton irrigated in global data. Thus, an irrigated 5-acre wheat farm yielding ~6 t might use ~11,000 m^3 (a mix of rain+irrigation) **(Mekonnen et al., 2008)**. In summary**, ≈6,000–10,000 m^3/5 acres** is a ballpark for wheat, with rainfed towards the lower end and irrigated the higher end.

CO_2 Emissions: Wheat production contributes to greenhouse gas (GHG) emissions primarily through soil management, fertilizer use, fuel combustion, and in some cases, irrigation. These emissions are typically expressed as CO_2-equivalents (CO_2e), which also account for non-CO_2 gases like nitrous oxide (N_2O) from fertilizers and carbon dioxide from fossil fuel use. According to, Poore & Nemecek (2018), Global CO_2e emissions of wheat is (~1.57 kg CO_2e/kg).[20]

Potatoes (Solanum tuberosum)

Yields: Potatoes are a high-yield crop, but East African farmers often obtain far below potential. In Kenya, **average potato yield is about 7 t/ha [21]** (7000 kg/ha) – roughly **14,000 kg per 5 acres**. Many smallholders only achieve 3–5 t/ha due to use of non-certified seed and low inputs[22] . According to both reports (The **potential** is much higher: with best practices, yields of 30–40 t/ha are possible. Nonetheless, potatoes out-yield cereals; even at 7 t/ha, a 5-acre farm produces ~15 tonnes of potatoes. Some international organizations use ~14 t per 5 acres as a representative smallholder yield[23].Confirming the above estimated potential increase in yield with best practices, on **Viazi field in Mbeya, Tanznia**, 40 tons of potatoes were produced in one hectare of land **(see section 6)**.

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19 Crop productivity and competitiveness. Products with Competitive Potential in African Agriculture.

20 https://ourworldindata.org/grapher/ghg-per-kg-poore

21 Promoting nutrition-sensitive potato value chains in Kenya. International Potato Center.

22 The National Potato Strategy. Signed-Strategy-2021–2025.pdf

23 Promoting nutrition-sensitive potato value chains in Kenya. Promoting nutrition-sensitive potato value chains in Kenya. International Potato Center.

Water Usage: Surprisingly, potatoes use far less water per unit weight than grains. This is because potatoes have a short growing season and high-water productivity. In Kenya, the water footprint is about **373 m^3 per ton of potatoes (Mekonnen, et al.,2008)**– an order of magnitude lower than that for cereals. Thus, producing **~14,000 kg (14 tons) on 5 acres** might consume on the order of **5,000–5,500 m^3 of water** (mostly rainfall). This aligns with global data: e.g. potato's water footprint ~287–373 m^3/ton in various assessments **(Mekonnen, et al.,2008; Mekonnen**, **M. M. and Hoekstra, A. Y (2011)**) much lower than rice or wheat. Most potato farming in East Africa is rainfed in highland areas with adequate rainfall; supplementary irrigation is rare. (Potatoes require ~400–800 mm of water over the season for optimal growth which for 2 ha equals ~8,000–16,000 m^3 if fully met by rain – often the rainfall provides a portion of this.) In practice, rainfall in the growing season suffices for many potato farms, so **~5×10³ m^3 per 5 acres** is a reasonable estimate for water use given actual yields.

CO_2 Emissions: Potato cultivation involves intensive soil tillage and often higher fertilizer per hectare than maize, so the GHG footprint can be notable but is expressed per kg of product, it remains fairly low. Current estimates for East Africa put potato GHG emissions at 0.16–0.25 kg CO_2e per kg potato. This means for every 1 kg of potatoes produced, about 160–250 grams of CO_2e are emitted (through production of inputs, field N_2O, etc.). Using ~0.2 kg/kg as a mid-value, a 5-acre yield (~14,000 kg) would generate ~2.8 tonnes CO_2e in total. This is in line with a Kenyan analysis: the national potato sector emits an estimated 320,000 tonnes CO_2e for ~2 million tons produced– roughly 0.16 kg/kg. East Africa's lower-input potato systems fall on the lower end of emissions intensity[24].

To put crop footprints in perspective, Table 1 summarizes comparative yields, water use, and GHG for major East African staples (rainfed vs. irrigated) on a per-5-acre basis. Key points: irrigated rice can yield ~7,000–8,000 kg (5 acres) but consumes ~11,000–12,000 m^3 (green+blue water) and emits roughly 8–12 t CO_2e (chiefly CH_4 from flooding). Rainfed maize yields ~3,000 kg/5ac, using ~8,000–9,000 m^3 (rain), with about 1–3 t CO_2e (mostly N_2O from fertilizer). Potatoes (rainfed) typically yield only ~15,000 kg/5ac, using ~5,000 m^3 water, and emitting ~2.8 t CO_2e (mainly from N fertilizers). If irrigated, potato can reach ~40,000 kg/5ac and ~15,000 m^3, but emissions can rise (5–8 t) unless inputs are carefully managed. These figures illustrate that intensification (e.g. irrigation) can greatly boost yields and water use, but also raise emissions unless paired with mitigation (see Sections 4–6).

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24 Policy Brief: For a Climate Smart Potato Sector in Kenya. https://npck.org/wp content/uploads/2021/12/Signed-Strategy-2021-2025.pdf

Table 1: Crop yields, water use, and GHG for selected staples on 5 acres [30]

Crop	Scenario	Yield kg per 5 acres	Water Use m^3 per 5 acres	GHG Emissions (tCO_2e per 5 acres)	GHG Emissions (tCO2e/ton)
Rice	Conventional (Continuous Flooding)	~10,100	30,345 - 50,575	~10.1	0.99
	SRI (Alternate Wetting & Drying)	~16,200	16,184 – 24,276	~6.8	0.4
Maize	Rainfed	~3,000	~8,000–9,000	~1–3 (mainly N_2O from fertilizer)	0.5
	Irrigated (uncommon)	(>10,000 potential)	N/A	(~4–5 if high input)	0.45
Wheat	Rainfed	~4,000	~6,000+	2.1 – 5.0	0.925
	Irrigated	~6,000 (e.g. Sudan)	~10,000 (rain+ irrigation)	7.2	1.2
Potato	Rainfed (typical)	14,000	~5,000	~2.8 [2525] (N_2O + inputs)	0.2
	Irrigated (rare)	up to ~40,000 [26 27]	~15,000	~5 – 8 [4]	0.16
	Viazi Field	80,000	15,000	4	0.05

Source: Compiled from regional studies and Viazi database [28 29 30]

Note: A significant reduction in the carbon footprint (expressed as tCO2e/ton) has been achieved in Viazi field due to the substantial increase in potato yield resulting from the use of certified seed, solar-powered irrigation systems, appropriate fertilizer application, and intensive plant protection. This result aligns with the study referenced above in Section 4, Scenario 4 of Wageningen University.

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25 Policy Brief: For a Climate Smart Potato Sector in Kenya. https://npck.org/wp-content/uploads/2021/12/Signed-Strategy-2021–2025.pdf

26 The National Potato Strategy. Signed-Strategy-2021–2025.pdf

27 https://www.fao.org/land-water/databases-and-software/crop-information/potato/en

28 Carbon Flux Estimation for Potato Production: A Literature-Based Study. https://doi.org/10.3390/atmos16070764

29 Technical efficiency of rainfed and irrigated rice production in tanzania, technical efficiency of rainfed and irrigated rice production in Tanzania. Joseph Mkanthama; Godswill Makombe; John Kihoro; Elija M. Ateka; Matshidiso Kanjere. https://doi.org/10.1002/ird.2185

30 Analysis of rice yield response to various cropping seasons to develop optimal cropping calendars in Mwea, Kenya, Hiroaki Samejima et al., 2020. https://doi.org/10.1080/1343943X.2020.1727752

6. Carbon Offsets and Climate Financing

Carbon financing not only increase the likelihood of success of Reducing Emissions from Deforestation and Forest Degradation in Developing Countries programs and climate change mitigation but also promote food security for small-holder agriculture in the region **(Palm et al.,2010)**. Carbon offset schemes represent an emerging opportunity for financing climate-smart agriculture. However, literature shows limited integration of staple crop systems into formal carbon markets. Most offset programs focus on forestry or energy efficiency. Nonetheless, pilot programs in Kenya (The Kenya Agricultural Carbon Project (KACP)) has explored soil carbon crediting through improved land management practices.[31]

Opportunities in carbon markets: Emerging methodologies under standards like the Verified Carbon Standard (VCS) and the Gold Standard now allow generation of carbon credits from practices such as conservation agriculture, agroforestry, improved rice management, and reduced fertilizer N_2O emissions.[32] Small-holder farmers in Kenya are set to reap the rewards of the first soil carbon project in Africa. In the west of the country a group of farmers are changing practices and earning carbon credits. In the process, the groundbreaking Kenya Agricultural Carbon Project is set to improve food security, help address climate change, and improve the lives and livelihoods of rural dwellers who live in poverty.[33]

A blended value approach is often promoted: design projects where carbon finance is one revenue stream layered on top of productivity gains, climate adaptation benefits, and possibly premium prices for sustainably produced crops. Blended finance impacts the changing contour of climate finance and has emerged as an experimental structure in the de-risking agriculture sector. However, the lack of enabling environment and mainstream investor perceived risk of market distortion has affected blended finance governance, implementation, and monitoring **(Dey, K., & Mishra, P. K. (2022)).**

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31 https://www.worldbank.org/en/news/press-release/2014/01/21/kenyans-earn-first-ever-carbon-credits-from-sustainable-farming?

32 New Methodology Enables Farmers to Earn Income from Carbon Credits Resulting from Improved Agricultural Practiceshttps://verra.org/new-methodology-enables-farmers-to-earn-income-from-carbon-credits-resulting-from-improved-agricultural-practices

33 First African Emission Reductions Purchase Agreement For Soil Carbon Signed In The Hague

Case example – the VIAZI Project: Innovative financing models outside traditional carbon markets are also emerging to support CSA for staple crops. One example is the VIAZI Project in East Africa ("viazi" meaning potato in Swahili). Rather than selling carbon credits, Viazi leverages philanthropic and impact investment funds to help smallholder potato farmers transition to more productive and sustainable practices. Donors sponsor packages for communities – such as climate-smart inputs (certified seed potatoes, customized fertilizer blends, biofertilizers) and equipment (solar-powered irrigation pumps, drip kits, weather stations, etc.) – which are provided to farmer groups along with training in CSA techniques. This infusion of resources allows farmers to achieve big jumps in yield up to 80 ton per 5 acre which significantly increases the average 14 ton per 5 acres of smallholder yield and income. The environmental payback is significant: potatoes, as noted, can produce much more food with a smaller climate and water footprint than other staples.[34] While this claim is context-specific, it aligns with broader findings that potatoes use water far more efficiently than cereals (up to 7 times more food per unit water than rice or wheat) and emit less GHG per calorie produced. The project thus frames donations as both food security and climate action contributions. Farmers repay by improving their livelihoods and sharing a portion of increased profits or harvests to sustain the community initiative (a kind of revolving fund model). Though not a traditional carbon offset scheme, Viazi illustrates how climate financing – whether through markets, donors, or public funds – can be channeled into staple crop agriculture with tangible mitigation outcomes. It effectively subsidizes the upfront costs of CSA adoption (certified seed, fertilizer, irrigation) that farmers themselves could not afford, similar to how carbon credit revenue would function, but in a more direct-support manner. This points to a larger notion: blending carbon finance with development finance can create win-win outcomes, wherein the cost of GHG mitigation in agriculture is bundled with achieving food security and poverty reduction goals.[35]

34 Potato Facts and Figures – International Potato Center. https://cipotato.org/potato/potato-facts-and-figures/

35 Project Website. https://viazi.io/ (Accessed 2025). (Details on sustainable potato farming support initiative; claims on potato productivity and footprint vs other staples).

7. Conclusion

Aligning CSA efforts with regional food security programs and the Sustainable Development Goals (SDGs) will attract broader support. Indeed, CSA implementation contributes directly to **SDG2 (Zero Hunger)** by increasing food production and resilience, **SDG13 (Climate Action)** by cutting emissions and enhancing adaptation, as well as **SDG1 (No Poverty)** through raising farmer incomes and **SDG15 (Life on Land)** via promoting sustainable land management.

In conclusion, transitioning East Africa's staple crop farming to a more climate-smart trajectory is not only an environmental imperative but also a socio-economic opportunity. By adopting climate-smart practices, the region's farmers can produce more food on existing land, buffer themselves against climate shocks, and even generate new income streams (through better market access or carbon credits). This transition will require upfront investment, savvy policies, and capacity building, but the benefits are multi-fold and long-term. A climate-resilient agriculture sector underpins stable food supplies and livelihoods, which in turn fosters political and economic stability. As such, CSA should be viewed as a core development strategy for East Africa. The evidence reviewed – from successful pilot projects to quantitative benefits like emissions reductions per unit yield – shows that **climate-smart agriculture is not an abstract concept but a practical, "implementation-ready" approach**. The priority now is to move from isolated success stories to full-scale implementation, ensuring that millions of smallholder farmers are equipped and empowered to be agents of climate-smart change. With enlightened policies and sustained support, East Africa can make its staple crop systems a model of sustainable, low-carbon, and food-secure agriculture in the years ahead.

7.1. CSA in Potato Farming Offers Triple Wins

CSA interventions in potato farming – such as the use of certified seeds, mechanization, improved fertilizer regimes, and better crop protection – have the potential to **simultaneously achieve three critical outcomes**:

- **Increased productivity** (e.g., yield increases from 8.3 t/ha to 21.6 t/ha)
- **Reduced food losses** (e.g., post-harvest loss reduction from 257 kg/ton to 75 kg/ton)
- **Lower greenhouse gas emissions per unit of output** (from 263 kg CO_2-eq/ton to 128 kg CO_2-eq/ton)

This demonstrates that CSA is not only agronomically sound but also economically and environmentally viable for smallholders.

7.2. GHG Emissions Can Be Significantly Reduced

Potato farming under traditional practices emits relatively high GHGs due to inefficient input use, low yields, and high loss rates. The document shows that:

- Emissions **per ton of marketable produce** decline significantly as farm efficiency improves.
- CSA practices enhance **input-use efficiency**, meaning less fertilizer and land are needed per unit of food produced.
- Mechanization and improved agronomy reduce loss-induced emissions, which are often unaccounted for in conventional carbon accounting.

This highlights the **carbon mitigation potential** of CSA-based intensification strategies in root and tuber value chains.

7.3. Trade-Offs Are Manageable and Justifiable

While intensifying potato production may slightly increase **absolute emissions** (due to more inputs and machinery), the **emissions intensity per ton of food decreases sharply**, making it a net environmental gain.

From a sustainability perspective, **relative GHG efficiency** – not just absolute emissions – is key when assessing smallholder transitions under CSA frameworks.

7.4. Backward Calculation Enhances CSA Planning

The use of a **backward calculation method**, as highlighted in the case study by Soethoudt & Castelein (2021), provides a powerful tool to quantify:

- Input requirements
- Land use
- Economic profitability
- GHG impact

This enables **holistic planning and policy design**, aligning food security objectives with climate goals.

7.5. VIAZI Project's CSA Model Is Scalable and Validated

The scenario modeled as the most efficient (Scenario 4: certified seed + full mechanization) aligns directly with the VIAZI Project's strategy. It shows that:

- Potato smallholders can **transition to climate-smart systems** with the right combination of high quality inputs, finance, and training.
- GHG emissions per unit of food can be **halved** while improving livelihoods and food system resilience.
- There is a strong case for **scaling such models nationally and regionally** to meet both SDG 2 (Zero Hunger) and SDG 13 (Climate Action).

The case of CSA in potato farming demonstrates that it is **entirely feasible to decouple agricultural productivity from environmental degradation**. Through data-backed, farmer-focused interventions, projects like VIAZI can lead the way in transforming food systems that are both **climate-resilient and low-emission** – while significantly improving farmer income and national food.

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