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Research Article

Improving Carbon Sequestration, Climate Resilience and Increasing the Productivity of Farms using Nature Based Solutions: The Case of Salvation Farming Solutions

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Abstract

Global population growth is putting pressure on nature. Resources that are vital for human activities such as healthy soil for food production and clean water are becoming scarce. The world's agricultural land has become severely degraded rendering it unproductive and forcing farmers to abandon it. In Agriculture, Nature based solutions are considered long term beneficial environmentally, cost efficient and effective approaches in addressing sustainable land resource management, water quality and adaptation to climate change and is key in improving food security by increasing land ecosystem sustainability and productivity. This report is a comparison of 10+ years of maize research carried out in three different farming systems globally including India, America and Africa. Two studies were done in India in 2017 and 2018, three studies in the United States in 2014, 2020 and 2022 while in Africa two studies were done in Kenya and Zambia in 2023. Salvation Farming Solutions (SFS) has developed a line of nature based, non-GMO cropping solutions (patents pending) focused on smallholder farmers designed to disrupt the global agricultural industry by improving water availability/quality, detoxifying and increasing soil fertility, significantly improving crop production and improving the nutritional density of the food produced. The goal of the program is to provide Smallholder farmers with regenerative solutions that are nature-based technologies which improve carbon sequestration, climate resilience and increase the productivity of farms. Key findings from these researches demonstrate that maize crop productivity can be significantly enhanced in soils that have not been intensively farmed most likely due to the biome vitality of the soil enhanced through nature-based solutions to improve moisture, nutrient availability, and stimulate carbon sequestration and nitrogen fixation. Soils that have been intensively farmed such as in the United States seem to be less productive on an acre-to-acre comparative basis most likely due to non-regenerative approaches which are common for large scale farming. Nature-based agricultural solutions can provide small holder farmers significant financial benefits and provide consumers with more nutritious foods.

Keywords: Carbon sequestration; Climate resilience; Nature based solutions; Land ecosystem sustainability; Smallholder farmers; Crop productivity; Soil fertility; Nutritional density; Global Population growth; Food production; Regenerative solutions; Biome vitality; Nitrogen fixation; non-regenerative approaches; Water availability; Water quality

Introduction

Global population growth is putting pressure on nature. Resources that are vital for human activities such as healthy soil for food production and clean water are becoming scarce [1]. According to FAO report from almost 10 years ago, [2], already 52% of the world's agricultural land was severely degraded rendering it unproductive and forcing farmers to abandon it. According to World Bank [3] demand for food globally is expected to increase by 50% by the year 2050 and about 50% of the population in Sub Saharan

Africa (SSA) is vulnerable to extreme events, particularly climate change, which is mainly manifested through drought and flood [4]. A study carried out in 2016 by the World Bank indicated that the agriculture sector contributed a source of living to 65% of the poor working adults. This illustrated the key role that agriculture holds for the livelihoods of people and the need for its development being important tool in reducing poverty [5]. Land degradation coupled with increased demand on the food system and increasing risk of climate change has triggered public interest to move from conventional, high-input-driven farming to nature-based solutions in Agriculture [6-8].

Nature Based Solutions in Agriculture

In Agriculture, Nature based solutions (Nbs) are considered more long term beneficial environmentally, cost efficient and effective approaches in addressing sustainable land resource management and climate change [8,9]. Such practices improve water availability; restore ecosystems and soil health that is significant in improving food security by increasing land ecosystem production and productivity [10]. The benefits associated with the use of nature-based solutions include climate change adaptation and disaster risk reduction, climate change mitigation potential, provision of non–carbon ecosystem services, resource use efficiency without the use of mineral fertilizer and other external inputs, food security and income generation, and social benefits [11]. Nature based solutions can help farming communities establish a resilient food production to future weather extremes by improving soil health and water retention, enhanced food and nutrition security. They can reduce the use of chemical additives, which reduces production costs and creates safe foods [11]. Nature based solutions can play a critical role in mitigating climate change by reducing carbon emission from food sector by enhancing carbon sequestration and ways that enhance the carbon retained in plants and soils [12]. Studies by FAO show that Nature Based solutions can provide 37% of climate change mitigation until 2030 and 20% between now and 2050 [2]. Nature based solutions can further enhance ecosystem and species by improving habitat diversity while enhancing quality and reliability of water [8].

Nature Based Solutions in Food systems transformation

According to the Food and Land Use Coalition's Growing Better report [13], 3 out of 10 scientific evidences and economic cases critical for food systems transformations are nature-based solution- that, by 2030, could help bring climate change under control, ensure healthy diets for all, improve food security and create a more inclusive rural economies thus vital in establishing a sustainable future for food [1]. For a sustainable future food system, agricultural production should transition production approaches that restore nature and regenerative.

Nature based solutions in agriculture can combine climate change mitigation, biodiversity conservation, adaptation, sustainable resource management and disaster risk reduction in the fight against climate change through the preservation of biodiversity and carbon sink [12]. Nature based solutions are initiatives focused on ecosystem health whose actions aim to restore, protect and sustainably manage modified or natural ecosystems while addressing social challenges and promoting benefits for human and biodiversity [14]. They are designed to improve ecosystem services provided by nature. In agriculture, it can restore degraded land, increase crop productivity, resilience and improve carbon sequestration [8].

Nature based solutions for healthy ecosystem

According to Seddon et al [15], Nature based solution lead to a healthy ecosystem that is more resilient. It further increases soil health, nutrient availability, water retention, soil biodiversity and reduce soil degradation thus increase crop productivity with lesser chemical additives used creating a safer and more nutritious food [16]. According to Pearson [17], an increase in diversity above ground improves below ground biodiversity which immensely contributes to nitrogen fixation, nutrient cycling with ability to regulate the dynamics of greenhouse gas emission effects and soil carbon sequestration, effects on soil physical structure and water regimes with significantly positive effect on plant health [6,18,19]. Sonnenschein et al [16] reported that agricultural sector is primarily responsible for excess nitrogen in the form of ammonia, nitrite and nitrate, phosphorus, pesticides, and pathogen pollution of water bodies in agricultural zones. Nitrogen and phosphorous are causal to eutrophication in water bodies and affecting aquatic life [20]. Nature-based Solutions (NBSs) can be a valuable option for intercepting and treating various streams of nutrient pollution from agriculture [21].

Nature-based Solution for Nutrition and Human Health

According to the UN Food and Agriculture Organization (FAO) and The Nature Conservancy (TNC) ; (2023), nature –based solutions have the potential in agricultural production systems to address the nutritional need for people globally while restoring nature and the climate thus contribute to the 2030 Sustainable development agenda. The transition among the global producers to a nature-positive, regenerative food system requires the finance, policy and science [9].

Nature-based Solution for Food and Nutrition Security

According to UN-OCHA [22] report, Household production was worsened by the COVID-19 which also affected access to safe and nutritious food, hence threatening food systems already impacted by pre-existing or seasonal threats and vulnerabilities such as natural hazards, pests, armed conflicts and violence [23,24]. Extreme weather conditions have been triggered by climate change which has resulted in extended drought periods mostly followed by heavy rains and storms that end up ravaging crop production leaving smallholder farmers with no food for the household or to be able to sell for the household income. It has been shown that climate change has reduced the food supplies when crop yields is usually transformed into consumable calories on people's plates [25].

Background of the Reported Studies

In this report, we are going to compare different studies carried out in three different farming systems globally including India,

North America and Africa. Two studies were done in India in 2017 and 2018, three studies in the United States in 2014, 2020 and 2022 covering both residential community farms trials in Missouri, large scale Commercial farm trials in South Dakota and Illinois while some studies were done in a golf course and highly saline wheat fields in California while in Africa two studies were done in Kenya and Zambia in 2023. The results are from the studies that have been carried out across the globe with Salvation Farming Solutions products. Salvation Farming Solutions (SFS) has developed a line of nature based, non-GMO cropping solutions (patents pending) focused on smallholder farmers designed to disrupt the global agricultural industry by improving water availability/quality, detoxifying and increasing soil fertility, significantly improving crop production and improving the nutritional density of the food produced! This model relates to incorporating new ways to use natural means to remediate toxic soils using safe natural organic products that use geologic chemical binding processes that increase soil organic carbon content, soil health, improves drought resistance, removes and binds the toxic chemicals which prevent adsorption by the plants or into the crop while also rendering the toxic chemicals inert. It also improves the condition of the soil to a degree that draws and attracts worms; the earth's natural aeration and fertilizer system. The primary mission is to eradicate food security challenges while empowering smallholder farmers with cropping system that delivers greater production and generational regenerative enhancement of the soil. SFS ultimately provides Smallholder farmers with regenerative solutions that are nature-based technologies which improve carbon sequestration, climate resilience and increase the productivity of farms. The solutions are highly sustainable, multi-generationally impactful; changing cropping practices – A Historic Agricultural and Economic Legacy for the World.

India Studies

There were two studies carried out in India in 2017 and 2018.

Independent Evaluation by eKutir Rural Management Services for Corn Production in 2017, in Odisha India

An agricultural field trial was conducted by eKutir in 2017 in Odisha India with World Aquarium's Conservation Foundation, to test the efficacy of sustainable agriculture products offered to increase crop production, increase nutritional density and produce stronger, more resilient plants. A sweet corn crop was planted with Control, Seed Treatment only, and Seed Treatment and Fertilizer Treatment combined; in addition, a soil detox was used on the Treated crops and not the Control. Seeds used for the field trial were Advanta PAC 712 Hybrid Corn.

Over the course of the trial the following results we noted:

1. The planting was done in below average soil without erosion control, mulch, compost or crop rotation; therefore the expectation was low crop production and low nutritional density results;

2. The control plants showed strong infestation of corn pests, the corn borer pests, and the Treated crops showed no infestation.

3. No irrigation was in place therefore plants were subject to the stress of heavy rains and periods of non-optimal dryness;

4. This location suffers from top soil runoff and a lack of crop rotation in addition to the challenges of climate change such as warmer weather and longer dry periods of time;

5. The Treated seeds produced plants that grew significantly higher (~1.5X higher) and much faster compared to Control seed group with no Treatment;

6. Crop production was dramatically increased from the Seed Treatment + Fertilizer Treatment combined: an increase in crop production of 3-4 cobs per stalk compared to control production of 1-2 cobs per stalk.

7. Nutritional analyses done in December, 2017 by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) which is an international organization which conducts agricultural research for rural development and is chartered by UN and FAO showed g/100g percentage change of 400%, 374% and 257% for protein, carbs and fat respectively.

Previous Seed Pretreatment independent research has proved to offset lack of nutrition due to increased growth from CO2 abundance to improve nutritional density of crops including: significant increase in Protein (Figure 2), Carbohydrates (Figure 3), Fat (Figure 4), and along with significant overall production increases (Figure 1). Additionally, seed pretreatment has shown effectiveness in preventing pest infestations.

There was 66% increase in yield with use of Seed Treatments with no fertilizer while use of seed treatment with reduced fertilizer resulted in 125% increase in yield as compared to control as shown in figure 1.

Seed treatment led to over 400% increase in protein content in the corn as shown in Figure 2.

The application of seed treatment led to 374% increase in carbohydrates level in maize as compared to control as shown in Figure 3.

Seed treatment was demonstrated to increase the fat concentration in Maize by 257% as compared to control as shown in Figure 4.

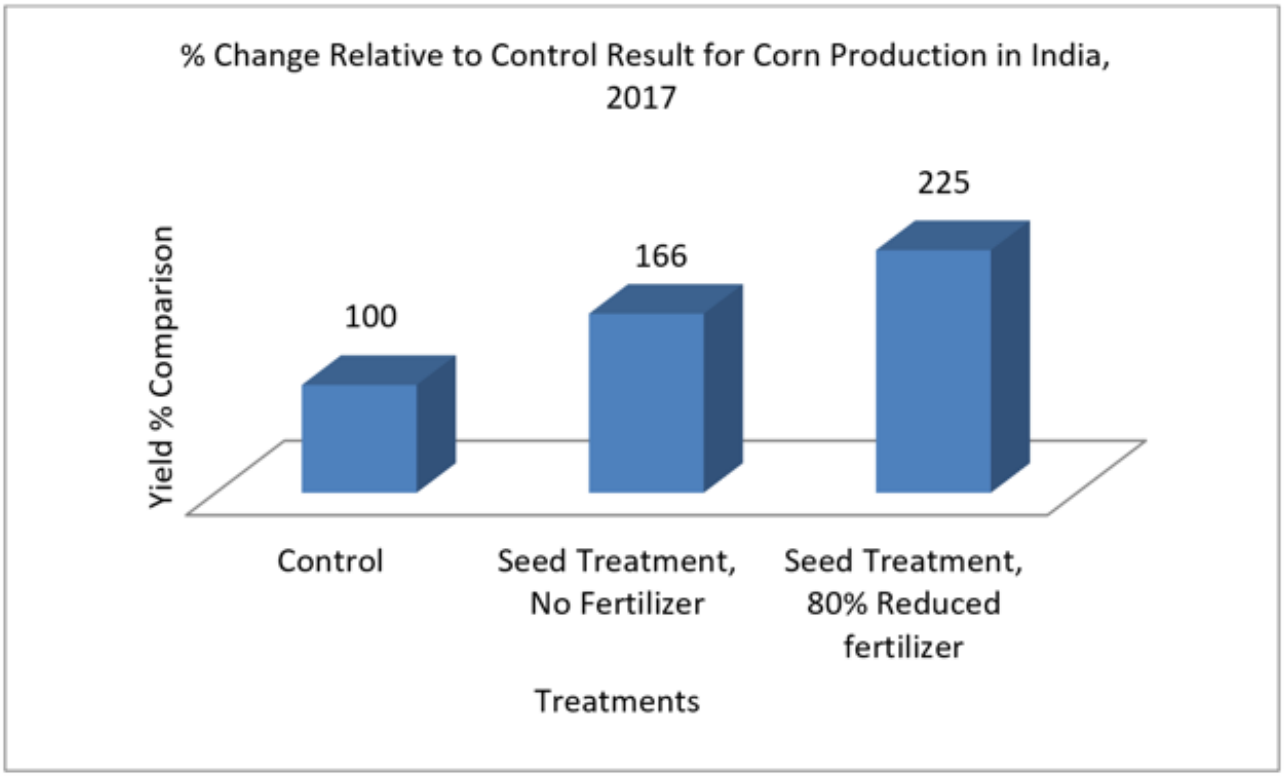

Figure 1: % Change Relative to Control Result for Corn production in 2017 by an Independent Evaluation e-Kutir Rural Management Services.

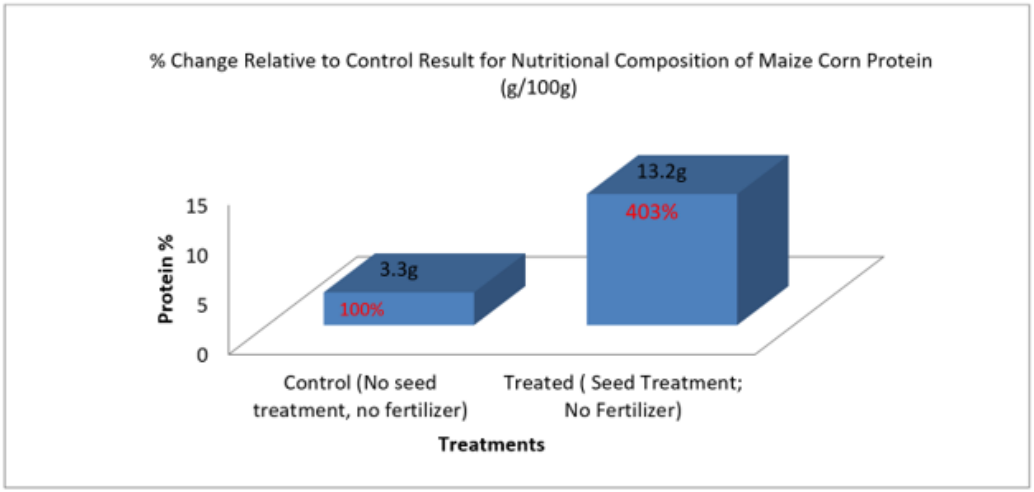

Figure 2: % Change Relative to Control Result for Nutritional Composition of Maize Corn by International Crop Research Institute for the Semi-Arid Tropics (ICRASAT) 2017, INDIA.

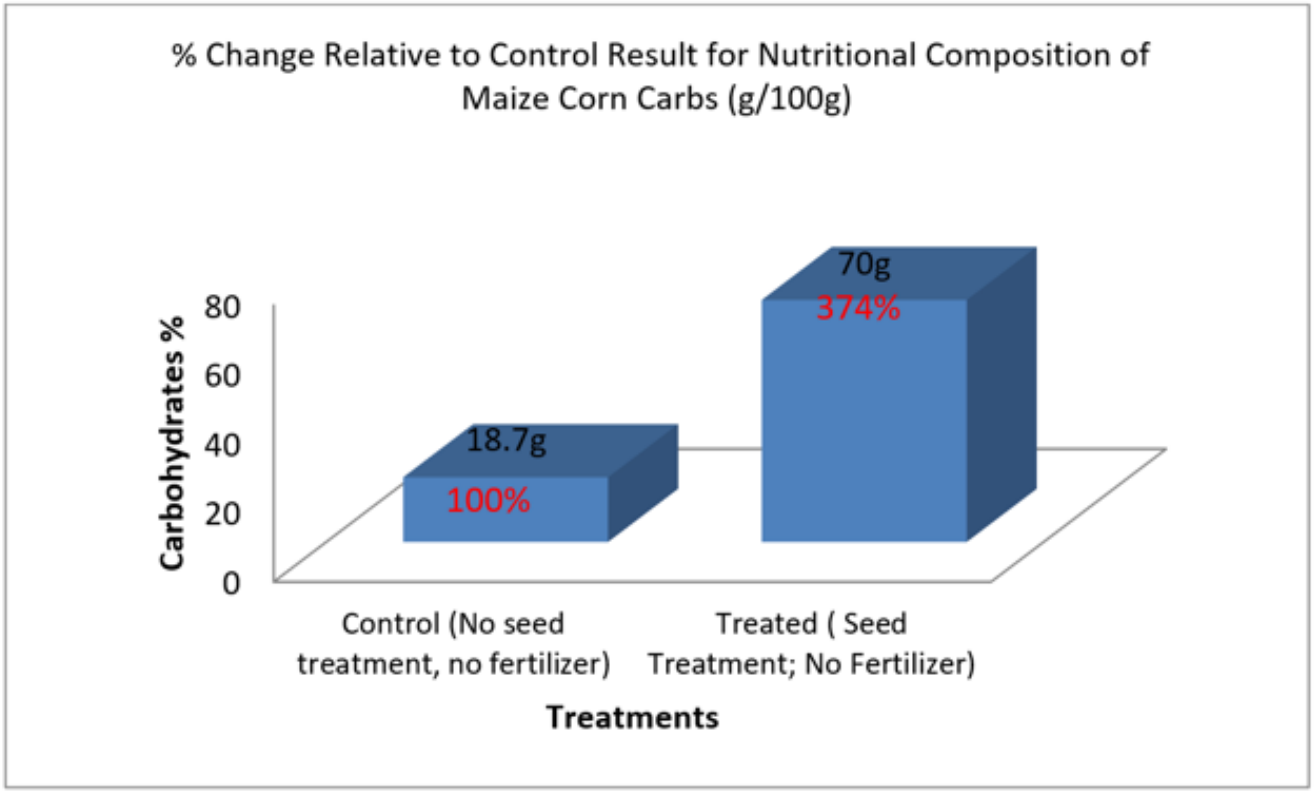

Figure 3: % Change Relative to Control Result for Nutritional Composition of Maize Corn by International Crop Research Institute for the Semi-Arid Tropics (ICRASAT) 2017, INDIA.

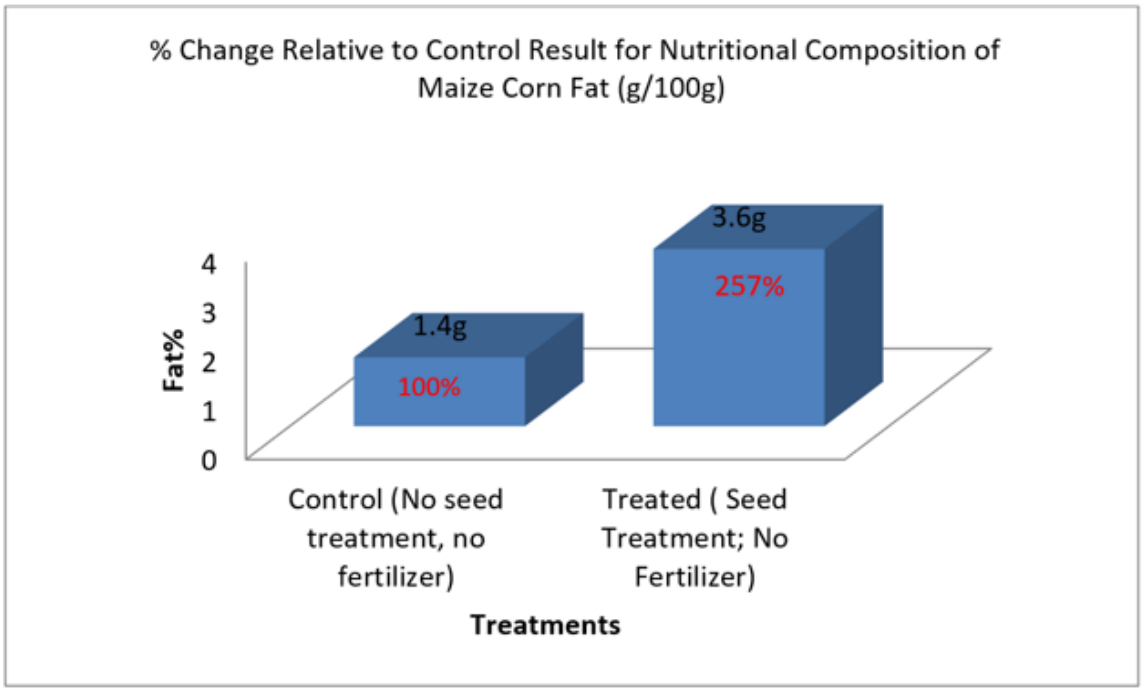

Figure 4: % Change Relative to Control Result for Nutritional Composition of Maize Corn by International Crop Research Institute for the Semi-Arid Tropics (ICRASAT) 2017, INDIA.

Sustainable Agriculture Trials – Maize Project, India 2018

A maize Demonstration Farm was established at Narayankhed, in the Sangareddy District of Telangana State of India in conjunction with the Saral Jeevan India Foundation from July to October 2018 as part of the "Sustainable Agriculture Trials – Maize" project. Two paid host farmers were actively involved in all the operations that were carried out in the farm. The demonstration Farm was established to exhibit to farmers the best technologies locally available in maize production, provide a learning platform for farmers to apply these technologies on their farms, interact with farmers and select them for the Regional Economics Agricultural and Community Help (REACH) program. It is through this mission that goals to empower local farmers in groups becomes the base for a farm-to-table solution that will benefit each level of the value chain as it currently exists as the core of the sustainable business proposition for Salvation Farming Solutions. The demonstration farm was further used to test the Sustainable Corn Program nature-based seed, soil and fertilizer treatment solutions marketed by Salvation Farming Solutions in the local field location.

Materials: The treatments available included:

- Soil Detox treatment supplied as a liquid concentrate that is mixed with water and sprayed on the field to be treated.
- Seed Soak Treatment supplied as a powder mix to be added with a liquid catalyst to a bucket of water. The seeds are soaked in 5-gallon bucket overnight.
- Seed Powder Treatment is a dry mix put in bag with seeds with a liquid catalyst and shaken to cover the corn kernels with powder.
- Fertilizer Treatment is a powder mix that is mixed into fertilizer to improve fertilizer and can reduce fertilizer used by 80% or more.
- Natural Pesticide is a multipart liquid mix diluted with water that is applied as a spray only if pests appear on the crop.

Plot was planted in sandy red soil with no irrigation used for crop watering, expected monsoon rains were the only source of water for maize crop. The only heavy rain was 2 days before planting and 10 days after planting otherwise only a few short showers; crops faced extreme drought conditions.

The field trial procedure: The Farm, under the overall coordination of Saral Jeevan India Foundation staff. The establishment of the Demonstration Farm was part of a Trainer of Trainers for Farmer Field Schools. The selected farmers were allowed to use their regular seeds and their practices for planting but just before the sowing few extra activities were carried out during the pilot process:

1. After tilling Soil Detox solution was sprayed in the selected treatment area.
2. Seeds were treated with the recommended solutions:
   - Seeds in one part were soaked in the recommended solution for 24 hours before the sowing;
   - Seeds in the second part were applied with powder coating.
3. Application of fertilizer advised and made sure that at least 75% less was applied in the treatment area

No pesticides and herbicides were used

Land Preparation and Planting: Land clearing using manual labor was done and the weeds were collected and field lay out was.

The field was ploughed in the presence of the selected farmers for joint learning. Planting was done on July 15, 2018 at the period when groundwater and soil temperature were suitable. Planting was scheduled such that the heat and water sensitive growth stage of maize (i.e., the flowering stage) did not coincide with the period of drought.

Planting depth of maize varied from 5 to 10 cm, depending on the soil type and planting date. As a rule, planting should be shallower in heavier soils than in sandy soils. Planting was done by the participating local farmers as shown in Figure 5 who were selected for joint learning so that they would apply the technologies on their respective farms.

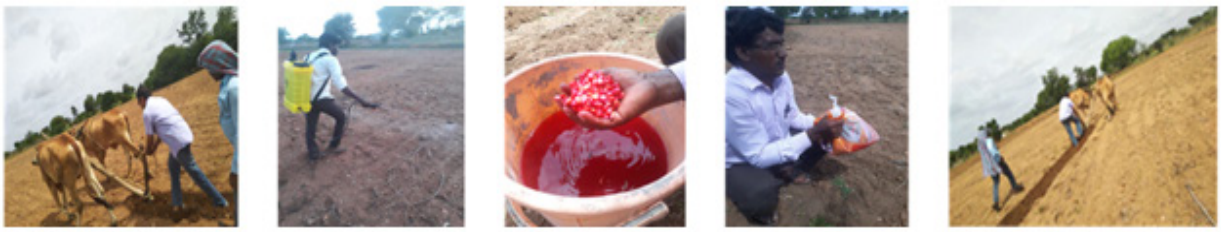

Figure 5: From L-R: Soil Preparation by ploughing, spraying soil treatment, soaking seed treatment, powder seed treatment and planting respectively.

Results from the field trial in India 2018: After 60 days the treated crops caught up on growth and significantly increased production. Control maize was ready for harvest at week 14 whereas treated plants were ready for harvest at week 10 (one month earlier).

- Compared by weights to control maize; Powder treated maize increased crop production by 290% whereas Seed Soak treated maize increased crop production by 200%.
- In terms of increase in maize plant biomass by volumes compared to control; Powder treated maize increased biomass crop production by 210% ($p<0.0001$) while Seed Soak treated maize increased biomass crop production by 142% ($p<0.001$). This biomass increase indicates higher carbon sequestration from carbon farming and potential applications for mulch, compost and green fodder or other uses.
- Compared to control; Powder treated maize roots were 214% ($p<0.0001$) larger than controls at mid-crop measurement; while Soak treated maize roots were 228% ($p<0.0001$) larger than controls at mid-crop measurement. These larger root measurements indicate the potential for higher plant resiliency to drought, plant strength and higher biomass growth, and the potential for increased nutrient uptake from the soil.
- The treated soil appeared darker, indicating greater soil microbial life and greater retention of water. Farmers also noticed treated maize leaves were noticeably brighter and larger than control group.
- When looking at cost savings from Field Trial products; there was 75% fertilizer use reduction and no herbicide or pesticide was used. This translates up to 5 times the actual costs of production. Conversely for the 75% fertilizer use and no herbicide or pesticide used translates to 80% saving in farm inputs. Control group was treated with 100% fertilizer.
- No pests or diseases were found on treated corn groups (Powder and Soak); beneficial red beetles also were found on treated corn and not on control corn. Control group was infested with pests and affected by maize mycotoxin.
- Harvested treated corn tasted softer and "tastier" in flavor compared to Control corn.
- Soaked and Powder treated maize plants were ready for harvest 25% time earlier (week 10-11 versus week 14) than Control, indicating the potential for additional second or third cropping production in relevant regions along with better opportunities for market pricing.
- Good agricultural practices were carried out on the farm with the participating farmers resulting in maximum crop growth and development

Discussion of India Study: These increases in nutritional density coupled with more than double growth rates using 100% natural and organic solutions can be quite competitive compared to present commercial farm conditions. Benefits of this system can reduce fertilizer use by up to 80%. Overall costs for this increased production may be up to 50% savings for the farmers with doubling crop production with potential to quadruple income. This economic value will be further driven by demand for this better tasting, healthier corn. The field that was used for the trial was later discovered to be a tract of unproductive land that locals were unwilling to grow maize on. However, through the efforts of the participating farmers and the Agriculture Extension Officer, a healthy crop with appreciable yield was obtained. The key lessons learned were that farming in dry lands was very challenging especially erratic rainfall during crucial crop growth stages such as sprouting and cob development. The lack of rainfall can result to total crop failure or losses to farmers. The Soaked seeds were able to withstand the drought well and sprouted well in time but Powder coated seeds withstood the drought very well and gave good yield.

Conclusion from India Study: Both the Powder and Soak Treatments increased productivity significantly (Powder 290%, Soak 200% respectively) compared to the Control Group under drought conditions and significantly increased stalk and root (silage production) size (Powder 210%, Soak 142% respectively). Secondarily, the improved flavor, pest and disease resistance provided by the treatments, even without pesticides will prove of value for future farmer and consumer adoptions of this innovative and novel treatment program. Given the significant farmer cost savings and improved production output with this program it is recommended that Market Demonstrations be pursued to make these solutions more available for smallholder farmers as climate resilient options for improved food security and economic development for the sector.

Overall, the farmers were very appreciative of the training given to them by the project. They, however, emphasized the need for the development of sustainable maize postharvest management system in Telangana with focus on efficient storage and marketing to enable maize farmers obtain good prices for their produce. As we make progress towards achieving the United Nations Sustainable Development Goals focus needs to be on game changing processes rather than business as usual with government support needed to be front and center for these new ways forward.

It is clear that we are what we eat and that our health is directly related to our nutrition [16]. We believe that consumption of the Salvation Farming Solutions treated corn will promote better community health and well-being just by the nature of consumption. Medical studies are planned in order to fully maximize and understand the health benefits of these technologically improved plants and seeds.

The United States Studies

The studies carried out in the United States covered both residential community farms trials in Missouri, large scale Commercial farm trials in South Dakota and Illinois while some studies were done in a golf course and highly saline wheat fields in California as reported below.

Missouri USA 2014

A study was commissioned in a residential community farm in 2014 to evaluate the efficacy of SFS products. The results are as follows.

Seed treatment with reduced fertilizer led to a 274% increase in Fat in Maize as compared to control as shown in Figure 6.

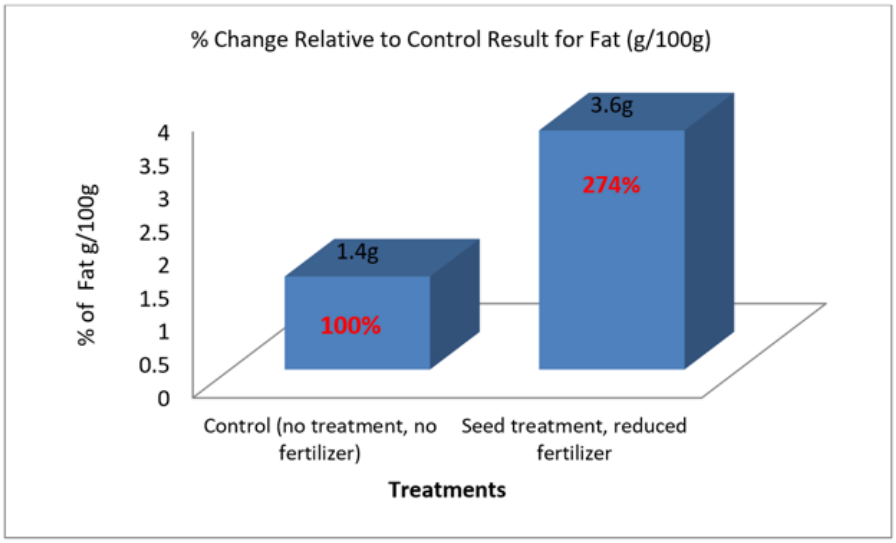

Figure 6: % Change Relative to Control Result for Nutritional Analysis for Fat done by Nestle-Purina Laboratories – St. Louis, Missouri USA 2014 from raised at George Washington Carver Experimental Farm, St. Louis, MO USA.

When looking at protein levels of Maize, seed treatment with standard fertilizer led to 8% increase in Protein levels while seed treatment with no fertilizer led to 16% increase in proteins as compared to control (no seed treatment, no fertilizer) case as shown in Figure 7.

Niacin level more than tripled with seed treatment without fertilizer treatment (337% increase) as compared to control while seed treatment with standard fertilizer led to a 521% increase in Niacin levels as shown in Figure 8 when compared to control (no seed treatment, no fertilizer).

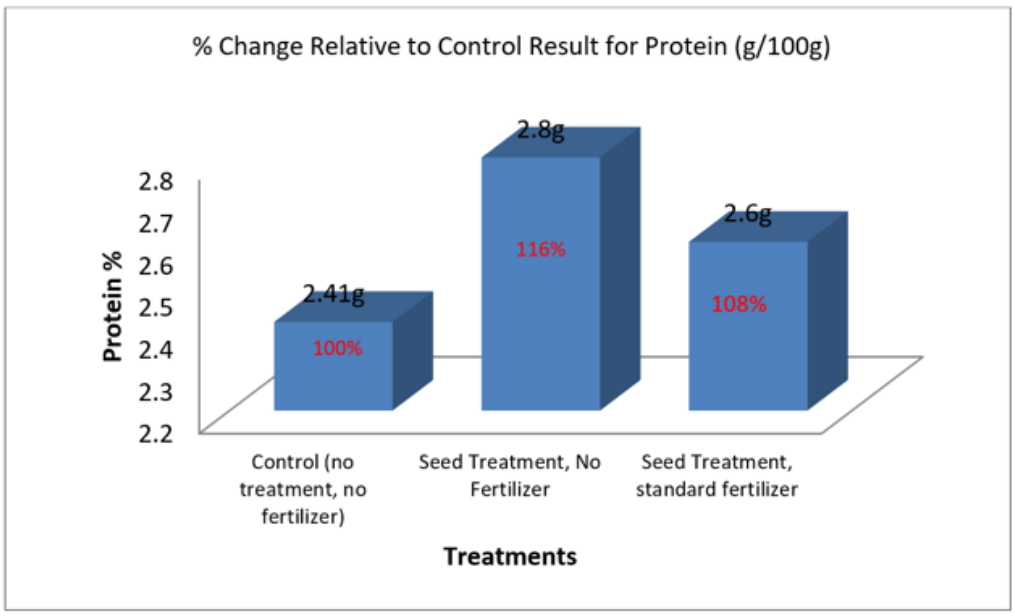

Figure 7: % Change Relative to Control Result for Nutritional Analysis for Protein% done by Nestle-Purina Laboratories – St. Louis, Missouri USA 2014 from raised at George Washington Carver Experimental Farm, St. Louis, MO USA.

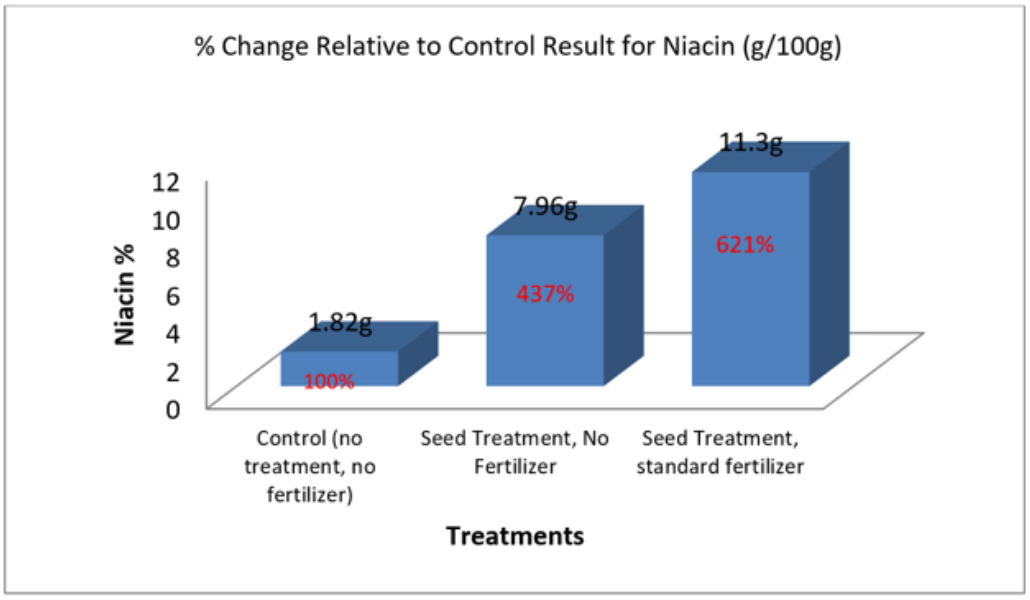

Figure 8: % Change Relative to Control Result for Nutritional Analysis for Niacin % done by Nestle-Purina Laboratories – St. Louis, Missouri USA 2014 from raised at George Washington Carver Experimental Farm, St. Louis, MO USA.

South Dakota Studies, 2020

The study was done on 3000 acres Carper Farms during the spring of 2020.

Key Findings for the Carper Farms Corn Tests:

- There was 37% yield increase in the SFS Treated Field with an 80% reduction of fertilizer use as compared to the 100% fertilizer use in the Control Fields with No SFS Treatment
- Corn ears for 20% fertilizer-SFS treated group were 32% larger than 100% fertilizer group with $p<0.05$ hence statistically significant.
- Minimally, this process can significantly reduce the planting cost and increased production.
- Soil moisture is increased by 50% or more which allows a 50% or greater savings in water use while also significantly improving the soil quality.
- Additionally, it was noted that the 20% SFS Treated Fields matured almost two weeks earlier than the 100% Fertilizer Control Fields.
- There was 77% more corn produced with the 80% fertilizer reduction SFS Treated Fields as compared to the SFS Treated 0% fertilizer use Field
- The results of the soil analysis are shown in Table 1 where significant changes were noted for Nitrogen, Sulfur, Iron, Manganese, Carbonate, Soluble Salts and Cation Exchange Capacity (CEC).

Table 1: Increase/Decrease Relative to Control for Carper Farms Soil Analysis.

Analyte		Untreated	Treated	Change	Increase/Decrease Relative to Control
Nitrogen	0-6"	54	110	56	**2x+**
	6-24"	135	171	36	1.3x+
	0-24"	189	281	92	1.5x+
Potassium		291	314	23	1.1x+
Chloride		28	64	36	**2.3x+**
Sulfur	0-6"	16	22	6	1.4x+
	6-24"	42	36	-6	1.2x-
Boron		0.5	0.3	-0.2	0.4x-
Zinc		2.43	1.39	-1.04	1.7x-
Iron		73.7	116.5	42.8	1.6x+
Manganese		9.5	79.3	69.8	**8.4x+**

Copper		1.19	1.5	0.31	1.3x+
Magnesium		507	384	-123	1.3x-
Calcium		3366	2181	-1185	1.5x-
Sodium		13	10	-3	1.3x-
Sol. Salts	0-6"	0.27	0.48	0.21	1.8x+
	6-24"	0.28	0.39	0.11	1.4x+
Soil pH	0-6"	6.4	4.4	-2	1.5x-
Cation Exchange Capacity -CEC		24.3	637.9	613.6	**26.3x+**

Analysis done by Agvise Laboratories, 5/29/2020

Nutritional Analysis Results: From the nutritional analysis done by Nestle-Purina Laboratories –St Louis, MO in the summer 2020, it was noted that the moisture content was slightly higher in all groups for earlier planting. Fat content was significantly higher in 0% (+64%) and 20% (+20%) Fertilizer with Seed Treatment compared to same without Seed Treatment. Seed Treatment also increased protein content. Fiber content with SFS Seed Treatment compared to SFS Soil & Fertilizer -41%. Ash content was lower in all groups in later harvest groups up to -73%. SFS Seed Treatment with Soil and Fertilizer Amendment Treatments increased Niacin levels as compared to 100% Fertilizer alone by up to +25%. Seed Treatment alone compared to SFS Soil and Fertilizer Amendment accounted for a 15x increase in Niacin for the 0% Fertilizer group comparison. Seed Treatment alone compared to SFS Soil and Fertilizer Amendment accounted for a 44% increase in Niacin for the 20% Fertilizer group comparison. Corn in the later harvest was significantly higher in carbohydrates (sweeter). Corn in the 0% Fertilizer with Seed Treatment and SFS Soil and Fertilizer Amendment group compared to the same group with no seed treatment had +22% more calories. Overall, Seed Treatment with Soil and Fertilizer Amendments significantly enhanced corn nutritional values more than Soil and Fertilizer treatments alone with the same or better nutritional values with the 100% Fertilizer.

California 2021

Two studies were implemented in California. One on a golf course field while the other was done on a highly saline wheat field. The soil analysis was done comparing the results before and after treatment.

Soil Analysis results for a Golf Course Field in California 12/21/2021: As shown in Table 2, significant changes were noted in the levels of Nitrate, Soil Organic Matter, Moisture levels, Chloride, Sulfate, Total dissolved solids, Boron and Magnesium when comparing treated and untreated soil samples.

Table 2: Increase/Decrease Relative to Control for Soil Analysis on a golf Course field in California comparing SFS Treated and Untreated soils on 12/21/2021.

Analyte		Untreated	Treated		
	units	Results	Results	Change	Increase/Decrease Relative to Control
General Chemistry					
Nitrate as NO3	Mg/kg	85	12.6	-72.4	**6.7x-**
Phosphate as PO_4	Mg/kg	3900	3200	-700	1.2x-
Total Alkalinity	Mg/kg	4970	4150	-820	1.2x-
Bicarbonate HCO_3	Mg/kg	4400	3380	-1020	1.3x-
Carbonate CO_3	Mg/kg	574	763	189	1.3x+
Organic Matter at 750°C	%	9.9	18.4	8.5	1.9x+
% Moisture	%	7.8	15.5	7.7	**2x+**
Chloride		63	19.9	-43.1	**3.2x-**
Specific conductance	Umhos/cm	1000	670	-330	1.5x-
Sulfate as SO_4	Mg/kg	67.4	24.2	-43.2	**2.8x-**
Total dissolved solids	Mg/kg	8200	24000	15800	**2.9x+**
Hardness as $CaCO_3$	Mg/kg	610	900	290	1.5x+
Metals - as received					
Boron	Mg/kg	6.5	0.1	-6.4	**65x-**
Calcium	Mg/kg	180	260	80	1.4x+
Magnesium	Mg/kg	39	62	23	1.6x+
Potassium	Mg/kg	29	35	6	1.2x+
Sodium	Mg/kg	95	71	-24	1.3x-

Soil Analysis results for a highly Saline Wheat Field in California 3/30/2022: Based upon a highly saline wheat field, application of SFS treatments had significant changes in the levels of Nitrate, Total Alkalinity, Bicarbonate, Chloride, Sulfate, Calcium, Magnesium, and Sodium as shown in Table 3. No significant change in Organic Matter was observed under the saline conditions due to lack of life in the soils.

Table 3: Increase/Decrease Relative to Control for a highly Saline Wheat Field in California 3/30/2022.

Analyte		Untreated	Treated		
	Units	Results	Results	Change	Increase/Decrease Relative to Control
General Chemistry					
Nitrate as NO_3	Mg/kg	539	9	-530	**59.9x-**
Phosphate as PO_4	Mg/kg	3300	2500	-800	1.3x-
Total Alkalinity	Mg/kg	359	3020	2661	**8.4x+**
Bicarbonate HCO_3	Mg/kg	359	2980	2621	**8.3x+**
Organic Matter at 750°C	%	3.39	3.51	0.12	*
Chloride	Mg/kg	2440	388	-2052	**6.3x-**
Specific conductance	Umhos/cm	23000	4500	-18500	**5.1x-**
Sulfate as SO_4	Mg/kg	8320	1230	-7090	**6.8x-**
Total dissolved solids	Mg/kg	16000	10000	-6000	1.6x-
Hardness as $CaCO_3$	Mg/kg	5400	3400	-2000	1.6x-
Metals - as received					
Boron	Mg/kg	2.6	1.7	-0.9	1.5x-
Calcium	Mg/kg	2000	910	-1090	**2.2x-**
Magnesium	Mg/kg	100	270	170	**2.7x+**
Potassium	Mg/kg	74	97	23	1.3x+
Sodium	Mg/kg	3300	580	-2720	**5.7x-**

*No change

Illinois Study, 2022

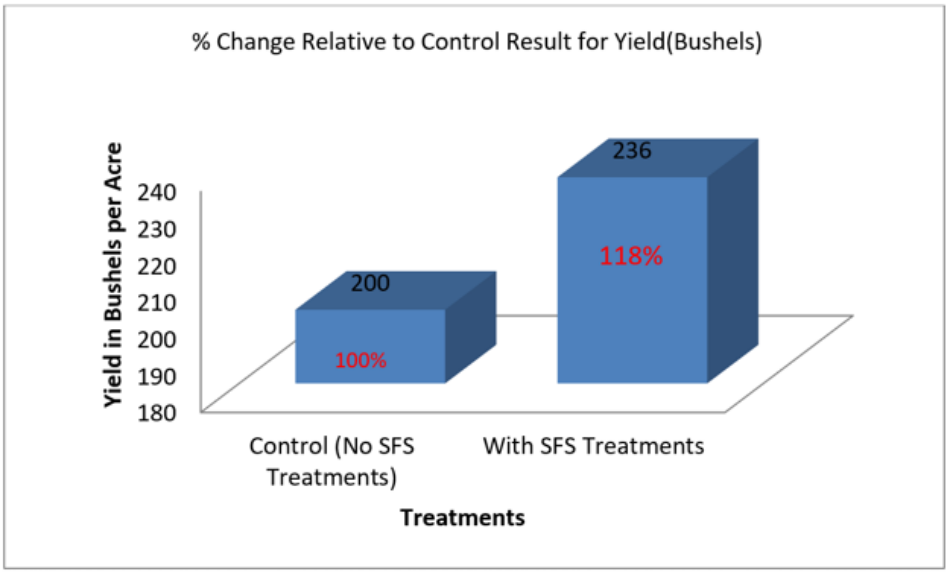

Figure 9: % Change Relative to Control Result for Commercial farm study in North America showing yield changes with SFS products use.

This study was done on an 8,000-acre commercial farm in Illinois in 2022. The results indicate that application of SFS products led to 18% increase in yield as compared to control (no SFS treatment) as shown in Figure 9.

Zambia Study 2023

A Maize on-station demonstration field was established at Zambia Agricultural Research Institute (ZARI) in Kabwe, Zambia in February 2023. The project aimed to provide smallholder farmers with regenerative solutions that are nature-based technologies that improve carbon sequestration, climate resilience and increase the productivity of farms in Zambia through the introduction of Salvation Farming Solutions (SFS) methods. The SFS method consists of Soil and Fertilizer treatment, Seed powder treatment, and Organic pesticide.

Description of the study site: The study was carried out at Kabwe Research Station (KRS) situated in Kabwe District of Zambia. KRS is approximately 142km from Zambia's Capital City, Lusaka, along the Great North Road. The station lies between latitudes -14.3954 and longitude 28.4934, with a gross area of over 500 ha. The area receives rainfall of between 800-1000 mm per annum with temperatures ranging between 20 to 34°C. According to ZARI [26] and Burke et al. [27], the soils in Kabwe are mostly Haplic Lixisols and Luvisols.

Experimental Design: A type 1 randomized complete block design (RCBD) experiment with a split-split plot treatment structure with three replications was used in the experiment. The test crop was Maize (Zea Mays) as sole crop. The selected treatments comprised of 3 (three) main plots composed of no chemical fertilizer (Nil Fertilizer), 20% of Full rate fertilizer application (80% less of the fertilizer use recommendation for Maize in Kabwe) and Full Rate fertilizer application (200kg ha-1 Basal and 200kg ha-1 for top dressing, =100% of the fertilizer use recommendation for Maize in Kabwe) which were designated as main plots. The main plot size was 12.25mx15m. Eight Sub plot factors composed of Salvation Farming Solutions (SFS) Nature Based solutions and included two sub plots with No SFS treatments, two with SFS Seed Treatments, two with SFS Soil and Fertilizer Treatment, and two with SFS Seed treatment with Soil and Fertilizer treatment. The sub-plot size was 5.9mx3m. The treatments were replicated three times in the experimental field. Inorganic fertilizer was applied in designated sub plots (Nil, 20% and 100% rates), followed by seeds and then sprayed with soil and fertilizer treatment.

a) SFS Field protocol: Each SFS TRIAL Kit provided enough sample products for Maize growth evaluation for 1+ acre of land. The SFS TRIAL Kit included the seed, soil and fertilizer treatments.

b) Seed Treatment Powder preparation: Maize Seeds to be planted was added into 20litres bucket. All the contents in the seed treatment powder were sprinkled into the bucket with seeds. A cup of treated water was added into the bucket containing seeds and the seed treatment. The content was mixed with wooden spoon. The bucket contents were stirred slowly until all the seeds were uniformly coated with the seed treatment. The seeds were planted one hour after mixing.

c) Soil and Fertilizer Treatment Concentrate: A backpack sprayer was filled with water, then a cup full bottle of the soil and fertilizer treatment concentrate was added to the backpack. An even moist was applied to the soil.

d) Field soil sampling and analysis: The zigzag sampling framework was used to sample composited soils at plot level (0-20cm depth) before planting, 9 weeks after planting and after harvesting of the experiment for soil nutrient analysis following the methods outlined in Okalebo et al [28]. To determine total organic carbon (TOC), the soil sample was oxidized using acidified dichromate at 150oC for 30 minutes followed by calorimetric determination [28]. Nitrogen (N) was analyzed by Kjeldahl method [29].

Results

Germination Rates

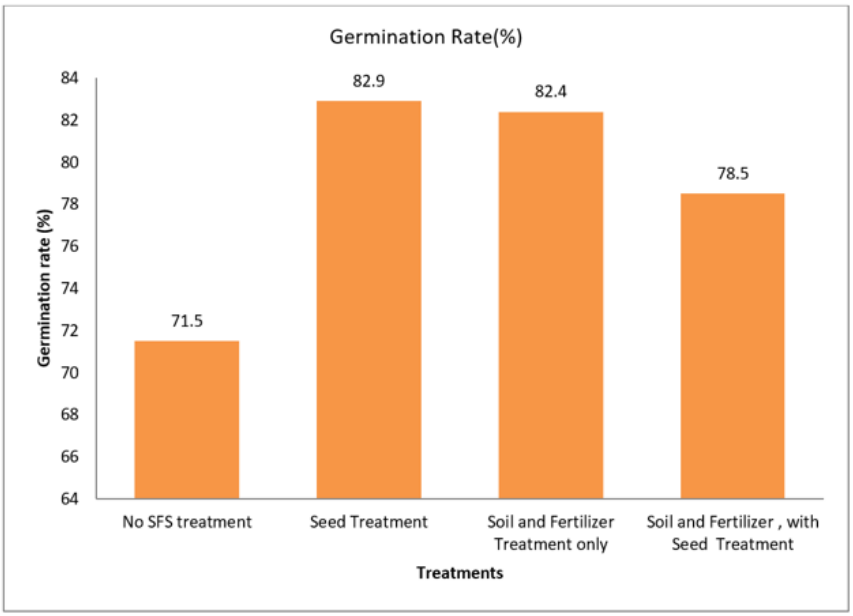

Figure 10: Comparing Germination Rate (%) with SFS Treatments.

A statistically significant (p=0.028) difference was observed when comparing germination rates between fields with no SFS treatments versus those with Soil and Fertilizer, with Seed Treatments as shown in Figure 10.

Yield data

The seed, soil and fertilizer treatment increased yield for staple crops by up to 330% and reduce fertilizer by at least 80%.

Maize yield was very significantly affected by the SFS treatments With No chemical fertilizer used; Seed treatment increased yield by 288%, Soil and Fertilizer treatment increased yield by 234% while combination of Seed, Soil and Fertilizer treatments increased yield by 330% as shown in Figure 11. SFS treatments can at least double the yield with no fertilizer application.

There was 223% increase in yield with reduced fertilizer application (20% of Full rate) compared to no fertilizer while with full rate fertilizer application an increase of 246% was observed when Seed, Soil and Fertilizer treatments are applied for maize production as shown in Figure 12. This demonstrates that reduction in fertilizer used by farmers by up to 80% hence reduced production costs and soil toxicity making farming affordable to many farmers while significantly increasing the farmers' economic position and making the soils healthier the subsequent cropping season.

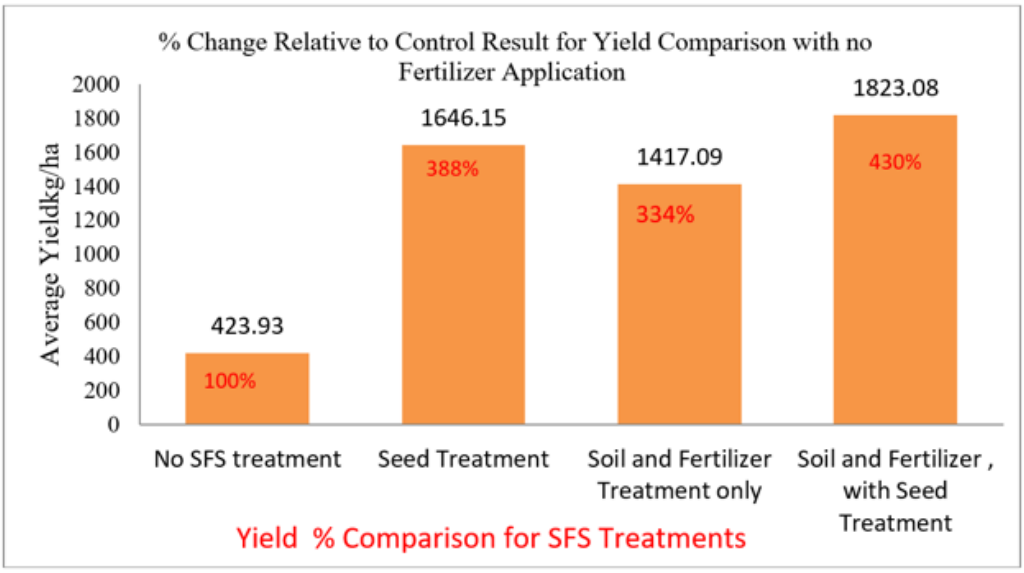

Figure 11: % Change Relative to Control Result for Yield Comparison with no Fertilizer Application with SFS treatments.

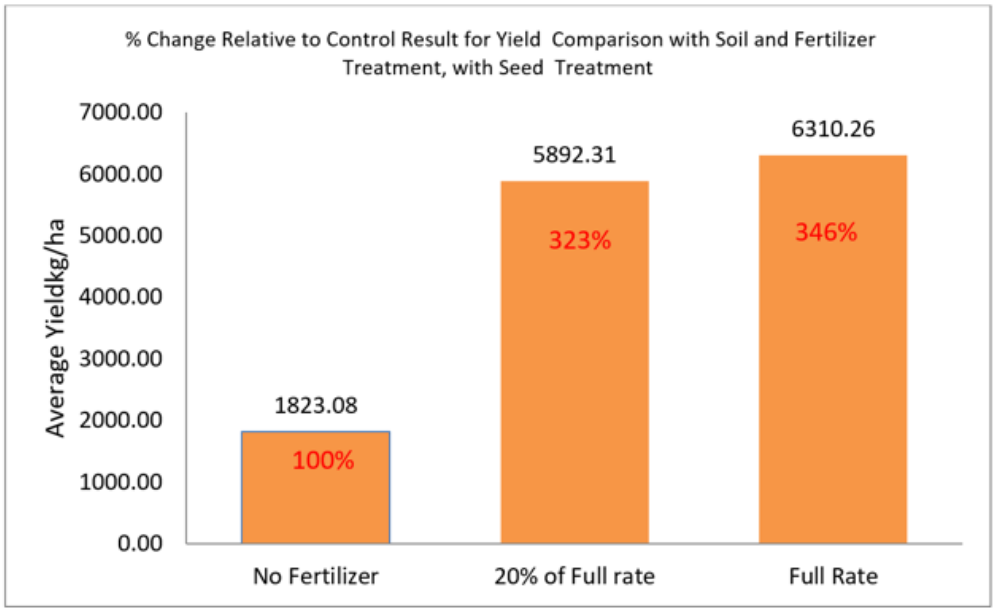

Figure 12: % Change Relative to Control Result for Yield Comparison with Soil and Fertilizer Treatment, with Seed Treatment.

Soil Organic Carbon

Significant Soil Organic Carbon Sequestration with SFS treatments was observed as shown in Figure 13 which is significant in establishing a resilient food system for generational impact. Treatments with SFS Soil and Fertilizer treatments with Seed treatment led to higher changes in Soil Organic Carbon (SOC) while those without SFS led to least changes in SOC sequestration. Soil Carbon sequestrations reported thus establish a significant resilient food system for generational impact

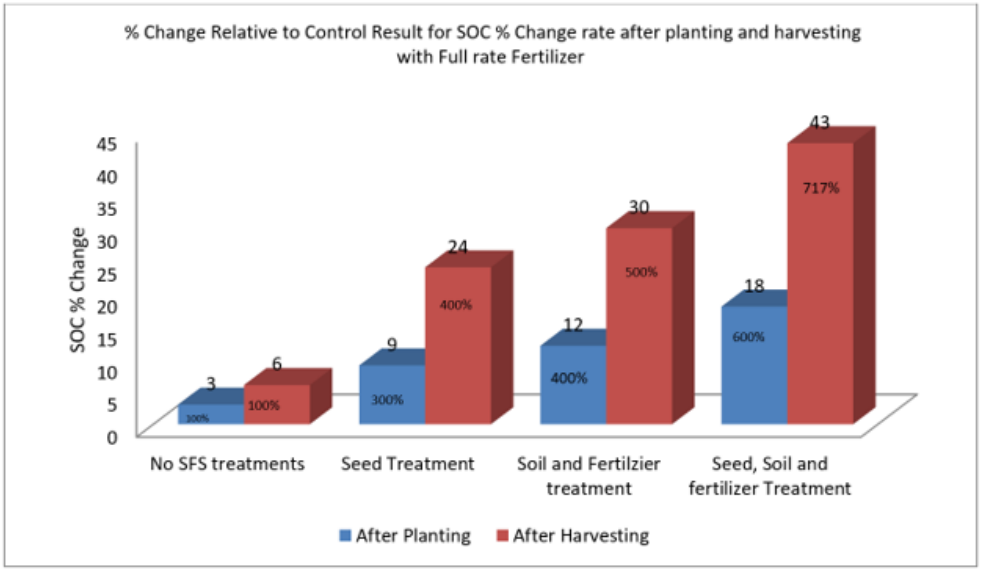

Figure 13: % Change Relative to Control Result for Comparing SOC %Change rate after planting and harvesting with Full rate Fertilizer.

Soil Nitrogen

Soil Nitrogen percentage changes showed significant increase in natural nitrogen production influenced by SFS treatments as shown in Figure 14. Soil and fertilizer treatments with seed treatment contributed to the highest percentage increase in soil N, while Control (No SFS treatments) contributed to the least increase in soil N during the crop growth phase. Use of SFS treatments significantly improve soil health and nitrogen sequestration through a nature-based solution

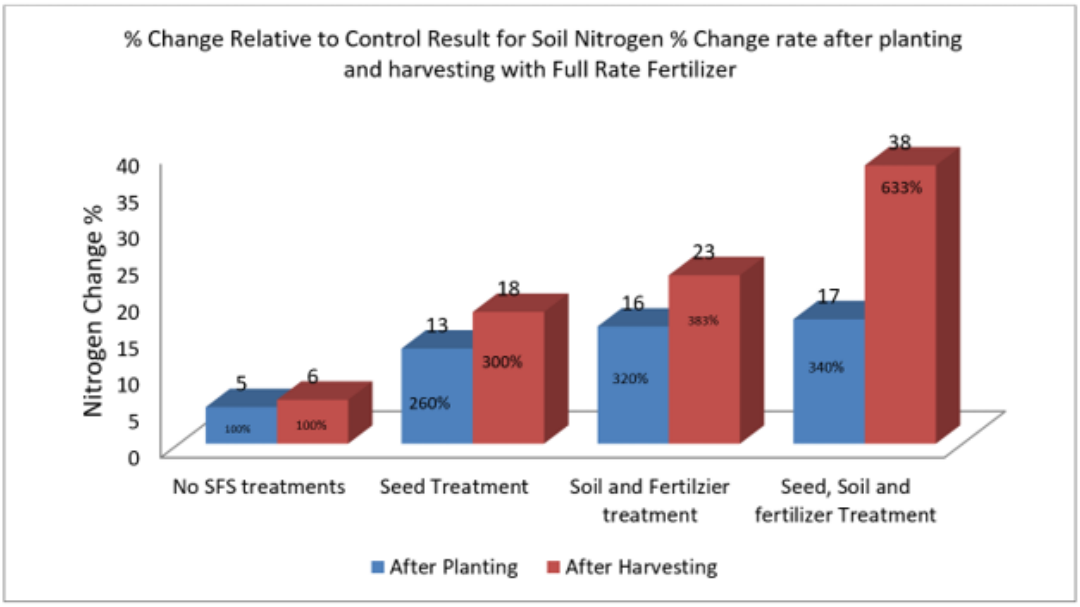

Figure 14: % Change Relative to Control Result for Comparing Soil Nitrogen % Change rate after planting and harvesting with Full Rate Fertilizer.

SFS benefits learned from studies in Zambia

SFS treatments can at least double the yield with no fertilizer application. The reduction in fertilizer used by farmers by up to 80% translates to reduced production costs and soil toxicity making farming more affordable to many farmers while significantly increasing the farmers' economic position and making the soils healthier for the subsequent cropping season. The SFS Treatments significantly improves soil health and regenerative of soil conditions through a nature-based solution. Soil Carbon sequestrations reported indicated a possibility for establishing a significant resilient food system for generational impact. The SFS treatments substantially enhance production results; as much as 200% more in yield thus a profitable business venture that can attract investment. SFS treatments significantly improve soil health and nitrogen sequestrations thus demonstrate ability of farming to be climate resilient with its application.

Kenya Study

This study was set up a farmer's field in Onyunyur, Kakoli and Amagoro in Busia County, Western Kenya region. Three fields were treated with SFS products while one field was control (no SFS products were applied). Same maize variety was planted at the same time.

Nutritional Analysis

Maize grown under SFS treatment showed overall tremendous increase in nutritional value as shown in Table 4.

Table 4: Increase/Decrease Relative to Control for Nutritional Analysis for Maize grown under SFS in Busia County, Western Kenya.

Parameters	Control		Average Treatment		%Change		Increase/Decrease Relative to Control	
	Wet Results	Dry Results	Wet Results	Dry Results	Wet Results	Dry Results	Wet Results	Dry Results
Crude Fiber	1.7	2.4	1.5	1.8	-7.3%*	-24.8%***	1.1x-	1.3x-
Crude Fat	3	4.4	5.1	6.2	72.0%*****	40.1%*****	1.4x+	1.4x+
Total Protein	5.2	7.5	7.9	9.5	54.1%***	25.9%**	1.5x+	1.3x+
Total Nitrogen	0.9	1.2	1.3	1.5	38.0%**	25.1%**	1.4x+	1.3x+
Niacin(Vitamin B3)	1.1	1.6	1.3	1.5	24.0%***	-2.8%****	1.2x+	0.1x-
Nitrogen Free Extracts	57.8	84.7	68.1	81.4	17.9%***	-3.9%*****	1.2x+	1.1x-
Total Carbohydrates	59.5	87.1	69.6	83.2	17.0%***	-4.4%*****	1.2x+	1.1x-
Metabolizable Energy	2478	3627	3117	3725	25.8%****	2.7%*****	1.3x+	1.03x+
Zinc	-	13.4	-	35.8	-	167.4%***		**2.7x+**
Iron	-	1.7	-	3.4	-	101.0%****		**2x+**
Vitamin A	-	0.01	-	0.08	-	700.0%****		**8x+**

Analysis done by Spectra lab Analytical Services Ltd Nairobi Kenya, July 27, 2023

*, **, ***, **** and ***** means the statistical significance at p<0.2, p<0.05, p<0.01, p<0.001 and p<0.0001 respectively.

Key findings:

- Crude Fat showed extremely significant difference when comparing maize treated with SFS and that without SFS treatment
- There was a very significant difference in total protein when comparing treated and untreated maize
- There was extremely significant difference in total nitrogen
- Niacin (Vitamin B3) and Nitrogen free extracts showed extreme significant result changes when SFS treated maize was compared with untreated maize
- Metabolizable energy showed extremely significant difference results changes when SFS treated maize was compared with untreated maize
- Zinc, Iron and Vitamin A showed extremely significant difference results changes when SFS treated maize was compared with untreated dry maize
- The results show extremely significant changes in nutritional value for the maize when comparing treated and untreated maize. Maize grown under SFS treatment showed an overall tremendous increase in nutritional value
- Improved nutritional values (increase of Fat by 72%, Protein by 54.1%, Niacin (Vitamin B3) by 28.3%, Carbohydrates by 25.9% while Metabolized Energy by 35.3%) hence that can improve health benefits to the consumers leading to a healthier community

Fortification

According to Mwai et al [30], in Kenya, compliance with food fortification standards is still low at 28% despite all the efforts put by both government and its partners. There is a need for concerted efforts to understand the main causes of the low compliance levels in order to develop targeted strategies for mitigation. According to East African Community, East African Standards; Micronutrient deficiencies in developing countries are widespread, particularly deficiencies of Iron, Vitamin A, Iodine, Folic acid and Zinc. The fortification compounds used for Vitamin B3 (Niacin), Iron and Zinc are Niacinamide, NaFeEDTA and Zinc Oxide respectively. From the Kenyan Study the nutrient levels of the above micronutrient were near or above the minimum requirements hence meeting the threshold for the fortification and better alternative to using the chemical fortification compounds because of bioavailability of the nutrients to the consumer using nature-based solutions.

Discussion

Yield change comparisons

Uses of SFS products have been demonstrated to have significant impact on the maize yield. When looking across the three farming systems, there was larger impact in the yield in Zambia and India as compared to the commercial farm in South Dakota as shown in Table 5.

Table 5: % Change Relative to Control Result for Yield change comparisons across different Farming Systems.

Study Area	% Change in Yield with Seed treatment, no fertilizer	% Change in Yield with seed treatment, reduced fertilizer	% Change in Yield with SFS treatment
India, 2017	166	225	
India, 2018	290	200	
South Dakota, 2021	137	177	
North America, 2022			118
Zambia, 2023	288	234	330

The yield difference tends are shown in Figure 15.

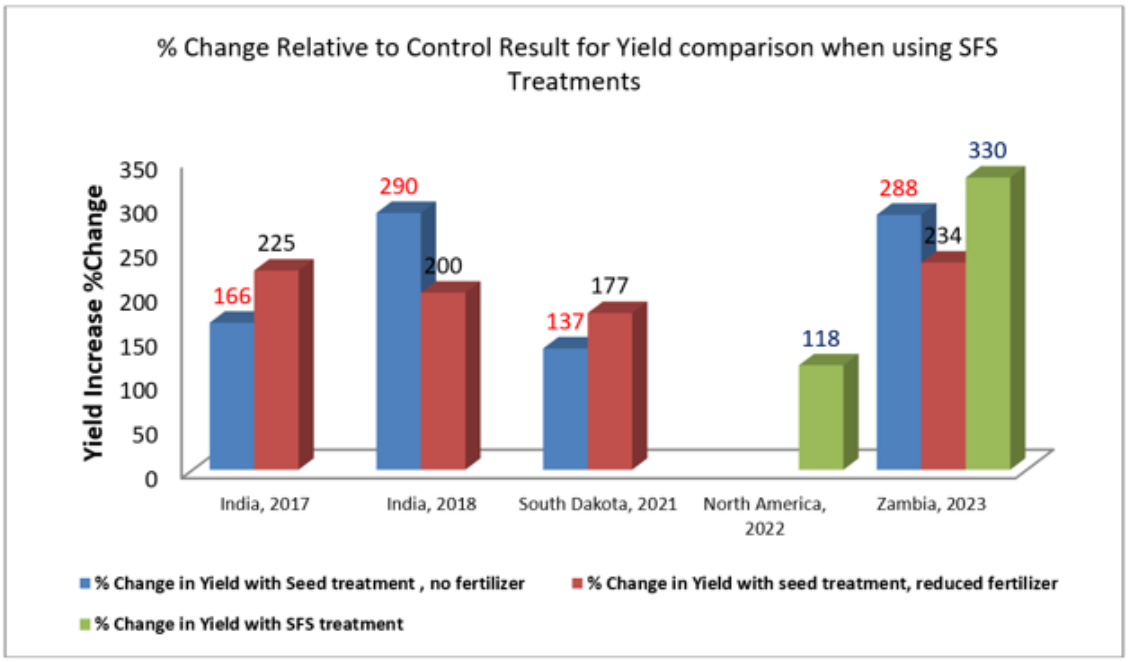

Figure 15: % Change Relative to Control Result for Yield Comparison when using SFS Treatments across different Farming Systems.

Nutritional Comparison % Change with SFS treatments

Highest Niacin Change was reported in the community farm in Missouri in 2014 study where over 500% increase was noted when applying SFS products. A 400% increase in protein was recorded in India during the study done in 2017 as shown in Table 6 (Figure 16).

Table 6: % Change Relative to Control Result for Nutritional Comparison % Change with SFS treatments.

Study Area	Protein	Carbohydrates	Fat	Niacin
Missouri, 2014	116		274	521
India, 2017	400	374	257	
South Dakota, 2020(no seed treatment)	107.2	117.5	114	193.7
South Dakota, 2020 (with seed Treatment)	105.6	101.2	146	124.8
Kenya, 2023	154.1	117	172	124

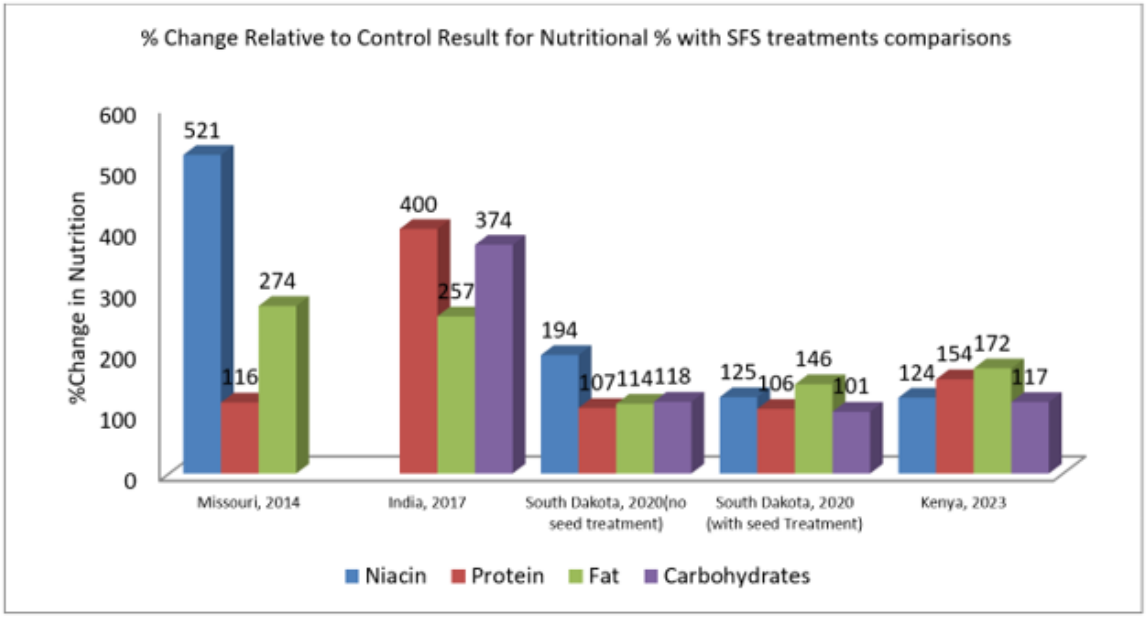

Figure 16: % Change Relative to Control Result for Nutritional % with SFS treatments comparisons.

Soil Analysis comparison using SFS Treatments

Table 7 shown comparisons of the effects of SFS treatment in a golf course and saline wheat field

Table 7: Increase/Decrease Relative to Control for Soil Analysis comparison using SFS Treatments on a Golf Course and saline Wheat Field.

Analyte	units	%Change Relative to Untreated		Increase/Decrease Relative to Control	
General Chemistry		**Golf Course Field**	**Saline Wheat Field**	**Golf Course Field**	**Saline Wheat Field**
Nitrate as NO_3	Mg/kg	15%	2%	**6.7x-**	**59.9x-**
pH	pH units	102%	110%	1.02x+	1.1x+
Phosphate as PO_4	Mg/kg	82%	76%	1.2x-	1.3x-
Total Alkalinity	Mg/kg	84%	841%	1.2x-	**8.4x+**
Bicarbonate HCO_3	Mg/kg	77%	830%	1.3x-	**8.3x+**
Organic Matter at 750°C	%	186%	104%	1.9x+	1.04x+
%Moisture	%	199%	108%	**2x+**	1.1x+
Chloride		32%	16%	**3.2x-**	**6.3x-**
Specific conductance	Umhos/cm	67%	20%	1.5x-	**5.1x-**
Sulfate as SO_4	Mg/kg	36%	15%	**2.8x-**	**6.8x-**
Total dissolved solids	Mg/kg	293%	63%	**2.9x+**	**6.8x-**
Hardness as $CaCO_3$	Mg/kg	148%	63%	1.5x+	1.6x-
Metals –as received					

Boron	Mg/kg	2%	65%	**65x-**	1.5x-
Calcium	Mg/kg	144%	46%	1.4x+	**2.2x-**
Magnesium	Mg/kg	159%	270%	1.6x+	**2.7x+**
Potassium	Mg/kg	121%	131%	1.2x+	1.3x+
Sodium	Mg/kg	75%	18%	1.3x-	**5.7x-**

Conclusion

This paper is a culmination of 10+ years of research to find ways to improve carbon sequestration, climate resilience and increase the productivity of farms using nature-based solutions in non-pollutive, regenerative and commercially successful ways. We have demonstrated ways to improve Maize yield, nutritional density, and resiliency to climate change effects that are sustainable. Additionally, the crop nutritional analysis results show nutritional density of the raised maize crops that meet or exceed WHO Nutrition/Fortification standards [31].

This report is a comparison of 10 years of maize research carried out in three different farming systems globally including India, North America and Africa. Two studies were done in India in 2017 and 2018, three studies in the United States in 2014, 2020 and 2022 while in Africa (Kenya and Zambia) two studies were done in Kenya and Zambia in 2023. Salvation Farming Solutions (SFS) has developed a line of nature based, non-GMO cropping solutions (patents pending) focused on smallholder farmers designed to disrupt the global agricultural industry by improving water availability/quality, detoxifying and increasing soil fertility, extremely significantly improving crop production and improving the nutritional density of the food produced!

There is increased momentum in use of Nature based initiatives to store carbon in soils as a measure to mitigate climate change while researchers have shown that combining Organic inputs including nature-based solutions like SFS treatments with mineral fertilizer seems to be the most promising carbon sequester in agricultural soils.

It is worthy to note that maize planted with SFS solutions seemed resistant to pest infestations as compared to control groups. Additionally, in India Aflatoxin appeared on control corn and none appeared in the SFS treated groups. Based on the growth of the corn plants and increased silage benefits along with the nutritional density, not only is the corn nutritionally beneficial, but also the nutrient density is likely to be beneficial for the livestock being fed the silage. It is also be noted that in various areas where drought has been a factor, the moisture benefit in the soils treated with SFS have had significant drought resistance characteristics and have been seen in other crops such as wheat and cotton in other field trials in the US using SFS products [32].

Key findings of this research demonstrate that maize crop productivity can be significantly enhanced in soils that have not been intensively farmed most likely due to the biome vitality of the soil enhanced through nature-based solutions to improve moisture, nutrient availability, and stimulate carbon sequestration and nitrogen fixation. Soils that have been intensively farmed such as in the United States seem to be less productive on an acre-to-acre comparative basis most likely due to non-regenerative approaches which are common for large scale farming. Nature-based agricultural solutions can provide small holder farmers significant financial benefits and provide consumers with more nutritious foods.

When looking at nutritional benefits associated with use of SFS products, significant increase in Niacin, Zinc and Iron was noted in the various thus present a healthier pathway in addressing hidden hunger being experienced by farming communities in developing economies. Use of SFS products provides a better alternative for the food fortification initiatives which ensure natural bio-availabity of the essential nutrients naturally instead of using chemical-based bio fortification compounds [33].

We also understand the enormous variability in Soil conditions, Fertilizer use and yield among the different cropping systems and geographies. The application of the nature-based solutions such as SFS treatments in addressing climate change mitigation, soil health, farm production and productivity should take into account the differences.

Fertilizer use and crop yields are very low in developing countries especially Africa [34]. Application of SFS treatments have been shown to have potential in transforming the farming systems with a focus on smallholder farmers by improving water availability/quality, detoxifying and increasing soil fertility, significantly improving crop production and improving the nutritional density of the food produced.

According to Van Ittersum et al. [35], and Ten Berge et al. [36], given adequate production potential, increasing nutrient has the potential of increasing the availability of biomass which can be returned to the field to sequester carbon hence providing a positive feedback loop between crops and soils. Results from the studies across the three farming systems have demonstrated the potential of SFS treatments for carbon sequestration and also increasing the soil Nitrogen especially in the developing world setting where farms have not been intensively farmed. It is further noted that in regions where fertilizer use is high in cases of highly commercialized farms, increasing nutrient use efficient which results in reduction on N2O emissions is the pathway that can be employed as mitigation to climate change.

Use of nature-based solutions such as SFS products is key in establishing sustainable farming practice. Results from the studies in Zambia demonstrate the potential in building a resilient farming system in Sub Saharan Africa with potential to cope with challenges associated with climate change [37].

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The contents are the responsibility of Salvation Farming Solutions LLC and do not necessarily reflect the views of USAID or the United States Government.

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Conflict of Interest

No conflict of interest.

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