COTTON CONNECT
REIMAGINING THE FUTURE FOR SUPPLY CHAINS

Egypt 2025

Report on Regenerative Demonstration Plots

In the framework of

THE EGYPTIAN COTTON PROJECT
مشروع القطن المصري

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

ITPO
INVESTMENT AND TECHNOLOGY PROMOTION OFFICE
ROME, ITALY

Ministero degli Affari Esteri
e della Cooperazione Internazionale

AGENZIA ITALIANA
PER LA COOPERAZIONE
ALLO SVILUPPO

Contents

List of Tables

1. Introduction and Background

1.1 Context: Cotton Cultivation in Egypt and Current Challenges

Egypt has a long history of cotton production and has been known for producing high-quality cotton fibres. Egyptian cotton is highly regarded for its softness, durability, and long-staple length. It has been sought after by textile manufacturers worldwide. Egypt's cotton sector has faced challenges in recent years but continues to be an important part of the country's agricultural heritage. There are several critical issues, including water scarcity, land degradation, lack of modern agricultural techniques, and climate change impacts. Egypt is currently facing the impact of climate change, where land degradation and desertification affecting the Nile Delta have made it one of the most vulnerable areas globally. Additionally, using extensive chemicals to enhance productivity has caused further soil degradation and affected the soil biodiversity[1]. As part of CottonConnect's initiatives in Egypt, soil test analysis reveal long-term adverse impacts on agriculture and productivity. Deteriorating soil health, water scarcity, loss of biodiversity and climate change have also led to the disruption of agricultural seasons. This has led to variability in the crop yield and has enhanced vulnerability to extreme weather events. To address these challenges, promoting regenerative agriculture practices is imperative.

1.2 Rationale: Adoption of Regenerative Agriculture in the Global and Egyptian Context

The way we manage agricultural land matters. It matters to people, it matters to our society, and it matters to the climate.

In 2014, Rodale Institute released its landmark white paper, "Regenerative Organic Agriculture and Climate Change: A Down-to-Earth Solution to Global Warming", which was unquestionably influential. It stimulated corporate and governmental adoption of regenerative agriculture, inspired many farming organisations and farmers to adopt regenerative practices, and accelerated the recognition that agriculture done properly must be part of an effective global response to our climate crisis[2].

Adoption of Regenerative Agriculture has gained significant momentum in the cotton sector and represents an opportunity for Egypt to offer credible sustainability credentials alongside premium fibre qualities. Regenerative approaches underpin a shift towards more sustainable and resilient production systems in Egypt. This has enabled cotton farmers to secure stable yields and maintain the exceptional fibre quality demanded by global markets, positioning the industry to meet rising consumer expectations for sustainably sourced textiles[3].

1.3 Alignment of UNIDO and CottonConnect

In continuation of the long-standing collaboration between the United Nations International Development Organisation (UNIDO) and CottonConnect, focusing on enhancing cotton sustainability, a pilot project focusing on the establishment of different regenerative demonstration plots at the Cotton Research Institute (CRI) and the farmers' level was implemented in June 2025 onwards to assess the impact of different demo plots[4] and to identify the best applicable practices for the Egyptian context.

1 Source: Paper on Egyptian Agriculture Scenario
2 Rodale Institute, 2020, Regenerative Agriculture and the Soil Carbon Solution
3 CottonConnect Insights Paper, April 2025

4 Demo Plot are such plots where one or combination of sustainable practices were implemented whereas in Control demo plots cotton farming was done following conventional method without any intervention

2. Project Overview and Objectives

2.1 Project Overview

The project aimed for the deployment of the regenerative demonstration plots, focusing on addressing the region's needs for improved soil health and biodiversity promotion, which in turn will help promote climate resilience and economic sustainability. The implementation approach focused on two levels:

1.Working with CRI on the Sakha Agriculture Research land to test the Regenerative Standard in the context of the Egyptian agricultural landscape. This was done in close coordination with the CRI.

2.Created a set of demonstration plots with farmers at Qalin District, Al-Ghunaimi Association, under CRI supervision, and drawing on CottonConnect's experience in applying the Regenerative Standard in Egypt.

2.2 Core Objectives of the Demonstration Plots Project

The core objectives of the demo plots spread over two phases were:

- Phase I: set up model demonstration plots introducing regenerative farming practices, which will demonstrate to the wider Egyptian agricultural community the importance and benefits of regenerative agriculture.
- Phase II: monitor and identify the practices that work best in the Egyptian context, as demonstrated in the plots.

It was envisaged that over a period of time, the impact from these demonstration farms would help take informed decisions at various levels with the ultimate objective of inspiring farmers at scale to adopt best regenerative practices, including:

- Introducing optimum crop rotation, which plays a critical role in trying to replicate the natural diversity of native plants
- Using integrated soil management to further increase soil fertility and increase Soil Organic Matter (SOM)
- Reducing tillage to provide better soil structure and microflora for plants to grow
- Demonstrating the benefits of increasing biodiversity in the agroecosystem, where applicable

2.3 Criteria for Plot Selection and Farmer Participation

CottonConnect, in collaboration with CRI, designed field experiments to generate data and extract insights relevant to regenerative practices.

The close coordination with CRI ensured that it would serve as the foundation for developing localised standards and training modules for farmers.

Super Giza 94, the most widely cultivated cotton variety in Egypt and extensively grown in Kafr El Sheikh, was selected for this project, making the findings more broadly applicable.

CRI demo plots were established at Sakha Agriculture Research Station (CRI programme) on land not exceeding 2 feddan. For the farmer's demo plot, the selection criterion entailed:

- The pilot farmers had not previously participated in any sustainable cotton initiatives
- Farmers are willing to cooperate and adopt Regenerative practices, as there is a significant gap between conventional agricultural practices and sustainable practices
- Easy access for farmers to observe sustainable practices in the demo plots, along with convenient access for CRI researchers and trainers
- Around 3 feddans with 3 farmers (aligned for the planning of demos plots)
- Farmers with a firm belief that good information leads to increased income, either through cost savings or higher productivity
- Priority was given to farmers with experience in cotton cultivation
- Proactive and approachable government extension staff available for support

3. Project Details

3.1 Project Implementation Strategy

The pilot began with the establishment of well-designed demonstration plots across research stations at CRI and selected farmer fields. A strong emphasis was placed on soil health through the use of compost, biochar, farmyard manure, reduced tillage, and diversified rotations, ensuring progressive improvement in soil structure, nutrient retention, and organic carbon levels.

The project adopted an integrated agro-ecosystem approach, combining plant density optimisation, biodiversity enhancement, and biological pest management using Agro-Ecosystem Analysis (AESA) techniques. These interventions aimed to reduce dependence on synthetic chemicals, enhance natural pest control, and promote ecological balance in cotton fields.

Farmer participation was central to the implementation process. Monitoring and evaluation served as a backbone for implementation and key indicators were regularly assessed to validate the performance of regenerative practices and guide future recommendations.

3.2 Project Timeline and Duration

Project implementation started during the 2025 cotton season, with project preparations beginning in May 2025. Sowing took place at the end of May and the beginning of June, followed by continuous monitoring. Harvesting started in October and continued until the completion of harvesting across all farmer fields and the CRI plots.

3.3 Key Partners and Stakeholders

The project was led by CottonConnect as the technical implementation agency, while UNIDO provided continuous oversight, supervision, and strategic direction; and CRI provided technical leadership on cotton production practices, trials, and scientific validation.

To strengthen the pilot, the Soils, Water and Environment Research Institute (SWERI), Agricultural Research Centre (ARC) provided expertise on soil and water management, and the Plant Protection Research Institute (PPRI), ARC extended support on integrated pest management and crop protection practices.

At the field level, the Agricultural Extension Directorate - Kafr El-Sheikh governorate facilitated on-ground technical assistance, farmer coordination, and extension services to ensure effective implementation at the farm level.

3.4 Project Coverage: Number of Plots Established

The demo plots were established at two levels:

- At the Sakha research station with the support of the CRI
- Farmers' demo plots at Qalin District, Al-Ghunaimi Association

The trials were implemented in coordination and partnership with the CRI at two levels:

- CRI: Nine trials including a control plot (area totalling two feddans).
- On-farm trials with farmers: Four trials were implemented with three farmers, covering a total of three adjacent feddans and a one-feddan control plot.

Table 1: Details of Farmer and CRI Demo Plots Established Under the Project

Sakha Research Station (in cooperation with the CRI)	Farmer Field Trials
1. Biochar + 20% farmyard manure 2. Biochar only 3. Farmyard manure only 4. Compost	1. Cotton after wheat 2. Cotton after flax 3. Cotton after clover (seed mixed with biochar) 4. Cotton after clover seed without biochar 5. Control plot
Plant Density Trials: 1. Planting at 30 cm spacing, one plant per hill 2. Planting at 30 cm spacing, two plants per hill 3. Planting at 20 cm spacing, one plant per hill 4. Traditional density (control)	
Pest Management through Beneficial Insects: 1. Application of Agro-Ecosystem Analysis (AESA) 2. Conventional pest control (control)	

3.5 Use of Fertilisers and Pesticides

In the case of demo plots at the farmer's field, the use of synthetic pesticides was quite indiscriminate in the control plot. Almost 3,000 ml/gm pesticide per feddan was used throughout the season, compared with 1,500 ml/gm in the field after wheat harvest, 1,940 ml/gm after flax, 1,700 ml/gm each after clover and in the plot where biochar-coated seed was used after clover.

Biopesticides were used in all demo plots at a rate of 500 ml/gm per feddan, compared with the control, where no biopesticide was applied.

In the case of synthetic fertiliser application, almost identical quantities were applied across all the demo plots at 400 kg/feddan, compared with 507 kg/feddan in the control plot at the farmer's field, indicating an almost 27% reduction in synthetic fertiliser use on Regenerative Agriculture demo plots.

Natural fertiliser was applied in both the demo and control plots; however, its utilisation was higher in the demo plots, averaging 3,270 kg per feddan, compared with 2,000 kg in the control. Similarly, biofertilisers were only applied in the demo plots.

In the case of demonstration at CRI, all input application rates were kept consistent to ensure accurate assessment of the targeted treatments without interference from other factors.

In the case of demonstration at CRI, all input application rates were kept consistent to ensure accurate assessment of the targeted treatments without interference from other factors. Chemical pesticide was kept constant at 2,225 ml/gm per feddan across all treatment groups, except in the agro-ecosystem, where 1,390 ml/gm per feddan was used.

The bio-pesticide was used only in the agro-ecosystem demo plot at a rate of 600 ml/gm per feddan. The use of synthetic fertiliser was kept constant at 400 kg per feddan across all demo plots, including the control plots, as recommended by the Cotton Research Institute.

Natural and organic fertilisers were applied in the demo plots, where Farm Yard Manure (FYM) (2,007 kg), FYM and Biochar (2,207 kg) and Compost (2,007 kg) were used, and 400 kg in the demo plot where only biochar was applied. The value "7 kg per feddan" represents organic fertilisers applied uniformly along with irrigation water across relevant treatments to supplement minor NPK deficiencies across all plots.

Table 2: Use of Fertilisers and Pesticides in Farmer Demo Plots

Type of Plots (Farmer)	Chemical Pesticide Usage (ml/gm) per Feddan	Bio-Pesticide Usage (ml/gm) per Feddan	Chemical Fertiliser Usage (Kg/Feddan)	Organic Fertiliser Usage (Kg/Feddan) FYM	Bio Fertiliser Usage (Kg/Feddan)
After Wheat	1,500	500	402	2,021	14
After Flax	1,940	600	402	3,020	14
After Clover	1,700	500	400	4,020	14
Seed mixed with biochar /clover	1,700	500	400	4,020	14
Control	3,000	0	507	2,000	0

Table 3: Use of Fertilisers and Pesticides in CRI Demo Plots

Type of Plots (CRI)	Chemical Pesticide Usage (ml/gm) per Feddan	Bio-Pesticide Usage (ml/gm) per Feddan	Chemical Fertiliser Usage (Kg/Feddan)	Organic Fertiliser Usage (Kg/Feddan)
FYM	2,225	0	400	2,007
FYM with Biochar	2,225	0	400	2,207
Compost	2,225	0	400	2,007
Biochar	2,225	0	400	407
30 cm double plant	2,225	0	400	7
30 cm single plant	2,225	0	400	7
20 cm single plant	2,225	0	400	7
Agro-ecosystem	1,390	600	400	7
Control	2,225	0	400	7

3.6 Use of Seeds

The cotton variety Super Giza 94 was developed through hybridisation between strain 10229 and the Egyptian cotton variety Giza 86. It belongs to the long-staple cotton category and was officially registered as a commercial variety on 23 January 2015.

Compared to Giza 86, Super Giza 94 is characterised by a longer staple length, comparable fibre strength, and greater fibre softness. These attributes enhance spinning limits and efficiency, contributing to the production of high-quality yarns suitable for premium textile applications.

Agronomically, Super Giza 94 exhibits early maturity, high yield potential, and a high ginning outturn, in addition to resistance to Fusarium wilt. These traits make the variety well-suited to the demands of efficient cotton production, combined with superior fibre quality.

According to data from the Cotton Research Institute, Super Giza 94 demonstrates excellent fibre characteristics, including an average staple length of 34.7 mm, fibre strength of 42.6 g/tex, and a micronaire value of 4.1.

At present, Super Giza 94 is the most widely cultivated cotton variety in Egypt, accounting for approximately 70% of the total cotton-growing area. Owing to its consistent quality and strong performance, it is recognised as the leading Egyptian cotton export variety, with sustained demand in international markets.

4. Study Design and Methodology

4.1 Study Design

The study employed a case–control design with demo plots established at the CRI and farmers' level along with a control plot. This design allowed for case-control comparisons to capture treatment-specific impacts on various aspects aligned with the outcome Key Performance Indicators (KPIs).

4.2 Monitoring and Data Collection Framework

Data was collected on an ongoing basis from both demo and control plots to assess changes across key agronomic, environmental, and economic key performance indicators (KPIs). In addition, soil sampling was done at the time of pre-sowing and post-harvest.

4.3 Data Collection Methods

Data collection was done using standardised demo plot data collection formats and a format capturing key agronomic details. The data collection format was finalised jointly between the key stakeholders: UNIDO, CRI and CC. The data was collected by agronomic experts from the SWERI and PPRI divisions of ARC.

4.4 Data Quality Assurance Mechanism

- Fortnightly data collection was done during the initial three months, followed by monthly data collection
- Data was collected by the agronomic team (CRI and Plant Protection Research Institute experts)
- Data was reviewed by CottonConnect experts on a regular basis to ensure the quality of data

4.5 Data Management and Analysis

The data collected from the field was entered into the Excel file. The data entry was reviewed by the CottonConnect teams on a regular basis. The data management was also done using Excel. Separate analysis is done for farmer and CRI demos, as they varied in terms of setting and exposure. In addition to the outcome KPIs, layered analysis across indicators- such as soil–yield–profit relationships, provided a holistic understanding of how each intervention influenced productivity, resource efficiency, and farmer income.

5. Study Findings[5]

5.1 Key Performance Indicators

5.1.1 Cotton Crop Growth Parameters

Plant height, sympodial branches, and bolls are important yield-associated parameters in cotton, each showing a positive association with overall yield. The farmer demo analysis shows that all plots produced taller plants than the control, with 'After Wheat' the tallest (28.2 cm more). A similar trend was observed for sympodial branches, except for 'After Clover', which was slightly lower than the control. For average bolls per plant, all demos except 'After Flax' outperformed the control (33.2 bolls per plant), with the 'Seed mixed with biochar/clover' demo recording the highest, 41.4 bolls per plant.

The results showed that cotton grown after wheat exhibits higher vegetative growth (plant height and sympodial branches) but a lower number of bolls, suggesting that wheat is a heavy feeder and depletes soil macro and micronutrients. The higher boll counts in the seed mixed with biochar/clover variety demonstrate the positive effect of biochar on improving boll formation and nutrient availability. These results highlight the benefit of crop rotation with organic inputs in enhancing cotton growth traits. Oluwaseun et al (2025) also found that continuous cropping with organic fertiliser application increased the number of bolls per plant, seed weight and resulted in greater seed cotton yield[6].

Across the CRI demos, most performed better than control in all the growth parameters. Regarding plant height, all demos except three (FYM with Biochar, 30 cm Double Plant, and 20 cm Single Plant) had taller plant heights than the control. "With compost" demo achieved the tallest height (160 cm), an increase of 4.2% compared to the control. In terms of sympodial branches, all demos performed better than control, and "with biochar" achieved the highest number of sympodial branches (19.2% more branches) as compared to control. Regarding the average number of open bolls per plant, all but three demos performed better than the control. "With compost" clearly performed better among all demos and had significantly more bolls than control. Therefore, "with compost" showed the strongest performance among all the demos.

The results showed that organic inputs, compost and biochar, contributed towards improvement in vegetative and reproductive growth of cotton. The increased plant height, sympodial branching, and boll count observed in these trials indicate that compost improves nutrient availability and soil health, while biochar improves soil structure and water retention capacity. Karthik et al (2020), indicates that integrating compost and biochar with soil has a positive impact on yield and helps in improving agro-ecosystem resilience[7].

5 In agreement with the CRI and other stakeholders, same irrigation was done for both demos and control. Thus, it is excluded from the analysis
6 https://www.maxapress.com/article/id/67c64d9afa6c58500c959776
7 https://www.academia.edu/43218619/Effect_of_biochar_on_the_growth_and_yield_of_cotton_and_maize_A_review

Table 4: Plant Growth Parameters

Type of Plots (Farmer)	Plant Height (in cm)	Sympodial Branches (Av. No./plant)	No. of bolls/plant (Average)
After wheat	170.6	14.3	34.0
After Flax	163.2	13.8	31.3
After Clover	146.8	13.6	38.2
Seed mixed with biochar /clover	157.4	13.7	41.4
Control	142.4	13.7	33.2
Type of Plots (CRI)	**Plant Height (in cm)**	**Sympodial Branches (Av. No./plant)**	**No. of open bolls/plant (Average)**
FYM	158.2	16.2	36.32
FYM with Biochar	152.4	16.0	43.28
Compost	160.0	16.8	44.88
Biochar	159.4	17.4	42.72
30 cm double plant	144.0	14.8	30.40
30 cm single plant	158.2	17.0	42.52
20 cm single plant	148.2	15.1	27.76
Agro-ecosystem	154.4	16.6	34.36
Control	153.6	14.6	34.72

The improvements in key growth parameters across both farmer and CRI demonstrations can be linked to enhanced soil health resulting from regenerative practices, including the application of organic amendments (farmyard manure, compost, and biochar), use of bio-fertilisers to stimulate beneficial soil microorganisms and nutrient cycling, crop rotation and intercropping to improve soil structure and biological activity, reduced tillage to conserve organic matter, and optimised water and nutrient management to reduce plant stress. Together, these practices contributed towards improving nutrient availability, root development, and overall plant vigour, leading to better crop growth performance.

5.1.2 Pest and Disease Infestation

According to Food and Agriculture Organisation (FAO) estimates, plant pests and diseases account for the reduction of 20 to 40 percent of global crop yields per year. Further, climate change is also likely to make plant pests more damaging to crops in intensity, distribution and spread[8]. Considering this, the pilot project focussed on integrated pest management.

The farmer demo plot analysis shows that all demo plots had lower average number of pests per cotton leaf. Among all demo plots, "after wheat" had lowest pests per leaf compared to control (0.9 fewer pests per leaf). It is important to mention that very few beneficial insects per cotton plant were observed in either demo or control. This implies that wheat cultivation as a preceding crop under crop rotation system helps to reduce pest infestations in cotton, even if beneficial insect populations are somewhat low.

However, supporting beneficial insect activity through integrated pest management practices (such as habitat management, intercropping, and the judicious use of pesticides and organic fertilisers) is essential for improving natural pest control.

Pest incidence data from the CRI plots show that agroecosystem (demo) plots generally recorded lower infestation levels than the control for most major cotton pests. Cotton leafhopper, aphid, and silverleaf whitefly populations were consistently lower in agroecosystem plots, with a marked reduction observed for cotton aphid.

Notably, aphids and whiteflies were found to be at least 50% lower in the agro-ecosystem than in the control plot. Therefore, it shows that crop management decisions based on agro-ecosystem analysis clearly outperformed the control plot in pest management, indicating greater effectiveness in reducing overall pest pressure.

These results indicate that sound, ecosystem-based agricultural management can naturally reduce pest pressure, thereby decreasing reliance on chemical pesticides and supporting sustainable cotton production. Furthermore, implementing a consistent, agro-ecosystem analysis-based crop management-based pest management programme, along with the appropriate use of bio-pesticides, can further enhance pest control, particularly when applied at the right time and dosage.

It is important to mention that lower pest levels in the farmer and CRI demo plots are primarily due to the efficient crop management decision resulting in healthier plants and improved field conditions created by regenerative practices.

Organic amendments like, biochar, compost and farmyard manure; better soil structure and crop rotations (such as cotton after wheat) helped reduce plant stress and disrupted pest cycles.

In addition, use of traps, specific insecticides at the correct time based on pest scouting prevented pest outbreaks. Combined together these practices made environment less favourable for pest, leading to lower pest pressure than control. Therefore, the findings show that regenerative practices can effectively suppress key pests and reduce reliance on chemical insecticides.

8 https://www.fao.org/pest-and-pesticide-management/about/understanding-the-context/en/

Table 5: Pest and Beneficial Insect Population in Farmer and CRI Demo Plots

Type of Plots (Farmer)	Average number of pests per cotton leaf	Average number of beneficial insects per cotton plant
After wheat	0.8	0.04
After Flax	1.2	0.04
After Clover	1.3	0.02
Seed mixed with biochar / clover	1.2	0.03
Control	1.7	0.02

Pests in CRI Plots	Agro-ecosystem	Control
Cotton leafhopper	0.8	1.1
Cotton aphid	0.7	2.7
Silverleaf whitefly (Adults)	4.0	5.4
Silverleaf whitefly (Nymphs)	2.9	4.5
Two-spotted spider mite	0.3	0.3

Regarding cotton diseases, they generally do not pose a major problem in Egypt. No significant diseases were observed that could cause economic losses or impact crop performance. Therefore, no data on diseases were included, as cotton production in Egypt is not affected by any economically important diseases during the growing season.

5.1.3 Beneficial Insects vs. Pest Ratio

The FAO promotes the use and conservation of beneficial insects as a cornerstone of Integrated Pest Management. The ratio of beneficial insects to pests is a key metric to determine when intervention is necessary, helping farmers avoid unnecessary chemical pesticide use and leverage nature's own control mechanisms. In line with this, the demo pilot focused on assessing this important metric.

The farmers' demo findings reveal that "after wheat" had the highest number of beneficial insects per cotton plant (3.72), almost double that of the control (1.96), while all other demos also had significantly more beneficial insects per cotton plant than the control. The demo plots performed well and had a lower number of pests per cotton leaf as compared to the control plot. "After wheat" plot performed better and had an average of 6.69 pests per cotton leaf, significantly lower than the control plot (11.36). In terms of beneficial insect-to-pest ratio, "after wheat" performed best, with a beneficial insect to pest ratio of 0.08, over three times higher than the control (0.02), indicating stronger natural pest regulation. Overall, demo plots demonstrated better biological control than the control plot, highlighting the positive influence of regenerative practices, with "after wheat" delivering the best results. A study by Botir and Sanjar (2021) also found that crop rotation reduces reliance on chemical pesticides especially cotton planted after wheat, thus, promoting a more resilient agro-ecosystem. It was also found that the number of spiders in the cotton field planted after grain were 3-4 times less, and diseases were decreased by 25-30%[9].

The CRI demo analysis presents that the agro-ecosystem had 9.7 beneficial insects per cotton plant compared to 5.5 in the control, indicating a stronger presence of natural pest predators.

9 https://www.researchgate.net/publication/350178312_Management_methods_of_harmful_pests_in_the_cotton-wheat_crop_rotation_system

Lower pest per cotton leaf in the agro-ecosystem (69.84) than the control (112.12) resulted in a favourable pest ratio for the agro-ecosystem (0.14) than the control (0.05). This reflects stronger natural pest control in the case of agro-ecosystem demos.

Table 6: Beneficial Insects, Pest Population, and Pest Ratio in CRI Demo Plots

CRI Plot	Number of beneficial insects per cotton plant	Number of pests per cotton leaf	Pest Ratio
Agro-ecosystem	1.2125	8.73	0.14
Control	0.6875	14.015	0.05

It is important to mention that the demo plots achieved better pest-beneficial insect ratios due to lower usage of pesticides (1500-1940 Ml-GM/Feddan across demo plots compared to 3000 Ml-GM/Feddan by conventional farmers), which created a healthier agroecosystem. Rationalised insecticide usage, based on correct timing, dosage, and regular scouting, prevented unwarranted sprays and thus helped protect beneficial insects. Further, bio-insecticides and traps support natural pest control. Overall, these practices strengthened pest regulation.

These results are consistent with the well-established evidence for Integrated Pest Management (IPM) showing that lower synthetic pesticide densities, proper spraying timing, use of bio-pesticides and pest monitoring through pheromone traps improve pest-predator balance and ecosystem resilience while reducing pest outbreaks[10].

Table 7: Beneficial Insects, Pest Population, and Pest Ratio in Farmer Demo Plots

Type of Plots (Farmer)	Average number of beneficial insects per cotton plant	Average number of pests per cotton leaf	Pest Ratio
After Wheat	0.53	6.69	0.08
After Clover	0.31	10.01	0.03
Seed mixed with biochar/ clover	0.39	9.39	0.04
After Flax	0.47	9.61	0.05
Control	0.28	11.36	0.02

5.1.4 Lint Quality Parameters

Cotton quality is determined by key parameters like micronaire (fineness/ maturity), fibre length, uniformity, strength and elongation for consistent evaluation, impacting yarn strength, appearance, and processing efficiency. Longer, stronger, more uniform fibres with good maturity and less trash yield higher quality yarn, influencing market value and end-use suitability. All these key parameters were captured under the pilot.

The findings reveal that across all farmer demos, lint quality parameters showed clear improvements over the control, with each plot exhibiting specific strengths. Micronaire values remained slightly above the ideal range, with "after clover"

10 https://www.fao.org/agriculture/crops/thematic-sitemap/theme/pests/ipm/en/

In terms of fibre length, the "after wheat" demo produced the highest fibre length, an increase of almost 1 mm over the control. Uniformity index was good across the treatments, with "after clover" and "Seed mixed with biochar /clover", having advantage of 0.5 over the control.

Fibre strength was consistently higher in all demos as compared to control with "after wheat" emerging as the best performing at 42.6 g/tex. Elongation remained within an acceptable range, with "after flax" and "after clover" providing the highest elasticity (5.8%). Overall, "after wheat" demo had the strongest impact, showing the most consistent and meaningful improvement in key quality parameters, particularly, fibre length and strength, making it best performing among all demos.

Regular improvement in cotton fibre quality across all farmer's demo plots compared to the control group, indicates positive impact of crop rotation on cotton fibre growth. The slightly higher micronaire reading with better result under legume-based crop rotation, along with superior fibre length and strength, particularly after cereal-based crop rotation, reveal greater stability in nutrient availability and a balance nitrogen uptake. Crop rotation promotes cellulose deposition in cotton fibres. Improved uniformity and adequate elongation across all demo plots also suggest reduced plant stress and synchronised boll ripening.

Overall, the strong and stable performance of cotton following wheat determines that well-managed crop rotation can improve fibre quality attributes, especially length and strength.

This finding supports established research showing that crop rotation and improved soil organic matter contribute to better distribution of metabolites in bolls, causing superior fibre quality[11].

Across all CRI demos, lint quality was consistently better than the control in most parameters. Micronaire values were improved in all plots, with "FYM with Biochar" (4.14) closest to the ideal range, outperforming other plots. For fibre length, "FYM with Biochar" (36.66 mm) outperformed all plots, achieving 1.09 mm more than the control. Most demos recorded higher fibre length than the control.

Uniformity index was good for all plots, with "20 cm single plant" closest to the control, which had the highest uniformity.

Fibre strength was consistently strong across all plots, with "30 cm double plant" being the top performer at 44.73 g/tex, an increase of 2.16 g/tex over the control. Elongation was highest in the case of "FYM" (6.77%), indicating superior elasticity, while the majority of other demos and the control had similar elongation values.

Overall, "30 cm double plant" stands out as the good performer due to its combination of high strength, good length, and strong uniformity, providing the more balanced improvement over the control.

Another study found that organic amendments (such as FYM and biochar), balanced nitrogen management, and suitable plant density improve cotton fibre length, strength, micronaire , and uniformity by stabilising nutrient uptake and reducing stress during fibre elongation and thickening stages[12].

11 https://cottongins.org/blog/enhancing-cotton-fibre-quality-through-agronomic-practices/
12 https://www.cabidigitallibrary.org/doi/pdf/10.5555/20193326647

Table 8: Lint Quality Parameters of Cotton in Farmer and CRI Demo Plots

Lint Quality Parameter	Micronaire	Fibre Length	Uniformity Index	Fibre Strength	Elongation
Farmer Demo Plots					
After Wheat	4.1	35.7	90.8	42.6	5.4
After Flax	4.4	35.0	90.6	40.8	5.8
After Clover	4	35.3	91.3	41.6	5.8
Seed mixed with biochar/clover	4.2	35.1	91.3	40.6	5.7
Control	4.1	34.7	90.8	40.1	5.8
CRI Demo Plots					
FYM	4.34	36.13	92.80	43.87	6.77
FYM with Biochar	4.14	36.66	91.03	43.43	5.83
Compost	4.22	36.38	91.33	44.13	5.87
Biochar	4.28	35.41	91.27	44.00	5.47
30 cm double plant	4.27	35.68	91.47	44.73	5.43
30 cm single plant	4.42	36.37	92.67	44.47	6.63
20 cm single plant	4.36	36.16	93.20	44.53	5.37
Agro-ecosystem	4.19	35.48	91.07	42.37	5.57
Control	4.6	35.58	93.50	42.57	5.67

It is important to highlight that improved lint quality could be linked with healthier plant growth. This growth has resulted with adoption of Regenerative practices like compost, FYM, and biochar, which helped enhance soil fertility, nutrient uptake, and root development. Crop rotation helps in retaining and adding residual nutrients which helped in enhancing fibre formation. Further, optimised plant spacing reduced competition and improved boll distribution. The findings show that REEL Regenerative practices combined with timely irrigation helped create stable conditions that helped improved fibre length, strength, uniformity and elasticity. Overall, the results confirm that improved soil health, proper spacing, crop rotation and time appropriate irrigation help enhance cotton fibre quality.

5.1.5 Profitability and Yield Analysis

Profit, input cost, and yield are key outcomes of any agronomic intervention, as they are the primary drivers of farmers' engagement and continued participation in programmes, which ultimately influence soil health and biodiversity.

The farmer demo plot analysis shows that all demo plots achieved higher yield and profit than control plots. The 'seed mixed with biochar/clover' plots recorded the greatest gains, with 300 kg/feddan higher (21.4%) yield and USD 259/feddan higher profit (26%) than the control.

When it comes to analysis at CRI plots, most demo plots outperformed the control in both yield and profit, with "with FYM" and "with biochar" showing the highest gains. The demo "with biochar" plot achieved the highest yield (14.5% or 207 kg/feddan more) whereas "With FYM" demo demonstrated highest profit (16.4% or USD 159.2/feddan more) as compared to control plots. This reflects demo plots "with biochar" and "with FYM" as the top performing demo plots.

The superior performance of plots mixing biochar with cotton seeds after clover at farmer level, and biochar or FYM at CRI level, reflects improved nutrient use efficiency, enhanced soil organic matter, and better synchronisation between nutrient supply and crop demand. Zhang et al (2020), in another study found that the application of organic fertiliser had a positive effect on the growth and yield of cotton crop[13].

Regarding the input cost, notably all farmer demos had slightly higher input costs, well explained by adoption of regenerative agriculture recommendations. It important to highlight that while bio-fertilisers were used to improve soil health, the training provided on trash and contamination removal added to the additional cost for the demo while the control farmers did not incur such expenses.

In the CRI demos, the higher input costs compared to the control was primarily due to the use of more expensive inputs, such as local FYM, compost, and biochar, while the remaining inputs had similar costs across both demo and control.

Overall, the results show that while organic amendments increase input costs (in the initial years of transitioning from conventional to regenerative), they provide significant benefits for plant nutrition and yield.

13 https://scispace.com/pdf/benefits-of-organic-manure-combined-with-biochar-amendments-10j7fz8obk.pdf

Table 9: Cotton Yield, Input Cost, and Profitability in Farmer and CRI Demo Plots

Type of Plots (Farmer)	Yield (Kg/Feddan)	Input Cost ($$/Feddan)	Profit ($$/Feddan)
After Wheat	1,560.0	710.4	1,169.7
After Flax	1,500.0	756.7	1,051.1
After Clover	1,650.0	750.7	1,237.7
Seed mixed with biochar/clover	1,700.0	798.7	1,250.0
Control	1,400.0	695.3	991.9
Type of Plots (CRI)	**Yield (Kg/Feddan)**	**Input Cost ($$/Feddan)**	**Profit ($$/Feddan)**
FYM	1,617.3	818.3	1,130.7
FYM with Biochar[14]	1,496.3	801.4	1,001.5
Compost	1,560.5	815.8	1,064.8
Biochar	1,636.4	843.0	1,129.1
30 cm double plant	1,486.4	768.5	1,022.8
30 cm single plant	1,140.7	690.9	683.8
20 cm single plant	1,392.6	747.5	930.8
Agro-ecosystem	1,406.0	736.2	958.2
Control	1,429.0	750.6	971.5

In a nutshell, it can be concluded that higher yield and profit in the demo plots were the result of the combined contribution of improved agronomic practices. These include careful soil preparation, application of organic soil amendments and bio-fertilisers leading to enhanced soil fertility and nutrient availability, and optimised fertiliser management. Further, proper water management, weed control and integrated pest management practices helped maintain crop health and boosted productivity. Together, these practices strengthened plant growth, improved soil health, and enhanced cotton yield and profitability.

Therefore, the findings show that integrated regenerative and sustainable practices significantly improve yield and profitability. While input costs were higher, the resulting increase in productivity, better fibre quality, and economic returns demonstrates that holistic agronomic management under regenerative approaches is both sustainable and profitable.

5.1.6 Key Soil Health Parameters

According to FAO, to prevent soil degradation and the loss or reduction of soil functions, including the provision of healthy and nutritious food, there is an urgent need for soils to be sustainably managed.

A prerequisite for the sustainable management of soil resources is the availability of reliable information and in particular, of information on how different soil management practices impact soils[15].

Aligned with this, key soil health parameters were assessed using soil sample testing at pre-sowing and post-harvest stage to gauge the impact.

The result of the post-harvest soil analysis in Farmer plots shows that all demo performed better compared to the control group.

14 Although biochar is costlier than compost and FYM, its use at only 20% when mixed with FYM significantly reduced input costs. Additionally, total cost variations reflect yield-linked harvesting expenses, with higher yields incurring higher picking costs.
15 https://openknowledge.fao.org/server/api/core/bitstreams/a673cac1-636c-486b-b4c5-a39d522b659f/content

Among all the "cotton after clover" demo performed better. In comparison to the control plots, this demo showed higher improvement in nitrogen (120 mg/kg vs. 78 mg/kg), phosphorus (10.02 mg/kg vs. 7.56 mg/kg), and potassium concentrations (230 mg/kg vs. 206 mg/kg) post intervention.

The "cotton after clover (seed mix with biochar)" demo ranked second with significant increments found post intervention in nitrogen (90 mg/kg vs. 78 mg/kg) and phosphorus (10.32 mg/kg vs. 7.56 mg/kg) concentrations compared to the control group, with increment growth in microbial growth.

The "cotton after flax" demo emerged as a distinct variant based on its effectiveness in increasing the levels of micronutrients like manganese (0.74 mg/kg compared to control of 0.48 mg/kg) and Iron (11.82 mg/kg compared to control of 7.43 mg/kg) levels. For control, there was little improvement or decline, for various major nutrients and biologically active indicators.

Post-harvest soil analysis from farmers' demo plots indicates that crop rotation with legumes and organic amendments significantly improves soil fertility compared to conventional practices.

Cotton planted after clover showed the highest levels of key nutrients (N, P, and K), showing the effectiveness of bio-nitrogen fixation, improved nutrient cycling, and increased soil nutrient retention.

Additionally, the addition of seed cotton mix with biochar after clover demo enhanced nutrient availability and microbial activity, confirming its role in improving soil biological activities and nutrient use efficiency.

Tang 2025, in another study found that biochar significantly improves soil nutrient dynamics by enhancing nutrient retention, reducing leaching, and alleviating acidity.

Its porous structure and functional groups adsorb essential ions, buffer soil pH, and increase the availability of N, P, and K across diverse soil types. Long-term applications further stabilise nutrient cycling and improve root growth, soil structure, and fertility[16].

16 https://www.mdpi.com/2076-3298/12/11/425#:~:text=In%20summary%2C%20biochar%20significantly%20improves,K%20across%20diverse%20soil%20types

Table 10: Soil Nutrient and Soil Health Parameters in Farmer Demo Plots

Type of Plots (Farmer)	After Wheat		After Clover		After Clover (seed mixed with Biochar)		After Flax		Control	
	PS	PH	PS	PH	PS	PH	PS	PH	PS	PH
Nitrogen (mg/kg)	69	77	78	120	78	90	84	99	75	77
Phosphorus (mg/kg)	7.32	9.1	7.56	10.02	7.56	10.32	9.9	8.92	9.96	7.92
Potassium (mg/kg)	214	235	206	230	206	215	205	225	203	200
Manganese (mg/kg)	0.51	0.56	0.42	0.56	0.42	0.5	0.49	0.74	0.59	0.48
Zinc (mg/kg)	0.3	0.21	0.33	0.32	0.33	0.33	0.37	0.3	0.36	0.31
Iron (mg/kg)	11.38	10.22	11.54	9.68	11.54	7.34	7.68	11.82	7.56	7.43
pH	8.3	8.1	8.6	8	8.6	8.5	8.3	8	8.4	8.3
Electrical Conductivity	0.92	0.72	0.82	1	0.82	1.49	1.4	1.38	1.54	1.65
Organic Matter (%)	2.28	3.24	2.57	2.63	2.57	2.63	3.09	3.2	2.55	2.57
Organic Carbon (%)	1.34	1.88	1.51	1.52	1.51	1.52	1.82	1.94	1.51	1.49
T.N %	0.26	0.38	0.32	0.84	0.32	0.55	0.43	0.5	0.34	0.3
Total count of Bacteria	52×10^{6}	57×10^{6}	70×10^{6}	76×10^{6}	70×10^{6}	68×10^{6}	45×10^{6}	40×10^{6}	30×10^{6}	28×10^{6}
Dehydrogenase	40 µTBF	40 µTBF	42 µTBF	45µTBF	42 µTBF	42 µTBF	38 µTBF	30 µTBF	29 µTBF	25 µTBF

P.S.- Pre-Sowing, P.H.-Post Harvest

The post-harvest analysis of soil results across CRI Plots shows that the treatment group performed better than the control in terms of improvement in nutritional parameters of soil.

The 'FYM + Biochar' model turned out to be the most effective among all the demos. Compared to the control, this demo plot has shown a significantly higher content of nitrogen (120 mg/kg vs. 85 mg/kg), phosphorus (11.22 mg/kg vs. 9.84 mg/kg), potassium (232 mg/kg vs.200 mg/kg), and exhibited the highest improvement in the essential micro-nutrients like manganese (0.95 mg/kg vs. 0.54 mg/kg) and iron (11.22 mg/kg vs.8.18 mg/kg).

The 'FYM-only' demo plot was found second most favourable in improving soil micronutrients, with significant improvements in phosphorus, potassium, zinc, and iron compared to the control. While the 'Compost-only' demo plot showed moderate improvement in soil health, compared to the control. In general, the 'FYM + Biochar' demo had the overall better results and resulted in better improvement compared to the control regarding the nutritional health.

Table 11: Soil Nutrient and Soil Health Parameters in CRI Demo Plots

Nutrient Parameters (CRI Plots)	Nutrient Levels (Pre- Sowing)	Nutrient Levels (Post-Harvest)				
		Only FYM	FYM + Biochar	Compost	Biochar	Control
Nitrogen (mg/kg)	81	90	111	120	90	85
Phosphorus (mg/kg)	9.9	11.92	11.22	8.22	6.32	9.84
Potassium (mg/kg)	205	220	232	195	190	200
Manganese (mg/kg)	0.5	0.54	0.94	0.95	0.43	0.54
Zinc (mg/kg)	0.32	0.38	0.36	0.38	0.28	0.37
Iron (mg/kg)	7.12	9.56	7.98	11.22	7.8	8.18
pH	8.2	7.9	8	8.1	8.1	7.6
Electrical Conductivity	0.87	0.95	0.94	2.25	0.66	1.7
Organic Matter (%)	2.65	3.24	5.62	2.14	2.63	2.32
Organic Carbon (%)	1.65	1.88	3.26	1.55	1.52	1.35
T.N %	0.37	1.2	2.5	1.3	0.9	1
Total count of Bacteria	70×10^6	75×10^6	80×10^6	74×10^6	72×10^6	73×10^7
Dehydrogenase	42 µTBF	40 µTBF	45 µTBF	42 µTBF	39 µTBF	40 µTBF

The improvements in soil health across the demo plots were driven by a combination of regenerative practices. Key factors included reduced tillage, which helped preserve soil structure and organic matter; application of organic amendments (FYM, compost, biochar) and bio-fertilisers, which enhanced microbial populations and activity, facilitating nutrient availability throughout the season.

Crop rotations and intercropping contributed additional organic residues and supported beneficial microbial and insect activity. Sustainable pest management, with reduced chemical pesticide use, minimised harm to soil biota and maintained ecological balance, further supporting soil health and fertility. Compost often shows higher nitrogen (N) in soil analysis because it releases N through mineralisation, contains higher readily available nutrients, it acts as a slow-release fertiliser. The positive effect of mixing biochar with organic manure is evident, resulting in a high organic matter value of 5.62. This improves all soil properties in terms of nitrogen, phosphorus, potassium, iron, and organic carbon content.

Iqbal et al (2023), found that the application of biochar and FYM, particularly in combination (Biochar+FYM) resulted in a substantial increase in soil organic carbon content showcasing a synergistic effect on carbon sequestration[17]. In another study, Karthik et al (2019) found that application of biochar as amendment to soil, improved fertility by retaining applied nutrients and increased the nutrient availability throughout crop growing period.

Moreover, it also serves as a better alternate for other organic manures as it does similar work as that of FYM and other composts, but, in a compact and effective way yielding earlier crop response. Similarly, Berihun et al (2017), found that biochar application results in decrease in soil bulk density, increasing soil fertility and structure, improved water holding capacity, organic carbon content, availability of nutrients and biological properties.

The findings indicate that integrated regenerative practices—including reduced tillage, organic amendments, bio-fertilisers, intercropping, and careful pest management—significantly improve soil fertility, organic matter, and microbial activity. Demos such as "Cotton after clover" and "FYM + biochar" consistently outperformed the control, showing that these practices not only restore soil health but also support sustainable cotton production by enhancing nutrient cycling, reducing chemical dependence, and promoting overall agroecosystem resilience.

5.2 Qualitative Insights

This sub-section presents key inputs received from farmers, government extension worker and CRI officials.

5.2.1 Farmer

The interaction with farmers highlighted that fortnightly visits during the first three months of establishing demo plots and thereafter monthly field support and input from the CottonConnect, CRI, and local extension worker facilitated rationalised and informed pesticide and fertiliser application, as excessive usage earlier had adversely impacted the input cost; reduced water usage; awareness regarding biochar, biofertiliser, and pest scouting (to a limited extent); and led to an increased yield.

One of the farmers said: *"Good information (capacity building) is equivalent to Money (profit)."*

The farmers stated that there is a growing concern regarding diminishing profits due to declining prices over the years, as the price has declined from EGP 13,000 – 14,000 two years ago to EGP 12,000 last year, and there is a perception that it will decline further to EGP 9,000 per quintal this year. Further, climate change with soaring temperatures have pushed the sowing time from April to June gradually. Notably, farmers acknowledged the availability of inadequate information on agronomic practices.

17 https://www.researchgate.net/publication/374887957_Biochar_and_Farm_Yard_Manure_Synergy_Enhancing_Soil_Health_and_Mitigating_Climate_Change_Impacts_in_Cotton_Production

5.2.2 Extension Worker

Mr. Abou Bakar - an extension worker appreciated the pilot, as previously the farmers relied on their own knowledge. He stated that imparting knowledge to farmers is making them resilient to climate change, mitigating soil health, and improving all crops in Egypt.

"This is an overall excellent (Mumtaaz) experience because it seeks to change the traditional information and change (evolve) to sustainability by using demo plots, practical work, and data."

The key suggestions for scale-up included increasing farmer numbers and land area and extending the scope beyond cotton to engage with farmers throughout the year:

- Greater use of IEC/Behaviour Change Communication (BCC) material to enhance awareness and adoption of regenerative practices among farmers
- Improved accessibility of biofertilisers
- We should establish at least one demo plot per village

Key considerations for scale-up by the extension workers:

- We should open a "regenerative market" with the provision of a premium price
- Develop a cadre of skilled human resources, including extension workers
- Organisations like CottonConnect should develop more cadres at the ground level

5.2.3 CRI Officials

The CRI officials reiterated the importance of the demo plots, considering the evolving challenges and climate change. They also underpinned the importance of establishing demo plots at an enhanced scale under different settings to generate further evidence for greater upscale. One of the most encouraging results for the demo plots was the quality of the fibre based on tests done at the CRI.

The CRI officials suggested the need to have a roundtable after the final demo plot data is available to decide the way forward.

5.3 Layered and Cross-Cutting Analysis

In this sub-section, we analyse the farmer plots and CRI plots findings, especially the soil health parameters. In addition, we have referred to the secondary sources to validate the project findings, including presenting the key contributing factors. The key analysis includes the interaction between the crop sown previously in the demo plots and how the different nutrients impact the soil health.

With reference to the crops

As per Cole R, et al (2025), Winter Cover Crops (WCC) increased Microbial Biomass Carbon (MBC) and Potential Mineralised Carbon (PMC) by 8% each and increased Potential Mineralised Nitrogen (PMN) by 11%, regardless of time, since implementation. Furthermore, sampling biological soil health indicators in the spring resulted in more positive, significant treatment effects (12%–19%) compared to sampling in the autumn, where we found no effect. WCC may increase subsequent summer crop yields by 7% in the long run[18].

18 https://acsess.onlinelibrary.wiley.com/doi/full/10.1002/saj2.70032

Winter wheat cover crops accrued 4-14% more total nitrogen (TN) but have no significant impact on seed cotton yield. Moreover, soil N availability declined in early stages of cotton crop growth due to increased N immobilisation by cover crops biomass[19].

Wheat is an exhaustive crop and consumes maximum macro and micronutrients from the soil during the growing period. The analysis of various parts, such as grain, leaves, and stem, indicated that the export of nutrients from the field to the plant ranged between 35.2 and 192.6 kg N ha, between 10.1 and 34.7 kg P ha-1, and between 54.5 and 223.0 kg K ha. The differences are determined by the higher amounts of biomass obtained in the cotton crop from the fertilised reserves left from the previous growing season. Maintaining a certain nitrogen deficiency would have a positive effect on such soils with light texture, allowing the use of the applied fertilisation and part of the soil nitrogen, thus obtaining sustainable yields with lower impact on the agro-ecosystem.

As the wheat crop absorbs maximum macro and micro nutrients from the soil during the growing period, therefore, its availability is low at the sowing time of the subsequent cotton crop, and hence, the management of nitrogen is very important for effective and efficient cotton crop production, which depends upon the external input[20].

Therefore, we assume that a certain amount of nitrogen was left in the soil from the previous growing season, which was subject to various transformations and movement along the profile, and should be taken into account for this type of soil.

The cotton crop growth data clearly reflects that the vegetative growth of the cotton crop is comparatively higher in the cotton plot sown after the wheat crop and lowest in the control plot, reflected in terms of plant height and number of sympodial branches as compared with other demos. However, the number of bolls per plant are lesser in the cotton plots after wheat compared with the cotton crop sown after clover and after clover and seed mixed with biochar.

Looking at the post-harvest soil analysis, the availability of nitrogen is 77 in the plot after wheat, compared with other demo plots – 120 in the case of clover and 90 in the case of clover and seed mixed with biochar, 99 after flax, and 77 in the control. In the case of the control plot, there is a minor difference in soil nitrogen content in pre and post sowing results, which indicates irrational and inconsistent utilisation of nitrogen in the cotton crop.

Similarly, the average boll weight is also less in the case of cotton sown after wheat (3.93gm) compared with cotton sown after flax (4.27gm), clover (4.24gm), clover/seed mixed with biochar (4.20gm), and it was lowest in the control (3.92).

Wheat grain yield is a sensitive productivity parameter that is significantly influenced by the applied fertilization. Wheat is known as a crop that has an extremely high demand for phosphorus in the early growth stages.

A healthy wheat crop takes up 15 lbs/ac of phosphorus (P20 5 equivalent) in the first 30 days of growth, compared with other grain crops like soybeans that require only 1 lb/ac of phosphorus in the first 40 days of growth[21].

19 https://www.sciencedirect.com/science/article/abs/pii/S0378429022002325
20 Almaliev M, Panayotova G and Kostadinova S, 2013. Relationship of durum wheat yield and grain quality from nitrogen fertilization. Bulgarian Journal of Crop Science, 50, 5-9
21 https://agriscitech.eu/wp-content/uploads/2024/03/11-AST_1_March_2024.pdf

At the pre-sowing cotton stage, the available phosphorus in the soil was 7.32 percent in the plot after wheat harvest, lower than the available phosphorus in the plot after clover (7.56) clover/ seed mixed with biochar (7.56), and plot after flax (9.9), and it was maximum 9.96 in the control. Looking at the post-harvest soil analysis results, it was 9.1% phosphorus in the plot after wheat crop, 10.02 after clover, and 10.32 after clover/seed mixed with biochar. However, the phosphorus level dropped in post-harvest analysis in the case of after flax and in the control plot[22].

Looking at various cotton plant growth parameters, the average plant height was higher in the case of plot after flax (163.2), followed by plot after clover/seed mixed with biochar (157.4) and after clover only (146.8).

However, looking at the sympodial branches per plant, numbers are almost identical in all the treatments, ranging from 13.6 to 13.7 per plant.

The number of bolls per plant is maximum in case of the plot after clover/seed mixed with biochar (41.4), followed by after clover (38.2), after wheat (34.0), and lowest in after flax (31.3).

With reference to Soil Chemical Properties

Various soil characteristics, such as pH and soil macro and micronutrients, such as iron, zinc, and manganese, impacted crop and soil health significantly under different demonstrations.

The pH is higher in all the treatments except in the demo where FYM was applied (7.9%), and low impact of growing wheat, flax, and clover before cotton sowing and using seed treated with biochar.

The pH level strongly influences soil function, including the Nitrogen and Phosphorus cycles, which are inhibited by high pH, and pH values below 5.5 and between 7.0 and 8.5 limit the availability of phosphate for plants.

The effectiveness and potential carryover of certain herbicides are also impacted by soil pH.

Similarly, iron, zinc, and manganese availability to the plant reduces significantly under high pH levels[23].

Although Fe is abundant in soils, mostly present as ferric (hydro) oxides, its availability to plants is limited due to the extremely low solubility of oxides[24]. Moreover, the efficiency of soil Fe supply is influenced by soil pH[25].

Despite year after year positive Zn balances suggests that added Zn is rapidly fixed into non-available pools and not available to the plant in case of high pH levels in the soil[26].

Manganese (Mn) is an essential plant mineral nutrient, playing a key role in several physiological processes, particularly photosynthesis. However, due to a higher soil pH level, its availability to the plant is restricted to a greater extent[27].

In the plot where cotton was sown after the wheat crop, the percent organic matter was 2.28% before cotton sowing, and it was increased to 3.24% after the cotton was harvested.

22 https://www.ontariosoilcrop.org/wp-content/uploads/2023/01/V1Cer5.pdf
23 https://www.nrcs.usda.gov/sites/default/files/2022-10/Soil%20PH.pdf
24 https://www.sciencedirect.com/science/article/abs/pii/S016788092300364X
25 https://www.sciencedirect.com/science/article/abs/pii/S2211912423000676
26 https://fertiliser.org/wp-content/uploads/2023/01/2011_zinccrops2011_rashid.pdf
27 https://www.cropnutrition.com/resource-library/manganese-in-crop-production/

It was followed by 2.57% at the pre sowing stage compared with 2.63% at post-harvest in the plot where cotton was sown after clover compared with 2.57 at pre-sowing stage to 2.63% at post-harvest in clover/seed mix with biochar.

Whereas, it was 3.09% at the pre-sowing stage of cotton compared with 3.20% after the cotton crop is harvested in the plot after flax. Whereas, in the control plot, it was 2.55% at pre-sowing compared with 2.57% after harvest.

The long-term cultivation of winter wheat in the rotation contributed to an increase in the amounts of total organic carbon/matter, total nitrogen, and the available forms of phosphorus, potassium, and magnesium. However, key soil health indicators, such as the amounts of humic substance carbon and available nitrogen, tended to decrease with an increase in the share of winter wheat in the crop rotation[28].

The results concerning whether biochar can promote Phosphorus (P) uptake or release remain inconsistent.

Most studies have reported that biochar supplementation in agricultural systems can effectively increase soil P availability and thereby promote plant growth. In general, adding biochar to soil can effectively enhance soil P availability.

It is not currently possible to eliminate all risk of P migration when it comes to using compost, but that is not the most important point[29]. A study reported that the integrated application of FYM and Di-Ammonium Phosphate (DAP) increases nutrient use efficiency and crop productivity[30].

Another study concluded that FYM concoction with fertiliser-P not only improved SOM and residual soil P, but also enhanced crop yields with reasonable P efficiency, which is clearly reflected in the results – both soil analysis and seed cotton yield[31].

Biochar increases the soil's available Potassium (K) content by introducing water-soluble K while simultaneously improving the soil's long-term potassium buffering capacity.

The biochar significantly improved the potassium supply capacity and crop potassium accumulation across all soil types, although the optimal application rate varied based on the soil type[32].

The results indicate that cultivating flax contributes to carbon sequestration and enhances organic matter in the soil.

When flax is harvested, its leftover biomass decomposes, enriching the soil carbon, nutrients, and improving its structure[33]. The results of the demonstration support that flax helps in improving the soil organic carbon from 1.82% at the pre-sowing stage to 1.94% after harvest.

When clover is planted as a cover crop, it grows a dense mat of stems and leaves that helps to suppress weeds and retain soil moisture. This reduces soil erosion and runoff, allowing more water to penetrate the soil and reducing the need for irrigation. The roots of the clover plant also help to break up compacted soil, making it easier for air, water, and nutrients to reach plant roots.

28 https://www.mdpi.com/2077-0472/15/13/1456
29 http://www.mncompostingcouncil.org/uploads/1/5/6/0/15602762/mncc_p_white_paper_3-19_final.pdf.pdf
30 https://www.sciencedirect.com/science/article/abs/pii/S0378429025001972
31 https://pmc.ncbi.nlm.nih.gov/articles/PMC9900179/
32 https://www.mdpi.com/2223-7747/14/13/1959
33 https://knowingfabric.com/the-soil-health-benefits-of-growing-hemp-and-flax/

In addition to its physical benefits, clover also increases soil organic matter content by adding organic matter to the soil through its leaves and roots. This increases the soil's ability to support microbial life, which is essential for plant growth and soil health.

The soil analysis results from the demo plots indicates relatively high population of soil microorganisms, 70X106 total bacterial count at the pre-sowing stage, compared with 76x106 at the post-sowing stage, whereas in the case of the control plot, the population of microorganism range from 30X106 bacterial count at the pre-sowing stage to 28x106 total count at the post-harvest.

By attracting beneficial insects, clover helps to promote a balanced ecosystem, reducing the need for pesticides and improving soil health. Beneficial insects also help to pollinate plants, increasing yields and improving crop quality[34].

CRI DEMOS

Farm Yard Manure (FYM) provides the most effective options for improving soil quality and crop growth. It results in increasing organic carbon (OC) levels, nutrient availability, and enhanced activity of beneficial enzymes throughout the growth stages of the crops.

FYM enhances soil's water and nutrient availability by increasing Soil Organic Carbon (SOC) through direct C inputs or indirectly through the accumulation of belowground biomass, leading to increased agricultural productivity. Soil microbial biomass and enzyme activity are more responsive to changes in soil management than total soil organic matter (SOM).

Therefore, their assessment is a highly responsive indicator of SOM decomposition. Various soil parameters regulate enzyme activity, including physicochemical properties, N supply and its dynamics, soil microbial community, vegetation type, crop growth stages, and ecological disturbances.

Microbial activity tends to be more intensive during the intense growth stage of crops, particularly at flowering. However, it gradually decreases when the crop approaches maturity[35].

Compost is a source of organic matter, providing nutrients and structure to soils.

Soil organic matter helps to create stable soil aggregates, which increases soil porosity and makes soil more resistant to being dispersed by wind and rainfall, inhibiting soil erosion. Improved soil porosity and lower bulk density facilitate water infiltration, water percolation, and soil aeration, helping soils absorb and retain more water and providing space for roots to grow and for soil organisms to move and breathe.

Compost application benefits soil chemistry as well, stabilizing the pH of soil and adding nutrients to increase soil fertility. Compost contains essential plant macro- and micronutrients, including nitrogen (N), phosphorus (P), and potassium (K). These nutrients are mostly in slow-release, organic forms, which are less prone to run off and cause pollution in water bodies, compared to inorganic fertilisers.

Applying compost can help soil retain nutrients and keep soil pH near neutral, which enhances the availability of nutrients to plants.

Compost also increases the organic carbon in soils by adding carbon directly and by increasing the productivity of plants, which in turn adds carbon through roots and residues.

34 https://gardenerbible.com/what-does-clover-do-for-soil/
35 https://www.nature.com/articles/s41598-024-72076-w

Finally, compost benefits soil biology by improving the diversity and abundance of beneficial soil organisms, which feed on soil organic carbon and make nutrients available for plants to use[36].

The soil analysis results indicate that total soil nitrogen was 81 at the pre-sowing stage compared with 90 at the post-harvest stage, where FYM was applied.

In case of plots where both FYM and Biochar were applied, the soil nitrogen content at post-harvest stage was 111, followed by 120 where only compost was used, and 90 where only biochar was used, compared with 85 in the control at post-harvest stage.

The compost facilitates effective utilisation of available phosphorus and potassium by the plant, and resultantly their ratio in the post-harvest stage decreases - phosphorus 8.22 and potassium 190 compared with 9.84 phosphorus and 200 potassium in the control.

The biggest advantage of using FYM and Compost is that both of them facilitate enriching the soil with microorganisms and accelerate the decomposition process[37].

Diverse microbial communities in compost/FYM enrich soils with various beneficial organisms that contribute to nutrient cycling and disease suppression[38].

Under various demonstrations, the maximum biodiversity load was observed in the plot treated with both FYM and Biochar 80x10x6, followed by FYM 75x10x6 in the plot with only FYM and 74x10x6 in the compost plot, compared with the pre-sowing control 70x10x6 and post-sowing control of 73x10x6.

Due to higher microbial activities in the plot treated with FYM (3.24%) and with both FYM and Biochar (5.62%), the percent organic matter was significantly higher at the post-harvest stage as compared with the control plot 2.32%.

The micronutrients – zinc, iron, and manganese were almost at the same level in all the plots during pre-sowing and post- harvest stage, except the level of magnesium was higher in FYM/ Biochar and compost plots due to higher concentration of magnesium in the compost and FYM – up to 277.

The results of this long-term experiment underline the fertilisation effect of compost through the soil nutrient pool and suggest that the compost can substitute mineral N, P, and K fertilisers to some extent. A major problem, however, is the synchronisation of plant N demand and N supply through minesalization. Compost application with the goal of fulfilling the crop's N demand results in imbalances of nutrients, especially a surplus of P.

Nutrient surpluses and deficits also affect the extractable soil nutrient content. Therefore, compost could be used to increase soils low in P, as often found in organic agriculture. In soils with moderate or high CAL-P levels, compost application should be limited by the P input and combined with additional N sources.

A combination of compost with mineral fertiliser can secure yields in all investigated crops and has the additional advantage of balancing out the P supply.

Growth Parameters

The cotton plant height was higher in the case of the plot where compost was used (160cm), followed by the plot with Biochar only (159.4cm), FYM (158.2cm), and mix with Biochar (152.4cm).

36 https://www.epa.gov/sustainable-management-food/benefits-using-compost
37 https://onlinelibrary.wiley.com/doi/full/10.1002/jpln.202200270
38 https://pure.au.dk/ws/files/404888462/Journal_of_Plant_Nutrition_and_Soil_Science_-_2023_-_Reimer_- _Assessing_long_term_effects_of_compost_fertilization_on_soil.pdf

The sympodial branches were higher in the plot where biochar was used (17.4), compared with other plots where these branches ranged from16.0 to 16.2 per plant. On the other hand, the number of bolls/plant was higher in the case of the plot where only compost (38.6) was used, followed by the plot with FYM mix with Biochar (34.8), Biochar only (28.9), and FYM only (25.1).

The FYM contains a sufficient amount of Nitrogen (0.87%), Phosphate (0.47%), Potassium (0.77%), and Sulphur (0.42%), while the chemical composition of compost is 0.5% Nitrogen, 0.15% Phosphate, and 0.5% Potassium. Therefore, the external input of the synthetic fertiliser should be managed as per requirements to avoid excessive cotton plant growth.The biochar mainly comprises carbon, with total nitrogen 0.85 to 1.15%, total phosphate 0.11 to 0.14%, total potash 3.6 to 4.8%, and pH ranging from 8.0 to 10.4 in the case of biochar made from rice straw[39].

The average weight of the boll was maximum in 4.317gm in the plot with FYM only, followed by 4.307gm in the plot treated with compost, 3.94 gm in the plot with only biochar, and 3.84gm in the plot with FYM mixed with biochar.

Cotton Lint Quality

Regenerative cotton crop management practices can improve fibre uniformity by 5-10%, directly impacting gin turnout and market value.

These approaches draw on soil health, plant physiology, plant population, and efficient pest management using integrated pest management techniques.

Soil Management

Soil structure, pH, and organic matter directly influence root development, which in turn affects Fibre elongation and maturity. In loamy soils typical of many cotton regions, maintaining a pH between 6.0 and 6.8 optimizes micronutrient availability, preventing issues like short staple length from zinc deficiencies.

- Deep tillage allows roots to access deeper moisture and nutrients. Data indicates this can increase fibre length by up to 1/32 inch in responsive fields.
- Incorporating crop residues or cover crops to raise organic content improves water-holding capacity, reducing stress during boll fill that causes weak fibres. In trials, fields with higher organic matter showed 15% better fibre strength.
- Efficient nitrogen fertiliser promotes fibre quality parameters, as excess nitrogen promotes vegetative growth at the expense of fibre quality.

Nutrient Optimisation: Balancing for Fibre Traits

Nutrients play a pivotal role in cotton fibre quality through agronomic practices. Potassium, for instance, strengthens cell walls, enhancing tensile strength, while boron aids in fibre elongation.

Deficiencies show up as short, immature fibres, so timing and rates are critical.

In the case of cotton sown after the wheat crop, all the important lint parameters, such as micronaire, length, and strength, are on the higher side due to the availability of balanced macro and micro nutrients.

Similarly, plots with compost, FYM, and Biochar yielded high- quality cotton lint where micronaire, fibre length, and strength are within desired ranges. Use of micronutrients has no significant impact on lint quality except for magnesium[40].

Magnesium maintains ratios to avoid imbalances that cause micronaire to remain within the desired limit, and this is clearly reflected in the lint analysis results. In case of plots with FYM, Compost, and Biochar, the magnesium ratio is comparatively high and resulted in better lint quality parameters.

39 https://www.mdpi.com/2073-4395/14/11/2540

40 https://www.sci-int.com/pdf/636324839629753838.pdf

Water Management

Precision for Fibre Maturity: Irrigation directly impacts cotton fibre quality through agronomic practices by influencing boll development and maturity. Too little water stresses plants, shortening fibres and excess water leads to rank growth and delayed maturity.

Pest and Disease Control

Protecting Fibre Integrity: Pests and diseases compromise cotton fibre quality through agronomic practices by damaging bolls or stressing plants. Bollworms, for instance, scar fibres, while Fusarium wilt disrupts vascular flow, leading to immature lint.

Scouting Protocols: Weekly checks from squaring onward identify thresholds early and use traps for moth flights to time sprays[41]. The results clearly indicate that in the plot with Agro-ecosystem analysis, the lint has balanced characteristics.

Challenges in Fibre Quality Enhancement

Variable weather, input costs, and resistance issues challenge cotton fibre quality through agronomic practices. Drought shortens staples; mitigate with resilient varieties and conservation tillage. Rising fertiliser prices demand efficiency; soil tests guide reductions without quality loss.

41 https://cottongins.org/blog/enhancing-cotton-Fibre-quality-through-agronomic-practices/

6. Lessons Learned

It is critical to identify and document what worked well, challenges faced and the mitigation strategies adopted to address the challenges. This helps the roadmap for ensuring inclusion of the approach as well as considering the probable challenges from different perspectives for scale-up and extension to other geographies.

6.1 What Worked Well and Why

Since the conceptualisation and inception of the project, several initiatives were implemented that played a critical role in planning and execution, and were decisive to the overall success of the pilot. Some of these are highlighted below:

- Strong government engagement by involving the Under Secretary of Kafr El-Sheikh Agriculture Directorate, enhancing local ownership and commitment to project goals. The early and collaborative relationship with the local cooperative was established through continuous presence, regular meetings, and direct involvement in planning and implementation activities from the outset of the project.

- Leveraging the leadership of a woman head to advance women's empowerment and inclusive participation within the project. Special emphasis was placed on engaging the cooperative's leadership, and Mrs. Inas Badr, Head of Qalin Cooperative played a key role in facilitating communication and trust between the project team and farmers. It helped demonstrate that women can lead in senior leadership positions within agricultural cooperatives

- Trust-based engagement drives adoption, regular interactions, field demonstrations, and peer learning prove highly effective in encouraging farmers to adopt new sustainable practices. Adoption of regenerative practices was promoted through practical field demonstrations, continuous on-site technical backstopping, and regular follow-up visits to address initial resistance and build farmers' confidence. Farmers were also trained to use locally available resources to implement biological control measures, such as preparing simple traps made from sheets coated with grass and sticks and hanging them in the field to control whitefly populations.

- Due to the limited availability of regenerative agriculture inputs locally, the project team coordinated directly with the Agricultural Research Center (ARC), Cairo to source biofertilisers, biochar, and other required inputs. This collaboration ensured the technical credibility and quality of inputs, while also strengthening institutional linkages between the project and national research bodies. Although it required additional logistical planning, this approach enabled timely field application and supported compliance with regenerative agriculture

- Strengthened institutional collaboration by completing all administrative procedures in close coordination with CRI and forming a dedicated core team to drive joint implementation efforts. Strong collaboration between key stakeholders: UNIDO, CRI and CottonConnect through regular monthly progress updates and timely ad-hoc coordination, ensured continuous alignment, trust building, and addressing issues on an ongoing basis. This included assessing farmers' actual needs at the commencement, jointly developing the implementation plan, and preserving close coordination throughout all stages of execution. Such an inclusive and structured approach ensured that activities were relevant, well-sequenced, and responsive to on-the-ground actualities.

6.2 Implementation Challenges and Mitigation Strategy

Some of the key challenges faced along with mitigation strategies adopted are outlined below:

- Limited skilled staff in the cooperative was a challenge, which was addressed through continuous technical backstopping and on-site coaching by the project team to ensure the correct application of regenerative practices.

- Further, it was felt that there is a need for direct incentive mechanisms for farmers to support continued cooperation, particularly linking production to marketing.

- Another issue was regarding the local availability of Regenerative Agriculture Inputs, such as biochar, beneficial insects, and other materials, had to be sourced directly from the Agricultural Research Centre (ARC), Cairo, causing delays and added logistical coordination.

7. Conclusions and Recommendations

7.1 Key Findings

The key findings focus on the key project outcomes i.e. growth parameters, pest and disease infestation, beneficial insect to pest ratio, yield and profit, lint quality, and soil health parameters. Based on these findings, conclusions are drawn to identify the key contributory factors.

7.1.1 Growth Parameters

Farmer demo plots showed improved plant height, and bolls compared to the control, with "after wheat" giving the tallest plants and "seed mixed biochar/clover" the highest bolls per plant. Sympodial branches followed a similar positive trend. Across the CRI plots, most demos had better than growth parameters, with "with compost", achieving the tallest plants, and highest bolls per plant. All demos exceeded the control in sympodial branches led by "with biochar".

The improvements in key growth parameters can be linked to enhanced soil health resulting from regenerative practices, including the application of organic amendments, use of bio-fertilisers, crop rotation, optimised water and nutrient management.

7.1.2 Pest and Disease Infestation

The farmer demo plots had lower average number of pests per cotton leaf than the control with the "after wheat" showing the lowest incidence. Beneficial insects were scarce and showed no difference between the two groups. Agro-ecosystem plots consistently had lower pest infestation than the control, particularly for leafhopper, aphid, and whitefly. Aphid and whitefly populations were less by at least 50%, reflecting the effectiveness of agro-ecosystem based pest management.

Lower pest levels could be contributed to improved crop management, and regenerative practices that reduced stress and disrupted pest cycles. Further, timely pest scouting, targeted control measures and improved field conditions combined to help reduce pest pressure and thus, reliance on chemical insecticides.

7.1.3 Beneficial Insects vs. Pest Ratio

Demo plots had higher beneficial insect populations and lower pest levels than the control, with "after wheat" delivering the best results. This demo achieved nearly double the beneficial insects and a threefold higher beneficial insects-pest ratio, indicating strong natural pest regulation. Regarding the CRI, agro-ecosystem plots supported more beneficial insects and fewer pests per leaf than the control, resulting in a better beneficial insect–pest ratio, reflecting enhanced biological control.

This could be contributed to rationalised pesticide use due to regular pest scouting, use of bio-insecticides and traps.

7.1.4 Lint Quality Parameters

All farmer demos showed improvements in lint quality over the control, with gains in length strength, uniformity, and elongation. The "after wheat" demo delivered the most consistent improvements, particularly in fibre length and strength. For the CRI plots, all demos consistently performed better than the control across all the quality parameters, with notable gains in micronaire, fibre length and strength. The "FYM+Biochar" demo delivered the best outcomes, combining high fibre strength with good length and uniformity. Improved lint quality could be contributed to healthier crop growth under generative practices such as compost, FYM, biochar, crop rotation, and optimised spacing. Therefore, these regenerative practices helped enhance soil health and growing conditions, leading to better fibre length, strength, uniformity and elasticity.

7.1.5 Profitability and Yield Analysis

All demo plots achieved higher yield and profit than control plots, with 'seed mixed with biochar/clover' plots delivering the highest advantage of 21.4% and 26% more yield and profit respectively than the control. This highlights the strong positive economic impact of demo plots. For CRI, most demo plots outperformed the control in both yield and profit, with "with biochar" for yield and "With FYM" for profitability. This reflects demo plots "with biochar" and "with FYM" as the top performing demo plots. Input costs were notably higher for both farmer and CRI demos as compared to respective controls.

It can be concluded that higher yield and profit in the demo plots were the result of the combined contribution of improved agronomic practices including the use of organic applications and improved management practices. Further, it is important to highlight that though the demo plots had higher input costs, these critical interventions led to not only increased yield and profit but also improved soil health.

7.1.6 Key Soil Health Parameters

The post-harvest soil test analysis reveals that all farmer demos performed better than the control, with "cotton after clover" delivering the highest improvement in nitrogen, phosphorus and potassium. "Cotton after clover (Seed mixed with biochar)" also notable nutrient and microbial gains, while "cotton after flax" was most effective in improving key micronutrients such as, iron and magnesium.

All CRI plots also showed better soil nutrient status than the control, with the "FYM + biochar" demo overall delivering the best outcomes, achieving the highest gains in major nutrients and micronutrients, followed by "FYM only", while "compost" alone had moderate improvement. Therefore, we can say that demos such as "Cotton after clover" and "FYM + biochar" demonstrate strong potential for restoring soil health, and supporting resilient, sustainable cotton production.

The improvements in soil health across the demo plots were driven by a combination of regenerative practices including reduced tillage, application of organic amendments (FYM, compost, biochar) and bio-fertilisers that enhanced microbial activity and nutrient availability. Crop rotations, intercropping and reduced chemical pesticide use further supported biological activity and nutrient cycling.

7.2 Conclusion

Among the farmer demos, “after wheat” consistently had strong performance in growth parameters, having the tallest plants, and delivering the best in pest management and beneficial insect – pest ratio. The “seed mixed with biochar/clover” had the highest boll production and achieved the highest yield and profit, highlighting its significant economic impact. In terms of lint quality, “after wheat”, provided consistent improvements in fibre length and strength, while soil health improvements were highest in “cotton after clover” for major nutrients and in “cotton after clover (seed mixed with biochar)” for microbial and nutrient enhancements. Overall, these demos demonstrate the combined benefits of regenerative practices on crop growth, productivity, pest regulation and soil fertility.

For CRI plots, “with compost” delivered the best results in growth parameters, producing the tallest plants and the highest number of bolls per plant. Agroecosystem-based demos had consistently reduced pest incidences, thus achieving a favourable insect–pest ratio, reflecting strong natural pest regulation. Regarding the lint quality, the “FYM+Biochar” demo delivered superior fibre strength, length and uniformity. Key economic impact outcomes, yield and profit were highest in “with biochar” and “with FYM” demos, respectively. Soil health improvements were most remarkable in “FYM + biochar”, followed by “FYM only”, indicating the critical role of organic inputs and regenerative practices.

We can conclude that improvement in growth, yield and lint quality in the demo plots was driven by the adoption of regenerative practices that enhanced soil health, including organic inputs, bio-fertiliser, crop rotation and nutrient management. Lower pest pressure and a stronger beneficial insect–pest ratio resulted from rationalised pesticide application, regular scouting, targeted interventions like using traps and improved field conditions. Overall, we can say that the adoption of regenerative practices helped achieve increased yield and profit despite an increase in input costs but it also helped enhance soil fertility, microbial activity and economic resilience, thus supporting sustainable cotton production.

8. Recommendations for Replication or Scale-up

In this sub-section, we present key recommendations voiced by different stakeholders as well as those based on the key study findings

- **Implementation at Scale**: CRI officials strongly suggested implementing the select demo plots at scale in different settings with a large number of farmers to generate greater evidence to help develop national guidelines on regenerative cotton farming in the country
- **Private Sector Engagement**: Different stakeholders suggested involving private sector players (brands and traders) to support different regenerative programmes, linking the programme farmers to a premium pricing as a reward for adoption of the regenerative practices. The positive externalities were justified based on the positive and encouraging outcomes on lint quality which will be economically rewarding for the private sector. Further, it will help achieve better soil health, and address evolving climate challenges faced by the farmers, and the sector
- **Building Skilled Resource:** Develop a cadre of service providers at different levels (extension workers, CRI staff at the province, private sector and on-ground staff)
- **Demonstration Effect**: Establishing at least one demo plot in each intervention village will help demonstrate the benefits of the regenerative practices to help encourage further adoption
- **Engagement Strategy**: Engaging early with farmers before the beginning of the season and around the year, is likely to have a greater positive impact
- **Evidence Generation**: Proven on-farm trials produce immediate positive results; and it is preferred to conduct trials and share the outcomes with the farmers. Therefore, strong and sustained focus on strengthened monitoring, evaluation, and learning is imperative

9. Glossary of Key Terms

Demo plot: Demonstration plot is defined as plot on which regenerative practices are implemented

Control plot: Control is a convention plot with no intervention. It is implemented in a similar setting as that of a demo plot

Electrical Conductivity (EC): A measure of soil salinity. Higher values indicate more salts in the soil, which can affect plant growth.

pH: pH means "potential of Hydrogen." A measure used to show how acidic or alkaline (basic) something is, most commonly soil or water.

UNIDO

ITPO
INVESTMENT AND TECHNOLOGY PROMOTION OFFICE
ROME, ITALY

ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

The report has been drafted by CottonConnect team:

Prakash Menakel Philip, Global Director - Strategy and Impact (MEL)
Arif Makhdum, Consultant - Global Regenerative Lead
Hesham Hamoud, Senior Cotton Specialist

THE EGYPTIAN COTTON PROJECT
مشروع القطن المصري

For more information