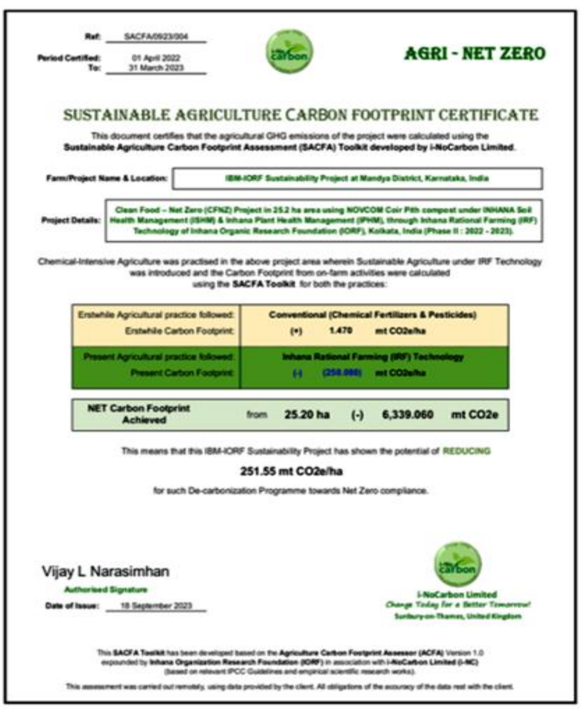
PROJECT REPORT

(Phase III : 2023-24)



Ref: SACFA/0923/004

Period Certified: 01 April 2022
To: 31 March 2023

AGRI - NET ZERO

SUSTAINABLE AGRICULTURE CARBON FOOTPRINT CERTIFICATE

This document certifies that the agricultural GHG emissions of the project were calculated using the **Sustainable Agriculture Carbon Footprint Assessment (SACFA) Toolkit developed by i-NoCarbon Limited.**

Farm/Project Name & Location: IBM-IORF Sustainability Project at Mandya District, Karnataka, India

Project Details: Clean Food – Net Zero (CFNZ) Project in 25.2 ha area using NOVCOM Coir Pith compost under INHANA Soil Health Management (ISHM) & Inhana Plant Health Management (IPHM), through Inhana Rational Farming (IRF) Technology of Inhana Organic Research Foundation (IORF), Kolkata, India (Phase II : 2022 - 2023).

Chemical-Intensive Agriculture was practised in the above project area wherein Sustainable Agriculture under IRF Technology was introduced and the Carbon Footprint from on-farm activities were calculated using the **SACFA Toolkit** for both the practices:

Erstwhile Agricultural practice followed: Erstwhile Carbon Footprint:	Conventional (Chemical Fertilizers & Pesticides) (+) 1.470 mt CO2e/ha
Present Agricultural practice followed: Present Carbon Footprint:	Inhana Rational Farming (IRF) Technology (-) (250.080) mt CO2e/ha
NET Carbon Footprint Achieved	from 25.20 ha (-) 6,339.060 mt CO2e

This means that this IBM-IORF Sustainability Project has shown the potential of REDUCING

251.55 mt CO2e/ha

for such De-carbonization Programme towards Net Zero compliance.

Vijay L Narasimhan
Authorised Signature
Date of Issue: 18 September 2023

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Sunbury-on-Thames, United Kingdom

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This assessment was carried out remotely, using data provided by the client. All obligations of the accuracy of the data rest with the client.

Adoption of a Cluster of Villages for Agricultural Sustainability and Food Security through Clean Food Program & Soil Health Management Program in about 25 ha

Phase – III

- New 100 ha : Mandya District , Karnataka, India
- Continuation Project 100 ha : Nadia District, West Bengal, India

Project Period : 2023 – 2024

Submitted By
Inhana Organic Research Foundation (IORF)
168 Jodhpur Park, Kolkata – 700068, West Bengal, India
Email : inhana.rftprojects@gmail.com
Website : www.inhana.in

IBM - IORF SUSTAINABILITY PROJECT

Adoption of a Cluster of Villages for Agricultural Sustainability and Food Security through Clean Food Program

PROJECT TEAM
Inhana Organic Research Foundation (IORF)
Dr. Ranjan Bera
Dr. Antara Seal
Dr. Anupam Datta
Ms. Susmita Saha
Mr. Somesh Dutta

Project Sites :

- Continuation Project 100 ha : : Mandya District, Karnataka, India
- Continuation Project 100 ha : Nadia District, W. B., India

Project Duration : 2023 – 2024

TECHNICAL ASSOCIATION

Dr. Koushik Mukhopadhyay,
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Visvabharati University, Santiniketan

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Foreword

As we navigate the intricate tapestry of agricultural sustainability, it is imperative to acknowledge the interconnectedness of our actions with the broader ecosystem. Inhana's journey has been one of relentless pursuit, driven by a profound recognition of the symbiotic relationship between humanity and the earth.

In our quest for Sustainable Agriculture, we confront the formidable challenges of global warming, climate change, and the imperative of nourishing one billion lives in India alone. The agricultural sector, intertwined with the fabric of our society, stands as **both a sustainer of livelihoods and a significant contributor to greenhouse gas emissions.**

Within this paradigm, the emergence of the **'Clean Food' to 'Clean Food Net Zero' models,** borne out of the collaborative endeavors of Inhana and IBM, epitomizes a beacon of hope. Rooted in the ethos of sustainability, this model transcends conventional agricultural practices, ushering in a new era of conscientious cultivation. **Through the fusion of IRF Technology for Plant Health Management and Novcom Composting Technology for Soil Health Management, we embark on a transformative odyssey towards agricultural sustainability.**

The Clean Food Net Zero Model, a culmination of rigorous experimentation and visionary foresight, heralds a paradigm shift in our approach to food production. **By mitigating methane emissions and sequestering organic carbon in the soil, we not only tread the path towards carbon neutrality but aspire towards carbon negativity.**

Foreword

Moreover, our collaboration, Inhana & IBM, extends beyond the realms of agrarian innovation, encompassing the development of pioneering tools such as ACFA and SACFA. These standards not only elucidate the carbon footprint of agricultural practices but serve as litmus tests for sustainability and resilience.

As we reflect on the milestones achieved over three years of collaborative endeavor, we stand poised at the cusp of a new dawn. The echoes of our achievements reverberate through the corridors of academia and industry, igniting a flame of inspiration for generations to come.

At the end of IBM-IORF Sustainability Project, Phase –III, let us embrace the spirit of stewardship and collective responsibility, for in our hands lie the power to sculpt a future where agriculture thrives in harmony with nature. Together, let us embark on this odyssey towards a sustainable tomorrow, where every harvest is a testament to our unwavering commitment to the earth and its inhabitants.

Dr. P. Das Biswas
Founder Director

Adoption of a Cluster of Villages for Agricultural Sustainability and Food Security through Clean Food Program

Phase - III

- Continuation Project 100 ha : : Mandya District , Karnataka, India
- Continuation Project 100 ha : Nadia District, West Bengal, India

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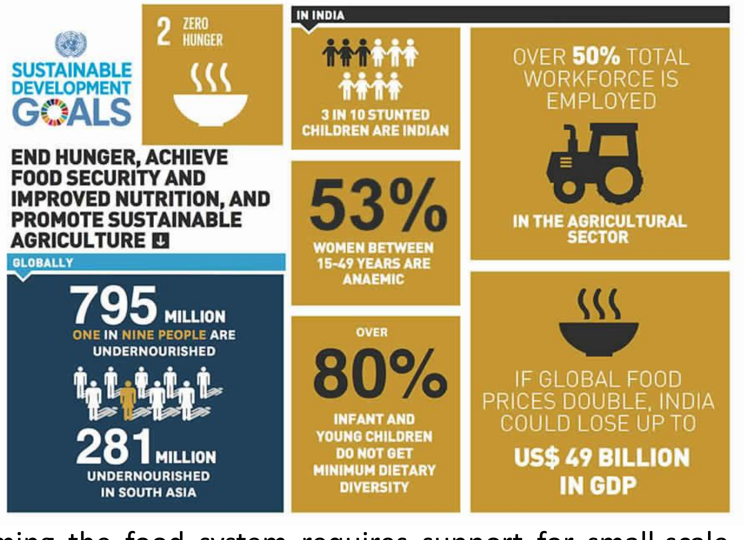
The most pressing issues facing mankind today, particularly in India, are global warming, sustainable livelihoods, and climate change. These issues are interconnected, with one often leading to or exacerbating the others. The impact of these issues is more in India. In India, approximately 60-70% of the population, around one billion people, rely on agriculture for their livelihoods. However, this sector is also a significant contributor to greenhouse gas emissions. This contributes to global warming, which in turn leads to climate change, posing a direct threat to agriculture. Additionally, out of total degraded land, nearly 50% of total agricultural land in India is degraded; further complicating efforts to increase food production sustainably while mitigating climate change impacts. Finding a path forward requires balancing the need for increased food production with the imperative of reducing greenhouse gas emissions and adapting to a changing climate.

With Climate Change Impact, Food Security Challenge will only become more difficult, as the world will need to produce about 70 percent more food by 2050 to feed an estimated 9 billion people.

Some 97.85 Mha (29.7%) of India's total geographical area (TGA) of 328.72 mha underwent land degradation till 2018-19; out of which 47 % is agricultural land.

The urgent need for sustainable agriculture is evident, with a focus on reducing unsustainable practices and improving efficiency. Despite the lack of clear understanding on what constitutes sustainable agriculture, global leaders, including those at COP 28, have recognized food and agriculture as a priority. This is particularly crucial for the countries like India, where ensuring food security, livelihoods, and economic stability is paramount.

The Sustainable Development Goal 2 (SDG 2) emphasizes not only food security but also the importance of pure and nutritious food for all. However, there is a significant investment gap of over $260 billion USD in SDG 2 interventions, highlighting the need for effective action. In the context of climate change, sustainable agriculture is the key to ensuring livelihoods for millions, especially in India. Transforming the food system requires support for small-scale farmers, particularly in areas affected by climate change. The Government of India has taken proactive steps towards sustainable agriculture, including initiatives like Soil Health Cards and identifying degraded lands. The introduction of frameworks for Voluntary Carbon Markets in agriculture further underscores the commitment to sustainability.



Inhana and IBM's commitment particularly through small and marginal farmers decided to adopt the **Clean Food Model** as the first step in Sustainable Agriculture. The decision was driven by the recognition of two major unsustainable inputs in agriculture: fertilizers and pesticides. While removal of both the unsustainable inputs ensures most safe & Sustainable agriculture, but removal of synthetic crop nutrients being resource dependent, removal of pesticides was chosen for its resource independency and can be ensured through plant health management. Pesticides, in particular, have been linked to climate change and nutritional depletions in plants, reducing their secondary metabolites. **In the 1st year the model was implemented in West Bengal, where high cropping (> 3.5) intensity and small & marginal farm holdings prevail.**

Clean Food Movement is probably the first initiative toward Healthy Life & Farmers' Empowerment; through the development of Safe & Sustainable 'Clean Food' (**Elimination of Chemical Pesticides**),

The program aimed to address three main areas: ensuring crop yield despite eliminating agrochemicals, producing value-added products without additional costs for farmers, and providing safe and sustainable food for consumers. Various Tools and indices of IORF were utilized, including soil resource mapping and soil health cards. A small model farm project where both synthetic crop nutrient &crop protectants were eliminated demonstrated significant insights, highlighting the relationship of unsustainable components with GHG footprints and energy Footprint. It also shows the potential for carbon-neutral and Net Zero Agriculture through Novcom compost and IRF Technology.

The IBM-IORF sustainability project, initiated in 2021 and spanning even three calendar years, introduced the pioneering 'Clean Food' a Single Inhana model in sustainable agriculture developed by Inhana Organic Research Foundation (IORF). This model was developed on **ECCES Model,** has been established for nearly two decades. It underwent Comprehensive Evaluations, proving its **Safety, Effectiveness, Convenience, Completeness, and Cost-Effectiveness in various crop and agro-climatic conditions.**

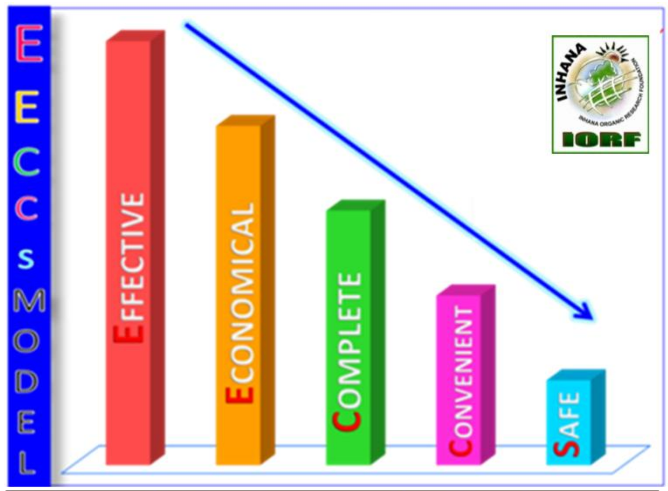
IBM-IORF Sustainability Project aims towards development of **Safe (Pesticide free) & Sustainable 'CLEAN FOOD ' Development** & **Sustenance of livelihood** for **Small and Marginal farmers**

The objectives of '**Clean Food' Program** is in accordance **with Sustainable Development Goals** of **UN** specially **SDG 2** (End Hunger, Achieve Food Security and Improved Nutrition and Promote Sustainable Agriculture)

Clean Food Program :
360 Degree Care
for
Farming Community with
SEED to SEED Sustainable Solution with a new direction in HEALTH & LIVELIHOOD Development

Technological intervention with IRF technology will provide 360 degree care from seed treatment to seed production, help to enhance crop productivity by upto 20 % (as validated through actual field trials), Reduce cost of cultivation with better resource utilization & technological support and enhance plant immunity towards increasing their resilience to environmental fluctuations & reduce the risk of pest & disease invasion.

The ECCESS Model comprises two key components: **IRF Technology for Plant Health Management and Novcom Composting Technology for Soil Health Management and Enrichment.** Plant health management is crucial, with plant varieties tailored for resilience and functionality, considering the prevalent use of high-yield varieties dependent on fertilizers. The role and relevance of Plant Health is of further importance as far Sustainable Agriculture with existing plant varieties will have to function with



Five essential pillars that are Irreplaceable and inevitable for the viability of any sustainable method to be successful

lesser inputs and possible through higher agronomic efficiency and that too with very minute fraction of readily available fraction of nutrients from organic soil input. Finally Plant Health Management is critical component for sustainable agriculture for host defense mechanism and plant immunity through higher, faster and greater metabolism. So with or without Soil Health Management, Plant Health Management always remained as the cornerstone of sustainable agriculture. Soil health management which is ensured through Novcom Composting Technology, though critical, is resource dependent.

Inhana Rational Farming (IRF) Technology 1st introduced the concept of **duel application of Soil & Plant Health Management** towards **Ecologically & Economically viable Safe & Sustainable Food Production**

The program aimed to address three main areas: ensuring crop yield despite eliminating agrochemicals, producing value-added products without additional costs for farmers, and providing safe and sustainable food for consumers. Various Tools and indices of IORF were utilized, including soil resource mapping and soil health cards. A small model farm project where both synthetic crop nutrient &crop protectants were eliminated demonstrated significant insights, highlighting the relationship of unsustainable components with GHG footprints and energy Footprint. It also shows the potential for carbon-neutral and Net Zero Agriculture through Novcom compost and IRF Technology.

After successful demonstration of large scale production of pesticide free safe and sustainable "Clean Food' Production under Phase-I IBM-IORF Sustainable program which is basically resource independent and more converse to small and marginal farmers - **we have conceptualized Clean Food ZERO CARBON ' (CFZC) under Phase-II IBM-IORF Sustainable program which not only deliver SAFEST FOOD (Safe for Human health, Soil & Environment) but also have a meaningful contribution towards climate change mitigation and soil health upliftment.** Thus a switch over from Conventional Farmers' Practice to Clean Food 'ZERO CARBON' Model, can totally transform the present GHG Emitting Agriculture to a GHG Sink Agriculture.

Clean Food 'Net Zero' Model was conceptualized in Phase-II program under IBM-IORF Sustainability Project

- an initiative which not only exhibits **CROP SUSTAINABILITY** under climate change impact but at the same time **Effectively Mitigates Green House Gases (GHG)** and **Creates More Carbon Sink**

While working on the **Phase 2 of the project in Karnataka on Clean Food Model ,** the issue of coirpith, a byproduct from the coconut industry, arose. With an annual production of around 600,000 MT, this agro- industry landfill waste. **Though experimentally Novcom Composting Technology could convert coirpith into mature compost, a challenge was to attend conversion into organic manure. Successful experimental endeavors by IORF in coirpith composting prompted the consideration of its potential for methane emission reduction and organic manure production and the most essential component for Net Zero agriculture in large scale.**

When this proposition was put before IBM they were convinced about its sustainability potential and thus the **Clean Food Net Zero model** was formally launched. This single model aimed to **mitigate methane emissions, and sequester organic carbon in the soil, resulting in sustainable organic food production with a huge negative carbon footprint.** With a methane offsetting potential and CO2e reduction of more than **-240 MT CO2e /ha, Clean Food Net Zero emerged as a pivotal program for Mitigation, Abatement, Carbon Retention, and Sequestration. Clean Food Net Zero** stands out for its comprehensive approach to sustainability, making it crucial for addressing multiple environmental challenges and achieving carbon neutrality to carbon negativity in agriculture.

Coir pith is most underrated and unaccounted Agro Industry waste which is a potent source of Soil & Water pollution and Methane emitter but hard to recycle without an Effective Technological Intervention

Present of high lignin part in coirpith which contains aromatic and aliphatic components and various functional groups, including phenolic, hydroxyl, carboxyl, benzyl alcohol, methoxy, and aldehyde groups, which can cause phytoxicity when applied untreated in agricultural soil. The present practices / mal practices in many parts of South India with application of these materials as organic manure with no /little intervention enhance the threats – which needs an established mechanism for proper recycling and agricultural usage.

Novcom composting technology – Safe, adoptable, effective, speediest and economical biodegradation technology it is the key behind conversion of coirpoith to quality manure along with GHG mitigation which make the clan food net Zero model as most viable Agro-Net Zero model

Novcom composting Technology developed by IORF, has enabled bioconversion of **2000 ton of Coir pith (in Phase-II & Phase-III) to Safe–Stable-Mature Compost rich in self generated microflora** (one trillion billion Microflora per ton Novcom compost) **within 30 days -** Bioconversion of Toxic Methane Emitter to an Excellent Resource for Soil- C Sequestration .

REGENERATIVENESS & RENEWABILITY components under Clean Food Net Zero Program was understood with Energy Usage & GHG Mitigation potential.

Clean Food Net Zero Program recorded 57 % Energy Transition with 432% Higher Energy Efficiency in crop production per unit energy investment.

Clean Food Net Zero Program is probably India's 1st Agri Net Zero Project which showed a potential of mitigate about 25000 MT CO_2 from 100 ha

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AGRI - NET ZERO

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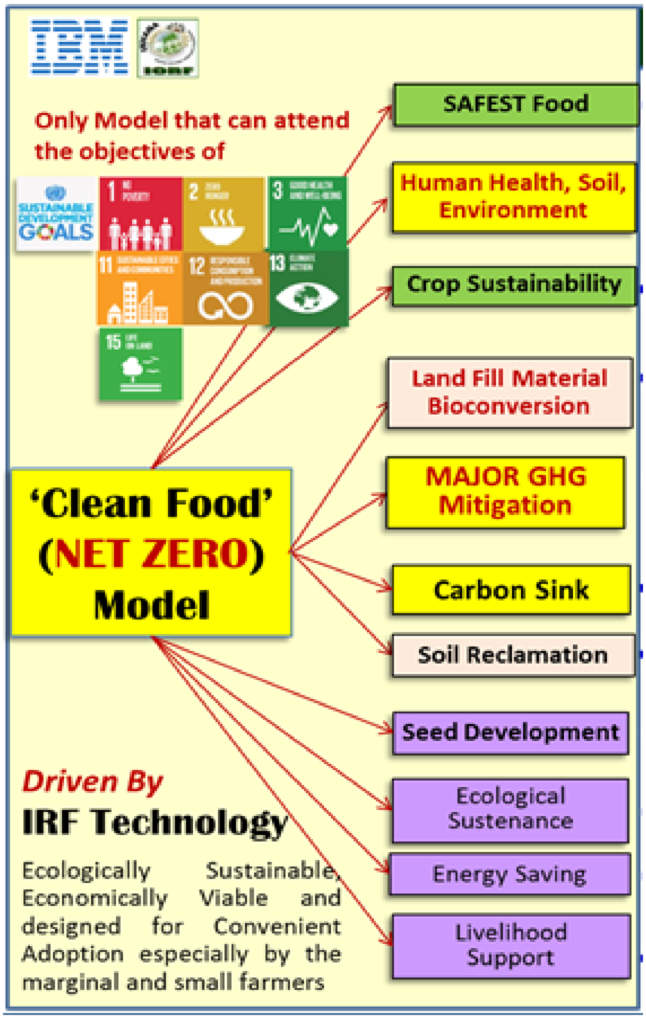
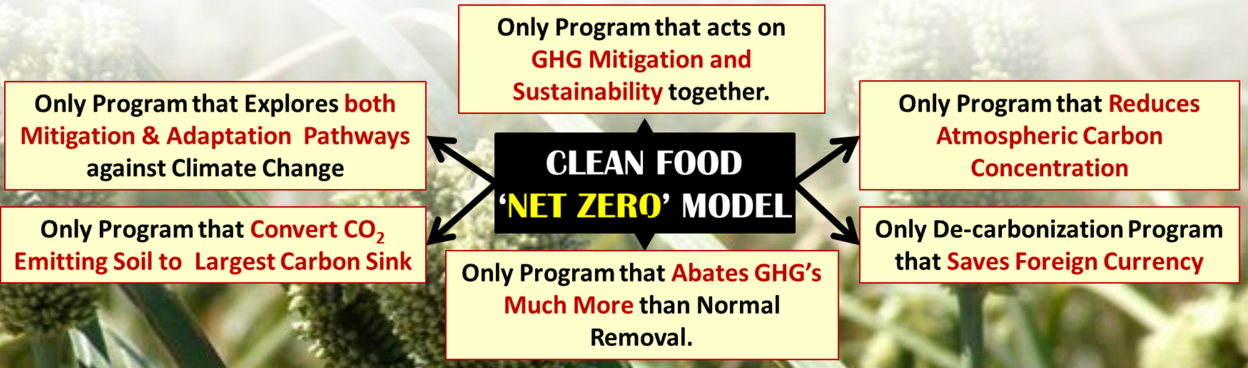
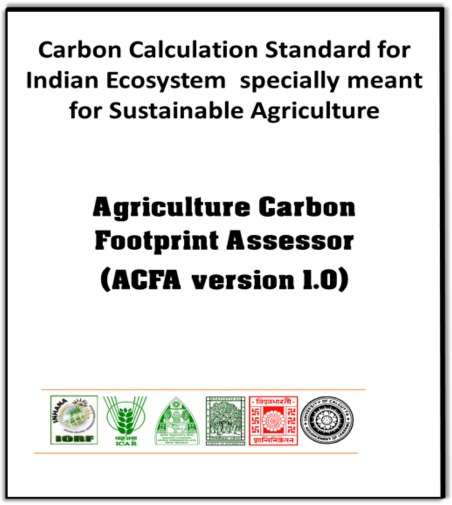
The **Clean Food Net Zero model** offers multiple opportunities and potentials, particularly in stimulating sustainable agriculture among small landholding farmers. Government initiatives to subsidize C-footprint reduction and finalize VCM projects than can be affordable to small & marginal farmers. Additionally, the model aligns with Corporate Net Zero Compliance efforts, providing a pathway for decarbonization projects. The impact of the **Clean Food Net Zero** model extends across seven Sustainable Development Goals (SDGs), but notably **SDG 2 (Zero Hunger& Pure Food Accessible to All) and SDG 13 (Climate Action), addressing investment gaps of over $700 billion USD.** Methane mitigation plays a crucial role in combating global warming, while benefiting small-scale farming communities and ensuring the production of safe and sustainable food.



Furthermore, the model contributes to the upgrade of degraded agricultural lands and promotes a Circular Bio-economy. Corporate involvement in the project could lead to significant impacts across these areas, potentially leading to government recognition and support, including the possibility of it becoming Voluntary Carbon Market (VCM) projects. Government compensation could further incentivize farming communities and fund net zero projects, ensuring broader sustainability outcomes including socio-economic development and environmental protection. Most importantly this **Clean Food Net Zero Model is the best model to support- adopts and pledge by the corporates for triple compliance – ESG Compliance, Net Zero Compliance and Sustainability Compliance. There is a potential of registering carbon abatement upto 17 million MT CO2e, out of which only Karnataka could be more than 3 million MT CO2e.**



Inhana recognized the need for effective computation and assessment standards for Carbon Footprints in agriculture, especially in the Indian context where such standards were lacking. Associating with various universities and research institutes, including the ISI developed the standard and finally developed **ACFA (Agriculture Carbon Foot Print Assessor) Version 1.0** to fill this gap. Additionally, **IORF entered into a technical collaboration with UK-based organization i-NO Carbon (iNC, UK), resulting in the development of SACFA, the first toolkit for Sustainable Agriculture Carbon Footprint Assessment.**



IORF believes that the remarkable and most unique component of ACFA- Version 1. And SACFA is to assess and validate the Sustainability status of any farmland or sustainability value of any farm produce. As Sustainability of any farmland or crop is directly and inversely related with carbon footprint and energy footprint of the same. Therefore this standard and toolkit can provide sustainability footprint of any produce, measure any interventional impact and sustainability growth for any period of time.

Recognizing the pivotal role of seeds as the foundation for sustainable millet cultivation, it is imperative to strengthen and enhance the efficiency of seed systems for overall production improvement. Thus under IBM-IORF Sustainability project (Phase-III), IORF took initiative to develop Net Zero Clean Seed in both West Bengal and Karnataka to support Sustainable initiatives

After established the CLEAN FOOD NET ZERO MODEL in crop production – **In Phase III (2023-24) effort was on development of** **Net Zero Clean Seed & Seedling Materials** in both West Bengal & Karnataka - climate resilient and suitable for sustainable agriculture

Over the course of three years in the IBM-IORF projects, significant developments were made in developing Sustainability Models, GHG & Carbon computation standards, certification toolkit. This included the development of the Soil Proximity Model for scalable soil analysis, as well as **Safety Assessment Tool such as Carometric Assay Test and Energy Calculator for Agriculture.**

These advancements not only contribute to sustainability assessments and benchmark studies but also serve as valuable tools for achieving Net Zero compliance. The project has yielded ten research publications, marking significant milestones. Furthermore, the project opens up numerous collaboration opportunities in the digital and software sectors, particularly through IBM's involvement, paving the way for transformative climate-smart sustainable solutions in agriculture.

IBM - IORF SUSTAINABILITY PROJECT

(3rd Year)

Detailed Project Report (2023 -24)

PHASE - III

Clean Food Program

Nadia, West Bengal

IBM-IORF Sustainability Project (Phase=-III)- West Bengal

3rd (Final) year Continuation of, 100 ha Clean Food Project in Nadia, West Bengal

Project Location

The Project Area is located in the Haringhata Block of Nadia District of West Bengal, India. The Project area consists of 5 adjoining villages with 589 ha area and about 1200 farmers' family**. Majority of the population are dependent on agriculture for their livelihood sustenance**.

Objectivity

In the third and final year of the project, the focus remains on continuity and validation of the impacts generated in previous phases. This includes assessing the Climate Resilience aspects of 'Net Zero' Vegetable Seed production achieved in the second year, with a focus on first-generation seeds produced under the elimination of chemical fertilizers and pesticides.

The milestone achieved in the first year with 'Net Zero' paddy seed development is being further validated. This is often said that a quality seeds sustainably developed perform well in different ago climate. Therefore, Clean Paddy seeds developed in West Bengal - Gangetic alluvial zone was tasted in Karnataka zone, and it was found that yielded higher& with higher qualities.

Now, in West Bengal, where rice cultivation dominates, the relevance of quality and climate-resilient paddy seeds is undeniable. Hence, in the third year, there's an initiative to validate the climate resilience aspects of second-generation 'Net Zero' Clean Paddy Seeds developed in Karnataka through replication studies in West Bengal. These seeds have the potential to significantly impact a large area under rice cultivation, crucial for climate-vulnerable small and marginal farmers.

Apart from 3rd year field demonstration of Clean Food Program in farmers field, the prime focus of Phase-III program was development of **Need Zero Clean Paddy and Vegetable Seeds** (2nd generation) **through Community Seed Development Program**

This is crucial given the significance of quality climate-resilient paddy seeds, particularly in a region like West Bengal where rice cultivation is predominant, recorded good performance in the adverse weather condition where many conventional paddy seeds considerably under performed.

Additionally, the assessment extends to first-generation **'Net Zero' clean vegetable seeds** produced under the Phase-II Continuation Project in West Bengal. A replication study is conducted to evaluate their climate resilience aspects, further emphasizing the importance of sustainable agricultural practices for small and marginal farmers facing climate vulnerabilities. These efforts mark significant progress in promoting sustainable agriculture practices and addressing the challenges posed by climate change.

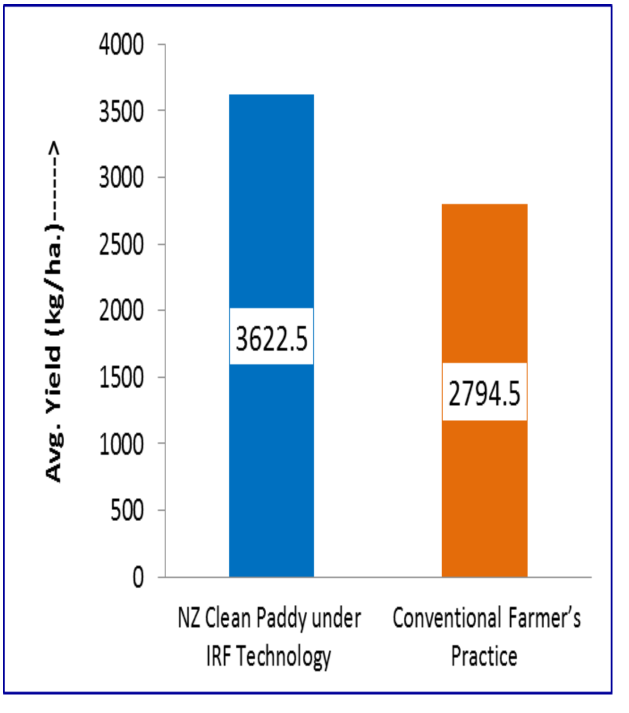
Chapter 1 : Validation of Quality Potentials of the Second Generation 'NET ZERO' Clean Paddy Seeds developed under Phase-II Project in Mandya District of Karnataka, in respect of Yield Improvement and Climate Resilience - in West Bengal Project Area 2023-24

The Satabdi Miniket IET-4786, a popular High Yielding Variety (HYV) grown in West Bengal during winter, sees farmers commonly saving a portion of their harvest as seed for the next season. However, there's a concern that using seeds saved over multiple generations may lead to a loss of desirable traits and reduced productivity due to natural genetic variability. Modern agriculture emphasizes using certified seeds for quality and productivity assurance. Seed multiplication procedures are crucial for certifying high yielding hybrid varieties under the Seed Act 1966 to maintain genetic purity. **The study focused on evaluating the productivity and resilience of second-generation paddy seeds produced using IRF Technology and organic management practices**. This assessment sheds light on the sustainability and effectiveness of IRF Technology in maintaining or improving the quality and performance of paddy seeds over generations.

YIELD PARAMETERS OF PADDY CROP UNDER DIFFERENT MANAGEMENT

Avg. 29.63% higher Yield has been recorded under NZ Clean Paddy Programme compared to conventional farming practice, using the 2nd generation Paddy seed developed & managed under same IRF Technology.

Though Miniket Satabdi (IET - 4786) is HYV (high fertilizer responsive) shows significantly higher response compared to conventional farming practice even under 100% Fertilizer Reduction and Elimination of Chemical Pesticides.



The superior performance observed with the complete elimination of synthetic fertilizers and pesticides emphasizes the heightened resilience and improved adaptability of the 2nd Generation NZ Clean Paddy Seeds. Having successfully completed two life cycles under the same IRF Technology , these seeds exhibit a remarkable capacity to thrive in varying agro-climates.


Pic.: Irrigation in the NZ Clean Paddy Plot (left); Inhana Plant Health Management Spraying (right) in 'NET ZERO' Clean Paddy Programme under IBM-IORF Sustainability Project, Phase III, 2023.


Pic.: Agronomic Data generation from field of 'NET ZERO' Clean Paddy Programme under IBM-IORF Sustainability Project, Phase III, 2023.

Pic.: Harvesting of paddy seedlings under Climate Resilient 'NET ZERO' Clean Paddy Production Program, Phase III, at Nadia, West Bengal, India.

Quality Analysis of 'NET ZERO' (NZ) Clean Paddy Seeds developed under IBM IORF Clean Seed Paddy Program, Phase III 2023

Along with the Yield Assessment the Quality of the NZ Clean Paddy Seed was done in terms of its Physical & Climate Resiliency. Seeds developed under IBM-IORF Sustainability Project, Phase III is having the Moisture 9.82% compared to max. seed moisture as per Indian Standard is 13%.

Comparative study of Seed Viability, Seed Vigor and Seed Resilience against Stress, of Clean Paddy Seed with intervention of IRF Organic Farming Technology.

Seed Quality parameters	Seed Viability		Seed Vigor			Seed Resilience against Stress			
	[1]G %	[2]SV %	[3]GVI	[4]SVI-I	[5]SVI- II	[6]G_{WS} %	[7]G_{SS} %	[8]G_{AA} %	[9]EC
Conventional Paddy Seeds (Farmers' Practice)	84	86.1	11.78	659.3	0.29	75	73.3	81.79	0.035
'Net Zero' Clean Paddy Seeds	96	99.12	14.96	780.3	0.32	79.3	76.2	84.41	0.027

Note : *[1]G % : Germination %, [2]SV % : Seed Viability %, [3]GVI : Germination Velocity Index, [4]SVI-I : Seed Vigour Index-I, [5]SVI- II: : Seed Vigour Index-II, [6]G_{WS} % : Germination under water stress (-0.6 MPa induced osmotic potential); [7]G_{SS} % : Germination under Salt Stress (-0.6 MPa induced osmotic potential), [8]G_{AA}% : Germination under Accelerated Ageing; [9]EC : Electrical Conductivity*

The potential crop efficiency of the second generation Net **Zero Clean Paddy Seeds** was to evaluate in actual crop performance for the field validation. Net **Zero Clean Paddy Seeds** developed under Net **Zero Clean Paddy Seeds** Program (Phase II) in Karnataka, successfully exhibited their crop yield, and at the same time improving overall seed quality. Through these Net **Zero Clean Paddy Seeds** , we can not only enhanced the vitality of paddy seeds but also achieved the environmental sustainability and biodiversity even in different agri-ecosystems.

OUTCOMES OF THE NET ZERO CLEAN PADDY SEED PROJECT

The outcomes of the Net Zero Clean Paddy Seed Project are significant. **Not only did the project achieve no yield loss, but it also surpassed the grain yield of conventional chemical farming practices.** It was found that the performance of second generation 'NET ZERO' Clean Paddy Seeds was very good in the adverse weather condition where many conventional paddy seeds considerably under performed.

This success underscores the sustainability of the crop, as it demonstrated better plant resilience against adverse weather conditions, even in scenarios where chemical inputs were drastically reduced.

Furthermore, the project showcased sustainable crop performance with consistent quality improvement in the same Miniket (IET-4786) variety developed and maintained under the Inhana Organic POP for two generations. These outcomes highlight the potential of organic farming methods in promoting crop resilience, sustainability, and quality enhancement.

Chapter 2: Assessment of Quality Potentials of the First generation 'NET ZERO' Clean Vegetable Seeds produced under Phase-II Continuation Project in West Bengal, in respect of Yield Improvement and Climate resilience, 2023-24

Climate-smart agriculture begins with the foundation of resilient, high-quality seeds tailored for organic and low-input farming. Seeds developed under conventional methods often exhibit high responsiveness to fertilizers, lacking the essential traits necessary to withstand fluctuating climatic patterns, thereby jeopardizing crop yields. The repercussions of poor seed quality are staggering, contributing to a staggering 40% decrease in overall crop production. In the Indian agricultural landscape, the scarcity of certified, high-quality seeds remains a critical bottleneck.

Recognizing this challenge, the Inhana Organic Research Foundation (IORF) has embarked on a groundbreaking initiative under the IBM-IORF Sustainability Project, Phase II, to pioneer the development of Net Zero Clean Seeds through the adoption of Inhana Rational Farming (IRF) Technology—a comprehensive organic package of practices. Vegetable seeds were specifically targeted due to their heightened susceptibility to climatic fluctuations, where even slight deviations in temperature or precipitation can profoundly impact yields.

we have taken a initiative to study the **Assessment of Quality Potentials of the First generation 'NET ZERO' Clean Vegetable Seeds** produced under Phase-II Continuation Project in West Bengal, in respect of Yield Improvement and Climate resilience.
At the same time we also tried to **develop second generation net zero clean seed development** under the same study

The resultant seed quality surpassed stipulated standards for foundation seeds, validated through rigorous comparative analysis against conventional counterparts across three key metrics. Field trials unequivocally demonstrated the superior yield potential of Net Zero Clean Seeds, showcasing significant productivity gains in farmers' fields. Building on this success, Phase III of the IBM-IORF Sustainability Project evaluated both crop productivity and climate resilience of seeds developed using the IRF Technology. Out of 13 crop varieties Eight diverse crop varieties, including Cauliflower, Cabbage, Chilli, Okra, Potato, Tomato, Red Amaranthus, Spinach, and Mustard, were carefully selected for the program. Primarily Crop performance under Clean Food Zero Carbon model was recorded compared to conventional farmer’s practice

Productivity of Vegetables & Oilseed under **CLEAN FOOD NET ZERO ' PROGRAM in IBM-IORF Sustainability Project-Phase III**

Productivity of Vegetables & Oilseed under Clean Food 'NET ZERO' Program

Crop		Clean Food 'NET ZERO' Yield (Tonne/ ha)	Conventional Farmers Yield (Tonne/ha)	'NET ZERO' Clean Seed Yield (Tonne/ ha)
BRINJAL	:	32.14	26.2 – 30.4	0.290
CHILLI	:	18.96	14.6 – 18.2	0.310
OKRA	:	19.41	13.4 – 16.6	1.340
TOMATO	:	33.20	24.5 – 30.7	0.242
RED AMARANTH	:	17.21	12.04 – 15.8	1.780
SPINACH	:	37.10	28.4 – 32.2	3.740
MUSTARD	:	0.558	0.46 – 0.50	0.558
POTATO	:	34.12	27.68	21.12

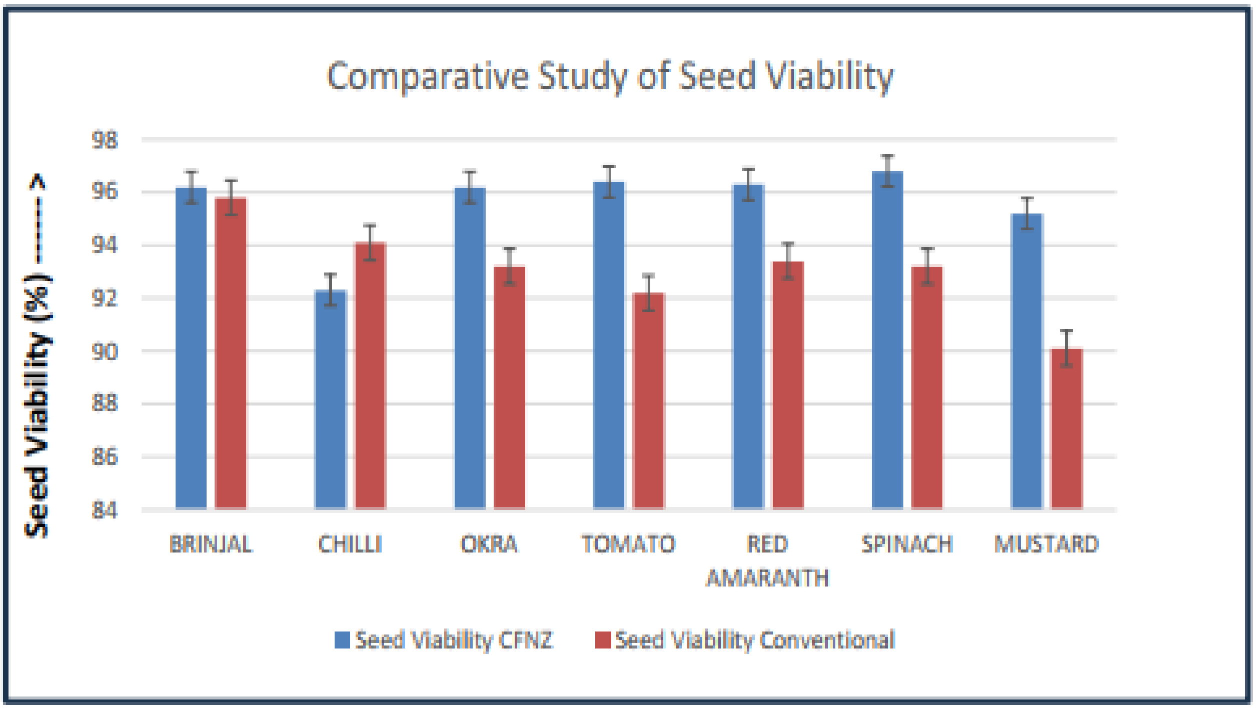
Productivity of vegetables grown under the Clean Food 'NET ZERO' (CFNZ) Program in the Project Area Model Farm was compared with the productivity range of the respective vegetables under conventional farmers' practice in this zone.

Productivity of almost all the vegetables under IRF package of practice was higher than the average productivity of the same under conventional farmers practice. The findings indicated that adoption of IRF technology as an effective nature friendly package of practice for increasing crop productivity. This initiative could be a benchmark study for sustainable management of vegetables and the technological advancement can be transfer to farmers field for facilitates sustainable crop production specially when excessive use of fertilizer and pesticides enhance the risk of deterioration of soil health as well surrounding ecology.

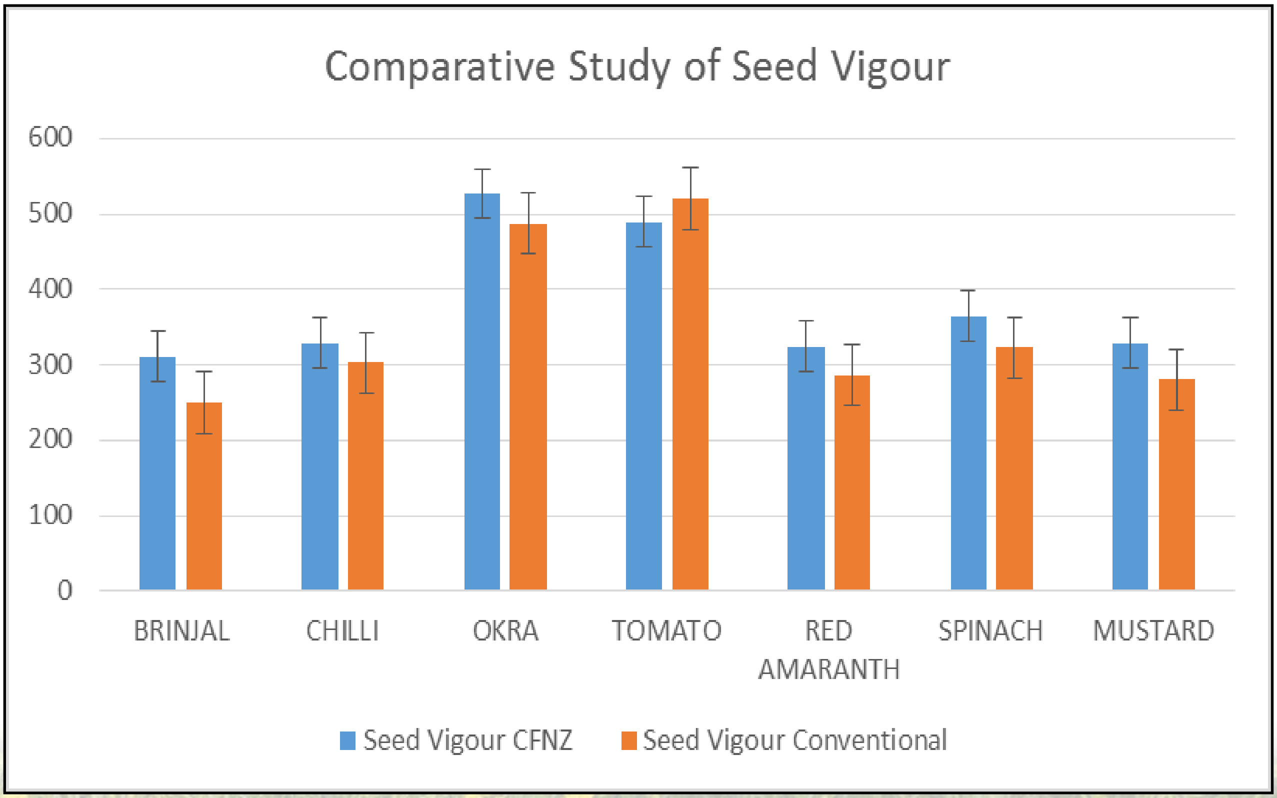
Development of Novcom poultry compost heap at the project area under IBM-IORF Sustainability Project

Field validation of Net zero clean seed in farmer's field under IBM-IORF Sustainability Project

Comparative study of Seed Viability between Conventional and Net Zero Clean Seeds.



Comparative study of Seed Vigor between Conventional and Net Zero Clean Seeds.



OUTCOMES OF THE NET ZERO CLEAN VEGETABLE SEED PROJECT

The relevance, importance, and objectivity of quality, vegetable seeds are well-known and well defined. **'NET ZERO' Clean Vegetable Seeds were produced with higher productivity and better quality. This experiment was laid down to exhibit, evaluate and establish their crop performance-potential to Actual.** The threat of productivity loss under any sustainable initiative was thoroughly ruled out as well as this model has showed further higher productivity due to incorporation 'NET ZERO' Clean Vegetable Seeds and crop management under IRF Technology.

Seed viability and seed vigour of the vegetables seeds grown under Clean Food Net Zero Program were upto 6 % and 24 % higher in comparison to conventional seed

The findings have indicated the qualitative superiority of the seeds over conventional seeds in terms of seed vigour and seed germination. **Moreover, seed production from these seed varieties proved not only economically viable but also remarkably cost-effective, with production costs amounting to less than 10% of prevailing market prices for organic seeds.**

Thus, it is evident that this **Net Zero Clean Vegetable Seed program** holds immense potential for widespread adoption among farmers, facilitated by technological interventions, robust **Plant Health Management**, and adherence to recommended guidelines. Such initiatives represent a pivotal step towards sustainable agriculture while safeguarding the rich diversity of vegetables in our region.

IBM - IORF SUSTAINABILITY PROJECT

(3rd Year)

Detailed Project Report (2023 -24)

PHASE - III

Clean Food Net Zero Program

Mandya, Karnataka

2^{nd} year Continuation of Phase-II, AMENDED 100 ha Clean Food Project in Mandya, Karnataka with SOIL HEALTH MANAGEMENT for 25% or 25 hectare Project Area using Novcom Coir pith Compost.

Project Location

The Project Area is located in the Mandya District, Karnataka, India.

Objectivity

- **CLEAN FOOD NET ZERO CONTINUATION (Karnataka)**

Agri Net Zero Model that was developed in **PHASE 2** of the project continued as the major project objectivity primarily & majorly on the same crops for standardization & conclusive validation.

The project exhibited similar success in the second year establishing the effectivity of IRF Technology towards **Plant Health Management, and Novcom Composting Technology for Novcom coir pith compost towards Soil Health Management.**

- **New models development through backward integration to offer 360° pathway to sustainable agriculture.**

The necessity and relevance of Net Zero Clean seed or seedling or planting materials are enormously lager for **Agri Net Zero Programme** with crop sustainability. Therefore, a program was taken to develop **Net Zero Clean seed and planting materials of the major crops grown and have bottleneck for quality seed or planting materials.** This program has specifically targeted four key crops: Coconut, Sugarcane, Ginger, and Millet. Through meticulous research and development efforts, the program has successfully demonstrated the efficacy in growth and crop performance across all the test crops.

Development of Agri Net Zero Model

for Net Zero Compliance is the major focus of the study.

NET CARBON FOOTPRINT from 25.2 ha. CFNZ is (-)6309.73 MT CO_2e has become certified by i-NO Carbon, UK. & Net Carbon Footprint from CFNZ Continuation Model - 250.39 MT CO_2e/ha.

The project focused on bringing all the major crops in this region under **Clean Food Net Zero Model,** development of Climate- resilient – Disease free – Net Zero Clean Seed/ Planting Material of these crops (through utilization of Novcom Coir-pith compost) and demonstrating to the farmers the Quantitative and Qualitative Developments that can be achieved through adoption of Sustainable Crop Technology (IRF Technology), that enables elimination of Chemical Pesticides through Plant Health Management and elimination of Chemical Fertilizers through Soil Health Management using Novcom Composting Technology.

Development of

Net Zero Clean Seed

for sustainable agriculture was another prime focus of the IBM-IORF Sustainability Project(Phase-III).

..and Inhana Rational Farming (IRF) Technology evolved as the key factor for the objectivity accomplishment

Chapter 1. Development of 'NET ZERO' Clean Ginger Planting Material, in the project area at Mandya District of Karnataka

India is a leading producer of Ginger in the world. Ginger is cultivated in most of the states in India. Kerala, Karnataka, Meghalaya, Mizoram, Arunachal Pradesh, Sikkim, Nagaland etc., are major Ginger growing states in the country. During 2021 India ranked 1st in Ginger Production in the world with the production of 17.88 lakh MT. Ginger is cultivated in most of the states in India. The average productivity of ginger in India is around 10.72 tonnes/ha in 2021. In India, it is cultivated in all most all tropical and subtropical parts. Though grown all over India, five states Madhya Pradesh, Karnataka, Assam, West Bengal & Orissa contributes about 61.5% production share of the country.

Ginger cultivation is steadily gaining momentum in Karnataka, showcasing promising prospects as a lucrative cash crop. According to Bhat et al. (2012), the allure of higher profitability associated with ginger cultivation has attracted a growing number of farmers to this crop.

In the agricultural year 2017-18, the total cultivated area dedicated to ginger reached 20,809 hectares. Notably, among the 30 districts in Karnataka, the districts of Shivamogga and Hassan stand out as the primary centers for ginger cultivation, boasting the highest areas under cultivation for this crop.

Ginger Cultivation Challenges

Ginger, being a highly succulent herb, is susceptible to various abiotic and biotic stresses, making its cultivation challenging. One of the major constraints in ginger production is the rhizome rot complex disease, which is caused by a combination of fungi, bacteria, and plant-parasitic nematodes (Dohroo, 2005). This disease, particularly soft rot, is globally recognized as the most destructive, resulting in significant economic losses in ginger-growing regions (Stirling GR, 2009; Chattopadhya SB, 1997). The soft rot, predominantly caused by Pythium spp., has been reported to cause production losses ranging from 4% to 100% in different locations (Stirling GR, 2009; Nepali MB, 2000). Furthermore, the disease is both seed and soil-borne, persisting between crops on infected seed rhizomes (Thomas KM, 1940; Park M, 1941).

In this background, under IBM-IORF Sustainability Project, Phase III the initiative was taken for the development of **Climate – Resilient, Disease free Net Zero Clean Ginger Planting Material** – the primary tool for progression towards sustainable ginger cultivation through elimination of Chemical Pesticides and Reduction of N- fertilizers.

At the same time objectivity of development of disease – free – quality planting material was to eliminate risk of seed born disease , better resistance against soil born pathogens by healthy mature seedlings, reduce use of chemical pesticides, weedicides, irrigation and mandays resulting higher return potentials.

Under IBM-IORF Sustainability Project, Phase II ginger was taken under Coconut- based Net Zero intercropping Model. The model was developed with the adoption of Inhana Rational Farming Technology – a comprehensive organic package of practice. As part of soil health management, Novcom coir pith compost was applied @ 40 ton/ha towards complete elimination of chemical N- Fertilizers. Inhana Plant Health Management solutions were applied in a periodical manner towards development of healthy plants capable of withstanding biotic and abiotic stress. This helps elimination chemical pesticides and fungicides.

A significant 17.9 – 18.2 (avg. 18.08 tons/ ha.) tons/ha. yield was recorded under Coconut-based Net Zero intercropping Model (as Net Zero Clean Ginger Crop) that too demonstrated in the marginal soil

Larger size of Ginger rhizome is related to better soil and plant health management under IRF Technology.

Ginger rhizome from the project plots at Mandya, Karnataka under IBM-IORF Sustainability Project.

Steps followed towards development of Net Zero Clean Ginger Seedling Development under IBM-IORF Sustainability Project at Mandya, Karnataka

Sourcing of Ginger Seeds locally from Mandya District, Karnataka

→ Selection of Healthy Ginger Rhizomes for seed purpose

→ Seeds were soaked in Inhana Seed Treatment Solutions for 30 mins., & dried under shades

→ seed rhizomes are cut into single buds with small piece of rhizomes weighing 8-10 g

→ Filling the plastic tubes of 6” X 8” with Soil & Novcom Coir pith Compost in 70: 30 ratio.

→ Planting the ginger buds sprouts in the tubes

→ IPHM PoP solution application initiated at 3” seedling height

→ Total 5 rounds of Inhana Plant Health Management Solutions were applied as per schedule.

→ Tubes are kept cleaned by manual weeding & Need based Irrigation was done.

→ Healthy Seedlings are ready by 60 days for Transplanting

Activity towards ginger seedling development under IRF package of Practice at model farm, Mandya, Karnataka under IBM-IORF Sustainability Project

Performance of ginger genotypes yield parameters under coconut ecosystem was recorded from Net Zero Ginger Cultivation Plot under IBM-IORF Sustainability Project, Phase II, Mandya, Karnataka.

No. Of Plots	Plant height (cm)	Shoot diameter (cm)	No. of shoots	No. of leaves	Leaf length (cm)	leaf width (cm)	Yield / plot (kg)	Yield (t/ha)
Plot/1	75.0	3.1	7.5	25	24.8	2.8	724	18.1
Plot/2	73.9	3.5	7.1	26	23.9	3.1	716	17.9
Plot/3	77.0	3.3	7.0	24	24.6	2.6	728	18.2
Plot/4	71.0	3.0	7.4	25	23.8	2.9	720	18.0
Plot/5	77.2	3.1	6.9	21	24.8	3.0	728	18.2
Avg.	74.82	3.2	7.18	24.2	24.38	2.88	723.2	18.08

Note : Agronomic parameters were recorded on 180 DAP



Experience of Net Zero Clean Ginger cultivation under IBM-IORF Sustainability Project was shared at a State-level workshop on ginger and turmeric crop organized by University of Horticultural Sciences, Karnataka.

OUTCOMES OF NET ZERO GINGER SEEDLING DEVELOPMENT PROGRAM

Development of Net Zero Ginger Seedling Program has huge impact on local ginger farmers as the initiatives not only eliminate the treats of seed born diseases but saves irrigation and maydays.

This year from their own they have taken an initiatives towards development of more than 2.0 lakh seedling development towards sustainable Ginger cultivation - a major impact of IBM-IORF Sustainability Project

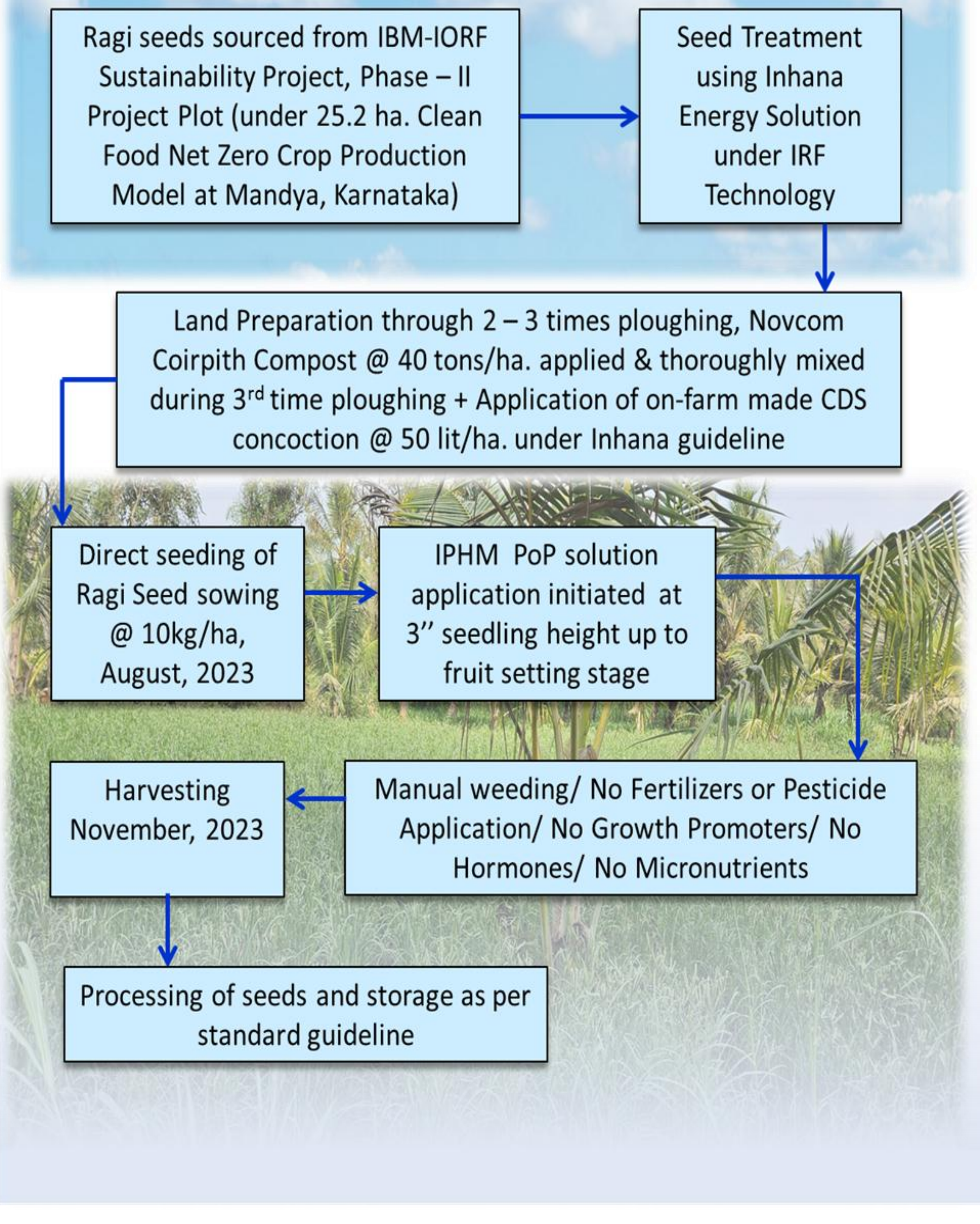
Chapter 2. Development of 'NET ZERO' Clean Millet Seeds; for Food Security and Farmers' Welfare, aligning with the 'Indian Millet Initiative', in the Project area at Mandya District of Karnataka

According to World Food Programme Millets are considered traditional food for 1.2 billion people across Asia and Africa. It requires less water and other agricultural inputs than other similar and higher stress tolerant staples. Millets are important by the virtue of its mammoth potential to generate livelihoods, increase farmers' income and ensure food & nutritional security all over the world. **Millets were also known as "coarse cereals" or "cereals of the poor" but now rebranded as "Nutri Cereals"**. The relevance has multifolded when UN amend the 2023 as the International Year of Millets. Among the various benefits most prominent are Health Promoting Nutritious Crop, Superior Micronutrient Profile, Bioactive Flavonoids, low Glycemic Index & Gluten free. Millets could be key to ensuring food and nutrition security, resource sustainability, and economic empowerment. Thus, it is critical to create policies towards reversing the global trends of decreasing consumption and production of millets, and enhance consumer awareness of their nutritional and health benefits.

Under the IBM-IORF Sustainability Project, Phase II, a pioneering initiative was undertaken to cultivate Ragi in a 4-hectare area using the Net Zero Clean Food 25.2 ha. Model. This model was meticulously developed through the adoption of Inhana Rational Farming (IRF) Technology for Phant Health Management. As part of soil health management, Novcom coir pith compost was applied @ 40 ton/ha was applied as the basal dose at the time of sowing during both the years.

Under IBM-IORF Sustainability Program (Phase-III). Development of **Net Zero Clean Millet Seed** is one of the important objectivity towards increase crop yield and withstanding climatic stress

Flow Diagram of - Net Zero Clean Millet Seed Development under IRF Technology (IBM-IORF Sustainability Project, Phase –III, 2023-24)



Crop performance of Ragi (Finger Millet) from 'Net Zero' Clean Millet Seed project plot under IBM-IORF Sustainability program at Mandya, Karnataka

Under the IBM-IORF Sustainability program in Mandya, Karnataka, the adoption of IRF Technology has led to a significant increase in Ragi (Finger Millet) productivity. A remarkable yield of 2289 kg/ha was achieved under the 'Net Zero' Clean Millet Seed production program, surpassing conventional farming practices by up to 24.8%.

The success in crop productivity can be attributed to various yield attributing characters, including the number of productive tillers per plant, number of fingers per earhead, earhead length, finger length, grain yield per plant, and 1000-grain weight. Additionally, the rate of accumulation of dry matter plays a crucial role in plant growth, with vegetative parts serving as sources and grains acting as sinks.

The implementation of Inhana Plant Health Management has contributed to higher levels of biomass accumulation and efficient translocation to reproductive parts. This activation of plant physiological functioning has facilitated better nutrient uptake and assimilation, ultimately leading to improved crop productivity. Through adoption of IRF Technology, the project has demonstrated its potential to revolutionize agricultural practices and enhance yields in Ragi cultivation, paving the way for sustainable and profitable farming in the region.


Pic. Ragi (Finger Millet) seed developed at Mandya, Karnataka for Clean Food 'Net Zero' Millet Seed Production program, Phase – III.

Comparative crop performance of finger millet under Clean Food net Zero Program at Mandya, Karnataka

Plots	Plant height (cm)	Productive tillers m^{-2}	Above ground biomass ($gplant^{-1}$)	No. of ears m^{-2}	Fingers ear $head^{-1}$	1,000-grain weight (g)	Grain yield ($kg\ ha^{-1}$)	Stover yield ($kg\ ha^{-1}$)	Biological **y**ield ($kg\ ha^{-1}$)	Productivity per day ($kg\ ha^{-1}$)	Harvest Index (%)
Finger Millet Productivity under Conventional Farming Practice											
CFP -1	108.6	76	22.8	189	6	1.80	2012	4416	6428	16.23	0.31
CFP -2	109.5	70	23.9	175	5.9	1.79	1978	4334	6312	15.95	0.31
CFP -3	112.3	68	24.4	183	5.8	1.79	1952	4287	6239	15.74	0.31
Mean Value	**110.1**	**71.3**	**23.7**	**182.3**	**5.90**	**1.79**	**1981**	**4346**	**6326**	**15.97**	**0.31**
Finger Millet Productivity under Clean Food Net Zero Program under IBM-IORF Sustainability Project											
Project farmer - 1	106.5	78	21.2	211	6.2	1.81	2313	4826	7139	18.65	0.32
Project farmer - 2	110.3	82	23.1	226	6.0	1.82	2436	5214	7650	19.65	0.32
Project farmer - 3	108.7	69	22.3	189	6.4	1.81	2154	4687	6841	17.37	0.31
Project farmer - 4	108.6	72	22.8	201	6.4	1.8	2259	4811	7070	18.22	0.32
Project farmer - 5	109.5	75	23.1	206	6.2	1.82	2284	4864	7148	18.42	0.32
Mean Value	**108.72**	**75.2**	**22.5**	**206.6**	**6.24**	**1.812**	**2289.2**	**4880.4**	**7169.6**	**18.46**	**0.32**

Note : CFP: Conventional Farmers Practice

Final Mature stage (Ragi) from the ‘Net Zero’ Clean Millet Seed project plots at Mandya, Karnataka under IBM-IORF Sustainability Project, phase - III

Ragi Harvesting from the ‘Net Zero’ Clean Millet Seed project plots at Mandya, Karnataka under IBM-IORF Sustainability Project, phase - III

Quality Analysis of 'NET ZERO' (NZ) Clean Ragi/ Finger Millet Seed developed under IBM IORF Net Zero Clean Millet Seed Programme, Phase III 2023-24

Along with the Yield Assessment the Quality of the NZ Clean Ragi/ Finger Millet Seed was done in terms of its Physical & Climate Resiliency.

The seeds were pure, free from any intermixed varieties, as indicated by the minimum presence of inert matter and absence of weed seeds .

IBM-IORF Sustainability Project (Phase III), Moisture of Net Zero Clean Ragi (Finger Millet) Seed is 8.36% compared to max. seed moisture as per Indian Standard is 13%. Physical seed quality attributes are crucial factors that influence the performance of seeds in terms of germination, emergence, and establishment of plants. These attributes play a significant role in determining the success of crop production and are of utmost importance in sustainable agriculture. Germination percentage of Net Zero Clean Ragi (Finger Millet) Seed achieved 91% compared to min. seed germination as per Indian Seed Standard 80%. The study of seed resilience against stress also indicated that Net Zero Clean Ragi (Finger Millet) Seed had better capacity to withstand abiotic stress due to climate change impact

Comparative study of Seed Viability, Seed Vigor and Seed Resilience against Stress, of NZ Clean Ragi/ Finger Millet Seed with intervention of IRF Technology.

Seed Quality parameters	Seed Viability		Seed Vigor			Seed Resilience against Stress			
	[1]G %	[2]SV %	[3]GVI	[4]SVI-I	[5]SVI-II	[6]G_{WS} %	[7]G_{SS} %	[8]G_{AA} %	[9]EC
Conventional Ragi / Finger Millet Seeds (Farmers' Practice)	86	89.1	12.80	670.0	0.31	78.0	65.0	84.79	0.028
'Net Zero' Clean Ragi / Finger Millet Seeds	92	94.62	16.16	789.0	0.43	84.2	68.5	89.40	0.025

Note : *[1]G % : Germination %, [2]SV % : Seed Viability %, [3]GVI : Germination Velocity Index, [4]SVI-I : Seed Vigour Index-I, [5]SVI- II: : Seed Vigour Index-II, [6]G_{WS} % : Germination under water stress (-0.6 MPa induced osmotic potential); [7]G_{SS} % : Germination under Salt Stress (-0.3 MPa induced osmotic potential), [8]G_{AA}% : Germination under Accelerated Ageing; [9]EC : Electrical Conductivity*

OUTCOMES OF THE NET ZERO CLEAN MILLET SEED PROJECT

IRF Technology successfully demonstrated the effectivity of Climate resilient – quality Net – Zero Millet Seed (Ragi / Finger Millet) production in terms of crop productivity enhancement even with locally-adapted variety of Mandya, Karnataka.

This indeed is a unique milestone towards the Govt's initiative for the promotion of millet as Shree Anna and establishment of a Center for Excellence for R & D for providing pathway for community based Climate Resilient Net Zero Clean Millet seed production and use of this technology for developing quality seed development and propagation for all the important varieties of millet.

Chapter 3. Development of 'NET ZERO' Clean Coconut Planting Material, in the Project area at Mandya District of Karnataka

India is the largest coconut-producing country in the world and accounted for about 31.45% of the world's total production during 2021-22, with a production of 19,247 million nuts. The crop contributes around Rs. 30,795.6 crore (US$ 3.72 billion) to the country's gross domestic product (GDP) during 2022-23. The 4 states Kerala, Karnataka, Tami Nadu and Andhra Pradesh, accounting for 89.13% of the coconut area and 90.77% of the coconut production in the country during 2021-22. *(www.ibef.org/exports/coconut-industry-india).*

Karnataka state holds second highest area (604.23 thousand Ha.) after Kerala (756.44 thousand ha.) during 2021-22 (GoI). In Karnataka state almost all districts are cultivating coconut crop. **The Coconut productivity of Karnataka (8,569 nut/ha.) is 25% lower than Tamilnadu (11,400 nut/ha.) and even 5% lower than the National productivity (8,966 nut/ha.) (GoI).**

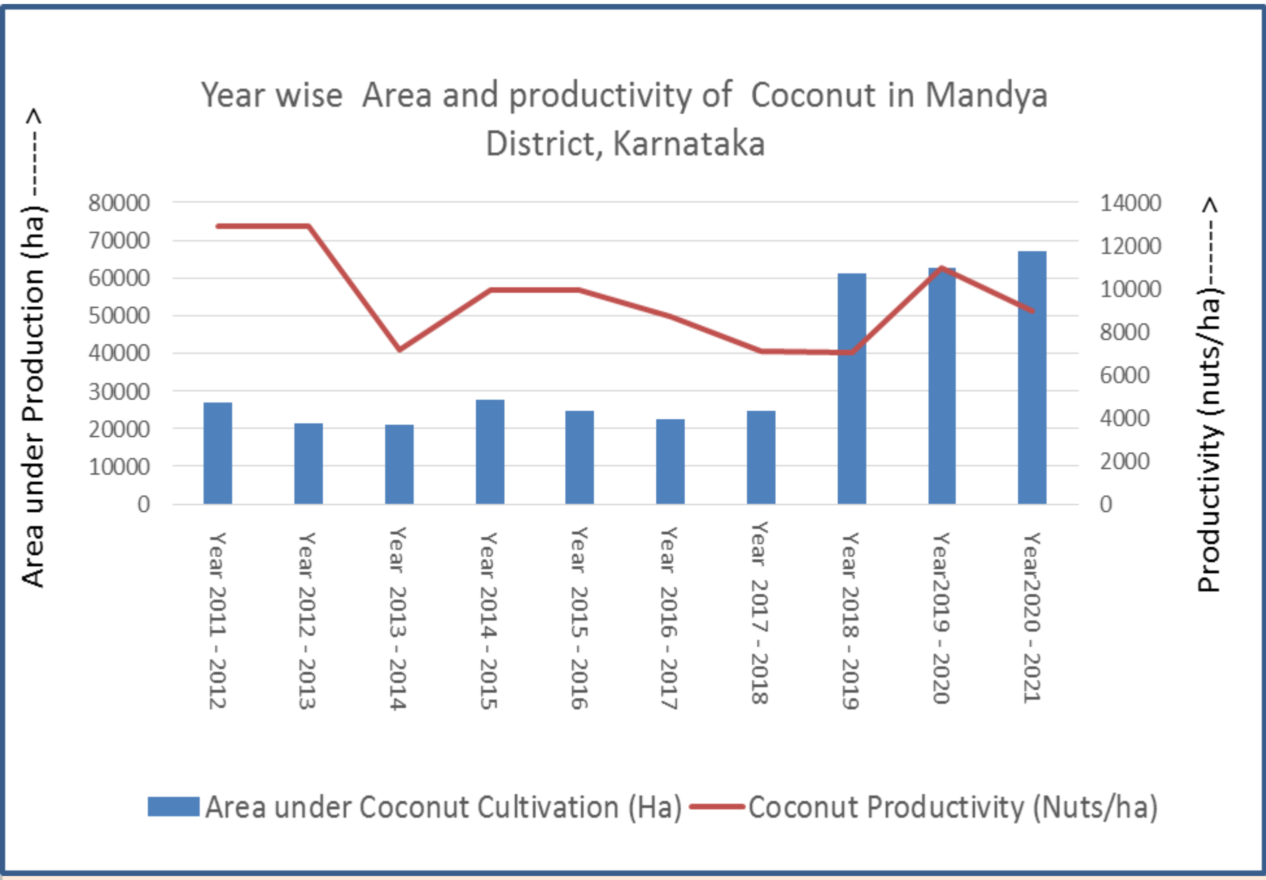


Fig. 1 : Year wise area under coconut cultivation and coconut productivity in Mandya District, Karnataka, India

According to the data available from Coconut Development Board, Ministry of Agriculture, Government of India, presently about **67106 ha area** is under coconut cultivation in Mandya and the average productivity is **8,955 nuts per ha**. Mandya is the 3rd largest district in Karnataka as far as area under coconut cultivation is concerned,2019-20. **Nearly 11% of area under coconut cultivation and 11.6 % of coconut production in Karnataka is from this district, 2019-20 (DIRECTORATE OF ECONOMICS AND STATISTICS, BENGALURU).** However comparing the data of last 10 years, it was found that though the production increased by about 151% **but the productivity sunk by about 31 %;** primarily due to climatic fluctuations, occurrence of higher pest and diseases and poor soil conditions

Challenges and Opportunities in Coconut Cultivation

Coconut cultivation has historically played a pivotal role in India's socio-economic development. However, the industry faces numerous challenges hindering its growth. **Despite providing livelihoods for over ten million farm families, low productivity remains a significant issue. Factors such as old and unproductive palms, along with a limited genetic base, contribute to this.**

Over the past two decades, coconut growers have encountered various problems leading to declining production and profits. **Inadequate technical knowledge, lack of quality planting materials, and absence of landowners are primary concerns. Recent studies highlight four critical issues faced by growers, with the lack of quality seedlings ranking highest, followed by pest damage, farm gate nut price, and access to technology. A survey revealed that 89% of growers struggle to find certified seedlings, indicating a severe shortage in the market.**

Given the gravity of the seedling shortage, a well-planned seedling production program is imperative. Immediate action is required to address these challenges and ensure the sustainability and prosperity of the coconut industry.

Objectivity:

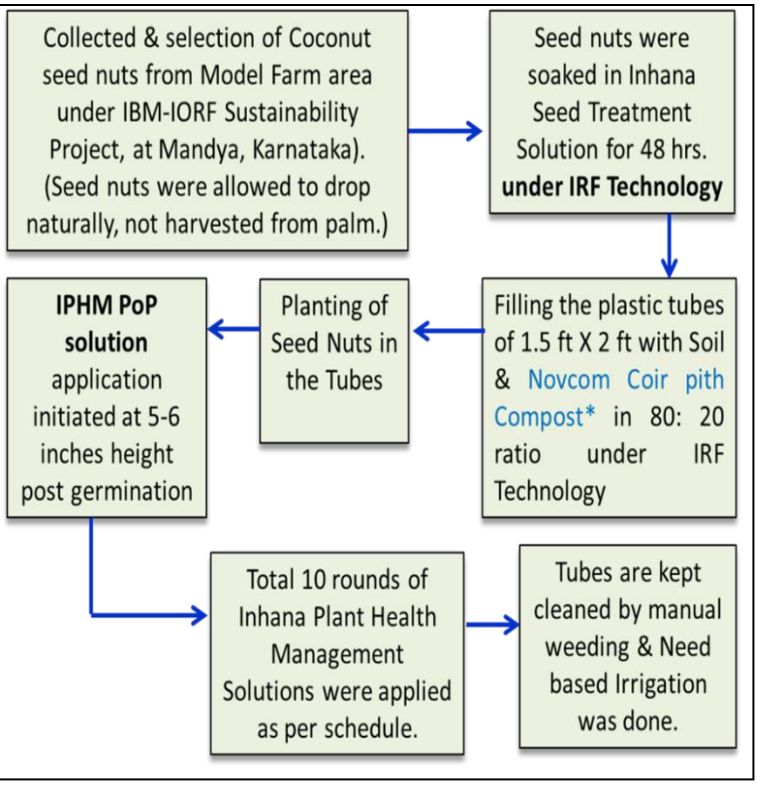
The quality of planting material determines the ultimate returns from arable crops, particularly from tree crops like coconut. The seedling vigour is highly correlated with adult palm characters such as early flowering, nut yield and copra production. Coconut, being a perennial crop, needs much attention in the selection of planting materials during establishments of an orchard or even for homestead garden.

Due to selection of the inappropriate mother palm, wrong planting technique, pest or disease attack during seedling/ nursery stage etc. ultimately impact on the coconut seedling quality. In this background Net Zero Clean Coconut Seedling Development programme has been taken under IBM-IORF Sustainability Project, Phase III at Mandya, Karnataka. The major objective taken under the IBM-IORF Sustainability Project was **production and distribution of high-quality planting material to enhance productivity.**

The objectivity was to develop **Clean, Resilient, Disease free and Healthy Coconut Planting Material** through adoption of Inhana Rational Farming (IRF) Technology.

Specially plant health management practice under IRF technology help to energized the plant system towards healthy seedling development .

Flow Diagram of - Net Zero Clean Coconut Seedling Development under IRF Technology (IBM-IORF Sustainability Project, Phase –III, 2023-24)



The initial and most crucial step is the selection of mother palms. Specifically, mother palms aged between 25-30 years with an average annual yield of 120 over the last 5 years are chosen for seed nut collection.

Coconut seedling quality under management of IRF Technology

Under IBM-IORF Sustainability Project, good quality clean coconut seedlings having average collar girth of 16 -18 cm, 8 -9 fronds and 145 - 175 cm height was obtained within 11^{th} month. The majority (92.5%) of the nuts germinated within 90 days and recovery of good quality seedlings was to the tune of 89.5 per cent.

Table 1 : The temporal change in seedling height, girth at collar zone and total number of leaves at Monthly intervals after seed nut laying in response to IRF package of Practice

Months	6	7	8	9	10	11
Seedling Height (cm)	72.8	90.2	103.3	123.5	145.5	162.5
Girth at Collar (cm)	8.4	9.3	12.2	14.3	15.6	17.4
Total No of leaves	2.6	3.4	4.9	6.2	6.9	8.6

From the above study it can be concluded that adoption of Inhana Rational farming technology and addition of Novcom compost in the nursery tube helps towards healthy and vigorous growth of coconut seedlings. This this study cloud be a benchmark for development of quality coconut seedlings which is a major constraint in India

When the general recovery percent of quality coconut seedling is about 60 – 65 %, under IRF Package of Practice the recovery percent increased over 90 % under IBM-IORF Sustainability Project

India stands as the world's largest coconut-producing country, contributing approximately 31.45% to global production. To bolster productivity, the IBM-IORF Sustainability Project prioritized the production and dissemination of high-quality coconut planting material. This initiative focused on developing Clean, Resilient, Disease-Free, and Healthy Coconut Planting Material through the adoption of Inhana Rational Farming (IRF) Technology.

Specifically, the implementation of **Plant Health Management under IRF Technology played a pivotal role in invigorating plant systems for healthy seedling development**. A study conducted as part of this project demonstrated the effectiveness of IRF Technology, coupled with the addition of Novcom compost in nursery tubes, in promoting the healthy and vigorous growth of coconut seedlings.

These findings highlight the potential of **sustainable practices to enhance coconut productivity and contribute to the long-term sustainability** of coconut cultivation in India.

OUTCOMES OF THE NET ZERO CLEAN COCONUT SEEDLING PROJECT

The study showed that adoption of Inhana Rational Farming (IRF) Technology and addition of Novcom compost in the nursery tube helps towards healthy and vigorous growth of coconut seedlings.
It will helps the coconut farmers to grow Clean, Resilient, Disease free and Healthy Coconut Plant and established coconut plantation

Mature coconut seedlings at Mandya under IBM-IORF Sustainable Project

Chapter 4. Development of 'NET ZERO' Clean Sugarcane Planting Material, in the Project area at Mandya District of Karnataka

In India, sugarcane stands as a pivotal cash crop with diverse applications, including sugar production and renewable energy through ethanol. However, ensuring an adequate supply of sugarcane amidst diminishing natural resources has become more daunting than ever before. **Sugarcane is the main source of sugar (80%) globally and holds a prominent position as a cash crop.** Sugarcane and sugar play significant role in economy of India, trade and livelihood. Sugar is country's second largest agro-based industry, next to cotton**. Sugarcane and sugar industry together impact the livelihood of over 5 crore farmers and their dependents involved in cultivating sugarcane in an area of almost 50 lakh hectares. India is the largest consumer and the second-largest producer of sugar in the world.** The largest producer of sugarcane in India is Maharashtra, which produced **over 138 lakh tonnes of sugarcane in 2022-23. Uttar Pradesh, Karnataka, and Maharashtra together contribute to 80% of the total sugarcane production in India. Karnataka stands 3rd in Sugarcane production next to Uttar Pradesh in India.**

MANDYA SUGARCANE SCENARIO

Sugarcane is important commercial crop of Karnataka. Sugarcane plays a vital role for the overall socio-economic development of farming community in Karnataka State and Mandya District. Mandya district is one of largest producer of sugarcane in Karnataka. The district ranks fourth in Sugarcane production from an area of 34.67 thousand hectares and production of about 3.72 million tonnes during 2018-19 .

Sugarcane producing farmers are facing issues like low productivity in this district and the average sugar recovery rate is lower than the key sugar producing nations. The growth of area under Sugarcane in Mandya district from 1997-98 to 2018-19 shows negative growth of 0.17 percent. At the same time production of Sugarcane reduced to 37,18,282 tonnes 2018-19 from 42,63,661 tonnes during *2001-02 (Madegowda Mand Dr. Mahesha M , IJSSER 2022).* Though sugarcane productivity of Mandya district is 107 ton/ha. which is 30% higher than the national productivity about 80.5 tons/ha. but the major limitations in the sugar recovery percentage.

Background of developing Quality Sugarcane Planting Material

The IBM-IORF Sustainability Project Phase III, g 2023-24, addressed the pressing challenges faced by sugarcane cultivation in Mandya District, Karnataka. Recognizing the importance of quality planting material for enhancing productivity**, the project focused on the development of Climate-Resilient Clean Net Zero, high-quality sugarcane planting material through the adoption of IRF Technology.**

Sugarcane, propagated vegetatively, requires healthy seed cane for optimal yields. However, conventional cultivation methods often lead to the accumulation of pathogens and the indiscriminate use of chemicals for nutrient supply and pest control, resulting in soil health hazards and environmental pollution.

By prioritizing the development and adoption of 'Net Zero Clean Sugarcane Planting Material,' we can pave the way for a safer and more sustainable future for sugarcane cultivation in Mandya district, benefiting both the environment and farmers' livelihoods.

The project aimed to develop

'Net Zero Clean Sugarcane Planting Material,'

laying the foundation for cultivating 'Clean Sugarcane' and eventually achieving 'Net Zero' status.

This approach not only safeguards the environment but also enhances sustainability, improving sugarcane yield and sugar recovery while boosting farmer income.

Flow Diagram of - Net Zero Clean Sugarcane Seedling Development under IRF Technology (IBM-IORF Sustainability Project, Phase –III, 2023-24)

Collected & selection of canes of 8-10 months old from Model Project area under IBM-IORF Sustainability Project, at Mandya, Karnataka).

→

Seed were soaked in Inhana Seed Treatment Solution for 48 hrs. **under IRF Technology**

↓

Filling the plastic tubes of 1.5 ft X 2 ft with Soil & Novcom Coir pith Compost* in 80: 20 ratio under IRF Technology

←

Planting of Seed in the Tubes

←

IPHM PoP solution application initiated at 5-6 inches height post germination

→

Total 10 rounds of Inhana Plant Health Management Solutions were applied as per schedule.

→

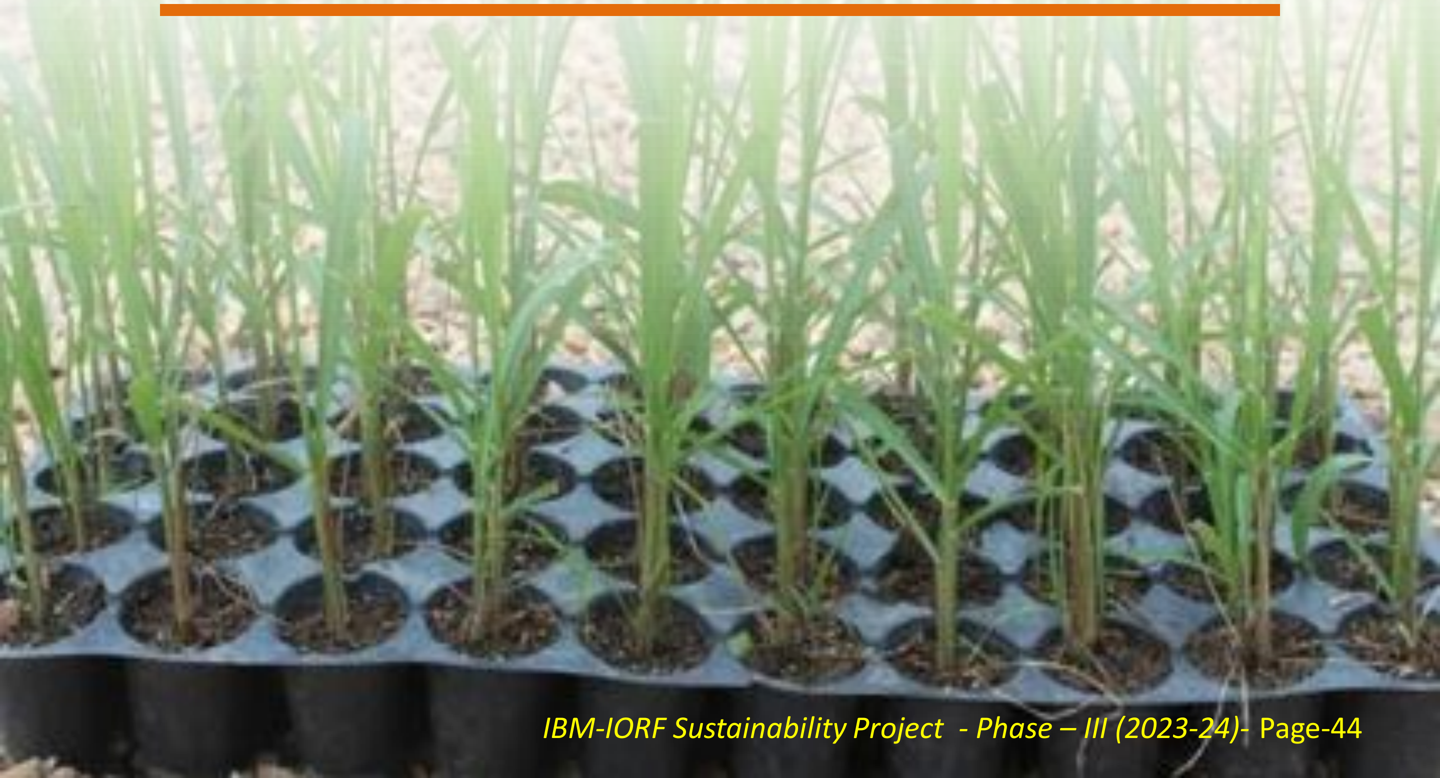
Tubes are kept cleaned by manual weeding & Need based Irrigation was done.

Development of Novcom coirpith compost under IBM-IORF Sustainability project at Mandya, Karnataka

Sugarcane plantation under Clean Food Net Zero program in IBM-IORF Sustainability project at Mandya, Karnataka

Future potential of the Net Zero Clean Sugarcane Development

Under the IBM-IORF sustainability project, the development of **'NET ZERO' Clean Sugarcane Planting Material is crucial in the context of climate change impacts.** Utilizing polythene bags or tray culture for sugarcane seedling development not only reduces seed costs but also mitigates the risk of crop failure. **This approach is particularly beneficial in regions like Karnataka, where water scarcity and irregular rainfall patterns pose significant challenges to sugarcane cultivation. By saving water, preventing the spread of seed-borne diseases, and reducing cultivation costs, the initiative supports local farmers in adapting to changing environmental conditions and achieving sustainable sugarcane production.**



Chapter 5 : Development of 'Clean Millet' encompassing different important varieties for improvement of Crop Productivity and Quality, in the Project area at Mandya District of Karnataka

Millets, celebrated as the ancient backbone of sustenance, occupy a distinguished position in agricultural history. These resilient grains, cultivated since antiquity, thrive in arid climates, defying soil limitations and water scarcity. India, with its rich agricultural legacy, hosts a diverse range of millets, recognized for their nutritional prowess. Acknowledging their significance, the Indian government has aptly labeled them as "Nutricereals," underscoring their exceptional dietary value.

India, a global leader in millet production, boasts a formidable position in the market. Sorghum, Bajra, Ragi, and various small millets such as Korra, Little, Kodo, Proso, and Barnyard millet flourish across the country. Government initiatives like the National Food Security Mission and the Millets Mission aim to bolster millet cultivation, augment market connectivity, and enhance consumer awareness.

India accounts for approximately 17% of global millet production, with an impressive 16.9 million tonnes of millets harvested annually. These grains are cultivated across 12.7 million hectares of land, contributing 6% to the national food grain reserves. Notably, India leads in the production of Barnyard (99.9%), Finger (53.3%), Kodo (100%), Little millet (100%), and Pearl millet (44.5%), yielding around 12.46 million metric tonnes from an area spanning 8.87 million hectares (B. Venkatesh Bhat, 2023).

Millet Resurgence in Karnataka's Agricultural Landscape

Karnataka, endowed with vast dry lands, faces a significant challenge of drought vulnerability, with over 79% of its arable area prone to dry spells. However, the state's agricultural potential remains underutilized, particularly by resource-constrained farmers. In this context, millets emerge as climate-resilient alternatives, capable of withstanding delayed rains unlike water-intensive crops like paddy. Ragi, jowar, and bajra stand out as staples, with ragi dominating the southern region and jowar and bajra prevalent in the north-western parts.

Recognizing the importance of millets in ensuring food security and environmental sustainability, there's a growing call to reorient agricultural practices towards millet cultivation. By promoting millets, Karnataka can leverage its climate-resilient nature to mitigate the impacts of drought and secure the livelihoods of its farming communities.

In the face of climate uncertainties and dwindling water resources, the revival of millets presents a promising pathway for Karnataka's agricultural resilience. By embracing millet cultivation and implementing supportive policies, the state can chart a sustainable course towards food security and rural prosperity.

OBJECTIVITY

Under the IBM-IORF Sustainability Project's Phase III, a concerted effort is underway to promote sustainable agriculture through the cultivation of five distinct millet varieties. These include small millets such as Proso and Kodo Millet, as well as sorghum, pearl millet, and finger millet. Recognized for their resilience to environmental stresses, these millet varieties are being cultivated using IRF Technology under Net Zero Clean Millet Development. The aim is to demonstrate the potential of sustainable agricultural practices in enhancing farmers' livelihoods while ensuring assured productivity and mitigating the adverse impacts of climate change within the project area.

Net Zero Clean Millet Development encompassing different important varieties viz Finger Millet , Kudo Millet, Proso Millet, Pearl Millet and Sourgam **at Mandya, Karnataka under IBM-IORF Sustainability Project Phase III, 2023-24 utilizing Inhana Rational Farming (IRF) Technology.**

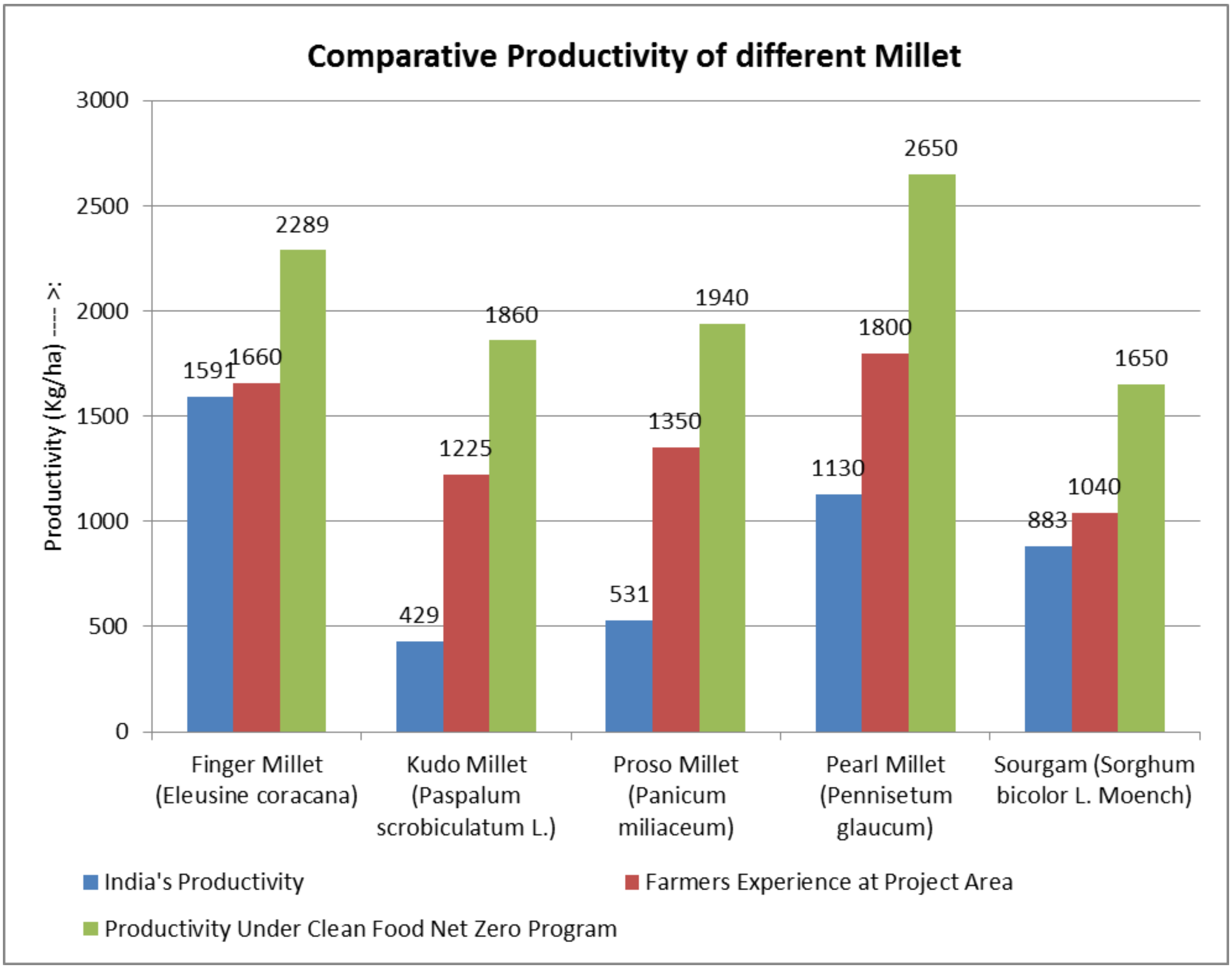
To improve crop productivity of Millets, Sustainable Management Program with adoption of an effective nature friendly technology which can ensure increase in crop productivity while maintaining the fine balance of our ecosystem and contribute to climate change mitigation is the major focus of our study under the IBM-IORF Sustainability Program.

Millet cultivation under IBM-IORF Sustainability Project at Mandya, Karnataka

Millet Productivity under Clean Food Net Zero Program with adoption of IRF Technology

Millets	World Productivity	India's Productivity	Farmers Experience	Productivity Under Clean Food Net Zero Program
Finger Millet (Eleusine coracana)	600 kg/ha	1591 kg/ha	1360 - 1960 kg/ha	2289 kg/ha
Kudo Millet (Paspalum scrobiculatum L.)	-	429 kg/ha.	850 - 1600 kg/ha	1860 kg/ha
Proso Millet (Panicum miliaceum)	-	531 kg/ha.	1200 - 1500 kg/ha	1940 kg/ha
Pearl Millet (Pennisetum glaucum)	500 kg/ha	1130 kg/ha	1500 - 2100 kg/ha	2650 kg/ha
Sourgam (Sorghum bicolor L. Moench)	1408 kg/ha	883 kg/ha	960 -1120 kg/ha	1650 kg/ha

Millet cultivation under IBM-IORF Sustainability Project at Mandya, Karnataka.



There was a huge variation in millet productivity as it was mostly cultivated in poor soil with minimum management effort. However with due management effort and introduction of agro-technology can improve the productivity dramatically. It was demonstrated under IBM-IORF sustainability project with adoption of IRF technology. Application of Novcom compost @ 40 ton/ha for organic soil management followed by spraying of energized and potentized energy solutions for crop health management helps to improve significant crop productivity. At the same time IRF Technology helps towards GHG mitigation with negative carbon footprint per kg millet which help towards value added marketing towards livelihood support for local farmers

OUTCOMES OF THE NET ZERO CLEAN MILLETS PROJECT

There was considerable yield improvement was noticed under Clean Food Net Zero program with adoption of IRF Technology irrespective of millet variety. This clearly indicated that adoption of effective agro-technology like IRF Technology have the potential to change India's Millet cultivation scenario, offering promising prospects for sustainable agriculture and rural development.

Chapter 6 : Development of Coconut based Circular Economy (CE) Model, in the Project area at Mandya District of Karnataka

One of humanity's primary challenges lies in meeting the needs of a rapidly growing population, with estimates suggesting a necessary increase of **5.1 billion tonnes in food production by 2050 (FAO, 2017)**. This poses immense pressure on agricultural ecosystems, which already serve as the primary food providers globally. However, this heightened demand risks exacerbating negative impacts on the environment, as agriculture consumes a substantial portion of water and energy resources, while also contributing significantly to greenhouse gas emissions (UN, 2021). **The linear nature of modern food production systems comes with substantial environmental, social, and economic costs, with food-related CO2 emissions projected to double by 2050 if current unsustainable practices persist.** Addressing these challenges requires urgent shifts towards more Sustainable Agricultural Practices and consumption patterns.

Towards sustainability and circular economy

The industrial revolution spurred the rise of economic models, but also brought challenges like resource scarcity, inefficient utilization, and environmental degradation. These issues have catalyzed discussions around new models to replace the linear economy. The Sustainable Development Goals (SDGs) have become focal points for sustainability efforts, with concepts like the Green Economy, Circular Economy, And Bio-economy gaining prominence in macro-level sustainability discussions of the policymakers.

Circular agriculture focuses on using minimal amounts of external inputs, closing nutrients loops, regenerating soils, and minimizing the impact on the environment. If practiced on a wide scale, circular agriculture can reduce resource requirements and the ecological footprint of agriculture. It can also help ensure a reduction in land-use, chemical fertilizers and waste, which makes it possible to reduce global CO_2 emissions (UN 2021).

Development of Coconut based Circular Bio-economy

A circular bio-economy offers the opportunity to transform our land, food, health and industrial systems and it could create new sustainable income opportunities. This transition will bring with it opportunities for decarbonization, and contribute to managing and rebuilding ecosystems and landscapes that desperately need it. Adoption of this new economic growth model, which aims at decoupling environmental growth from fossil fuel dependence and providing biomass-based feedstock for consumption. Thus, bioeconomy adds value to biomass resources, and analysis of the economic benefits of a particular resource can be performed via a “value web”. Thus the resource efficiency or replacement of fossil fuel-derived feedstock and innovations in the biotechnological perspective are the two great pillars in bio-economy which requires introduction of new sustainable technology to drive. This is because, circular bio-economy requires low-carbon energy inputs and promising disruptive conversion technologies for the sustainable transformation of renewable bioresources to high-value bio-based products. The bio-based circular carbon economy, in particular, stresses capturing atmospheric carbon via photosynthesis and it sits at the intersection between the circular economy and the bioeconomy concept, resulting in a framework that focuses on closing the carbon cycle and stressing the opportunity to create an additional carbon sink capability in the techno sphere by utilizing biogenic carbon for products and materials that are circulated in same or improved use cycles.

Now specially looking at South India’s vast arid and semiarid land scape with limited choice of crop, poor soil quality, coconut as natural vegetation and problems of recycling of coirpith –a agro waste generated from coir industry – a concept of circular bio-economy can be perfectly fit if a suitable technology can relates / binds all the factors in a single thread. This idea motivates to drive an agricultural sustainability initiatives with adoption of Inhana Rational Farming (IRF) Technology under IBM-IORF sustainability project to established an Coconut-based Circular Bio-economy Model for improvement of crop productivity, soil quality and farm economics. With Adoption of IRF technology, coir pith was utilized to make quality Novcom compost for organic soil management followed by IRF Plant Health Management package of practice for crop sustainability with the objectivity of efficient resource recycling, soil quality development, crop sustainability and finally enhance farm income.

Program undertaken at Mandya towards development of coconut based circular economy (CE) models

Coconut is a major crop in Mandya, but in the last 10 Years its yield has drastically reduced and is now about 30% lower than the national average and about 50% Lower than Tamil Nadu- the highest coconut producing state. Coconut plantations are highly suited for intercropping. Multispecies cropping under coconut can ensure higher resource utilization and additional income per unit area of soil. But to achieve the desired benefits in the already declining soil quality, adoption of Sustainable Practice will be crucial. Intercropping with sustainable practice results in improvement of soil properties and improves biological activities in the root region. At the same time coconut based intercropping system can produces adequate returns from land and labor within the constraints of unpredictable climatic conditions and limited inputs.

Under IBM-IORF Sustainability Project, an effort was generated to introduce Coconut- based Circular Economy Model to open up the scope for improving crop diversity as well as farm productivity especially concerning the marginal soil, especially on reuse and recycling of coirpith waste. The model was developed with the adoption of Inhana Rational Farming Technology – a comprehensive organic package of practice. Under this technology, coir pith- a waste generated from coir industry and a source for soil and water pollution and methane generation was utilized for soil health management; post effective bioconversion under Novcom Composting Technology. Novcom Composting Technology enables bioconversion of coir pith waste into a safe, stable and mature compost within 30 days and the end product is rich in self generated native microflora; which can help out in speedy regeneration of soil microbial population. Novcom coir pith compost was applied @ 40 ton/ha.

3 different cropping model were cultivated as intercrop within the coconut plantation. The significance was that this intercropping model was primarily demonstrated in the marginal soils (red gravelly soils with low soil fertility and microbial activity), deemed unfit especially for cultivation of nutrient sensitive short duration vegetable crops and that too with complete elimination of N- Fertilizers and chemical pesticides.

Circular economy models were analyzed with a focus on their impact on yield, nutrient utilization, soil health, energy usage, greenhouse gas (GHG) emissions, and cost-benefit ratio, all of which play crucial roles in influencing the livelihoods of resource-poor farmers. These models aim to optimize resource efficiency, minimize waste, and promote sustainability throughout the agricultural value chain. By emphasizing practices such as recycling, reusing, and regenerating resources, circular economy approaches strive to enhance productivity while reducing environmental impacts.

Under IBM-IORF Sustainability Project it was aimed to showcase how the circular economy principles can be integrated into agricultural systems through scientific technological intervention (IRF Technology) to improve the well-being and economic prospects of farmers facing resource constraints.

Management adopted in coconut based circular economy (CE) models

For **Soil Health Management** in the coconut plantation, 40 ton of Novcom Coir pith compost was applied per hectare. Also about 250 ltr. of Cow dung slurry was applied in the soil for enhancement of microbial activity, post application of Novcom Coir pith compost.

Dual approach of Soil and Plant Health Management under Inhana Rational Farming (IRF) Technology utilizing coir pith as major source for soil rejuvenation & Inhana Plant health management solutions for Crop Sustainability helps to develop the coconut based Circular Bio Economy Model

After transplanting/sowing of different crops, **Inhana Plant Health Management** solutions were sprayed in a periodical manner as per the recommended schedule. This management practice not only helped towards balanced growth, at the same time improved plant immunity and defense mechanism against pest and disease leading to natural elimination in the requirement of pesticides.

Crop performance under coconut based circular economy (CE) models

Crop productivity of coconut based intercropping under different bio circular economy model adopted in Mandya, Karnataka was compared with conventional coconut based intercropping practice. Under IBM-IORF Sustainability project, 3 major coconut based intercropping was taken under study.

(i) CE 1 : Coconut -Millet – Vegetable (Cabbage),

(ii) CE 2: Coconut based Maize – Vegetable (Brinjal) and

(iii) CE 3: Coconut – Ginger

Comparative crop performance under different coconut based intercropping practice under IBM-IORF Sustainability Project at Mandya, Karnataka

Management Practice	Crop Productivity			Coconut Equivalent Yield (Kg/ha)	System Productivity (Nuts/ha)
	Coconut (Nuts/ha)	Millet (Kg/ha)	Vegetable (Kg/ha)		
CE 1 : Coconut -Millet - Vegetable intercropping plot					
Conventional Farmers Practice	7200	1986	24400	9473	14555
Clean Food Net Zero Program	7900	2256	28260	10666	16387

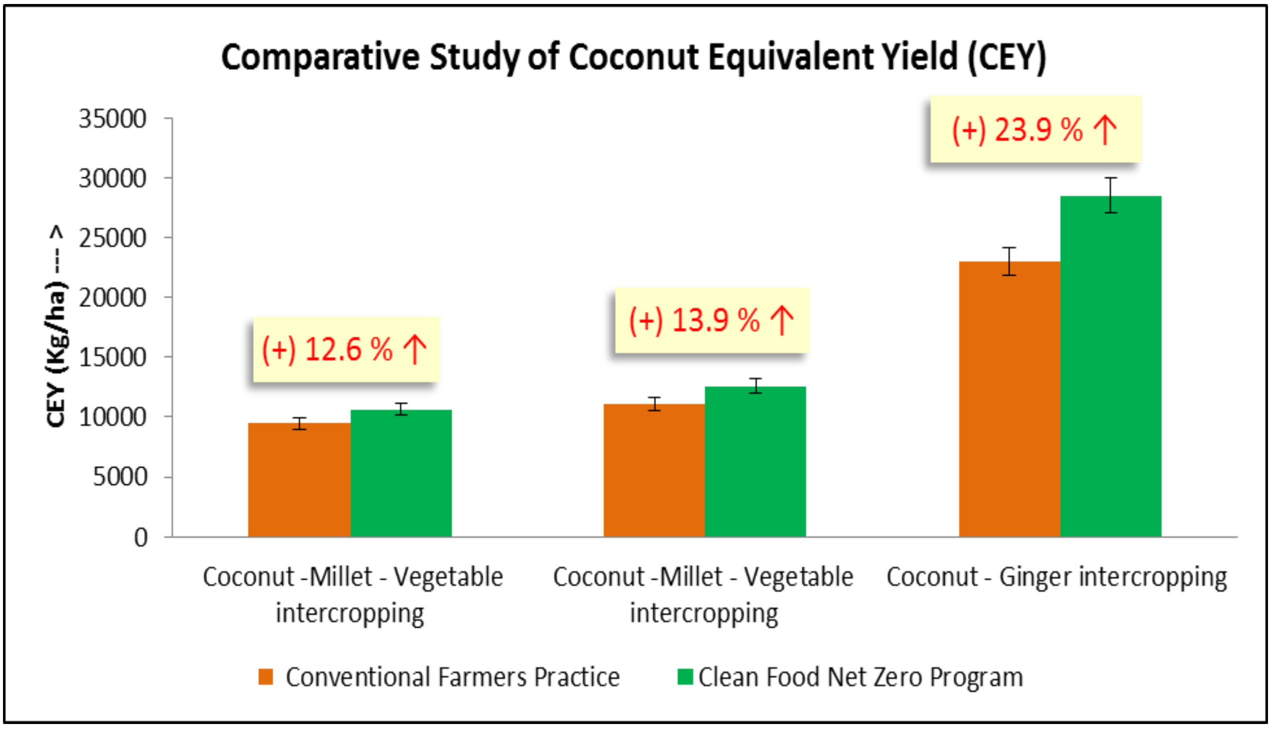
CE 2: Coconut - Maize - Vegetable intercropping plot

Management Practice	Crop Productivity			Coconut Equivalent Yield (Kg/ha)	System productivity (Nuts/ha)
	Coconut (Nuts/ha)	Maize (Kg/ha)	Vegetable (Kg/ha)		
Conventional Farmers Practice	7350	3120	22300	11044	16991
Clean Food Net Zero Program	8120	3440	26220	12574	19345

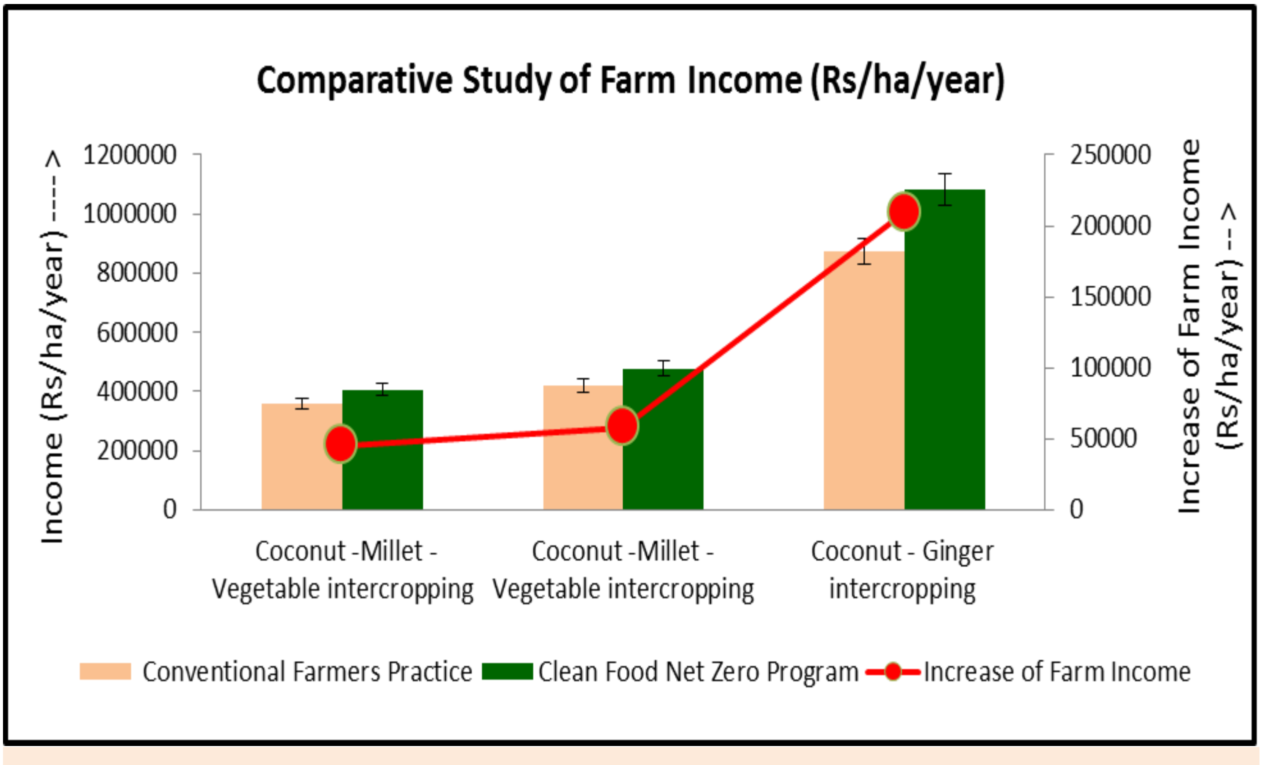
CE 3: Coconut - Ginger intercropping plot

Management Practice	Crop Productivity		Coconut Equivalent Yield (Kg/ha)	System productivity (Nuts/ha)
	Coconut (Nuts/ha)	Ginger (Kg/ha)		
Conventional Farmers Practice	7440	14400	23025	35424
Clean Food Net Zero Program	8240	18350	28535	43900

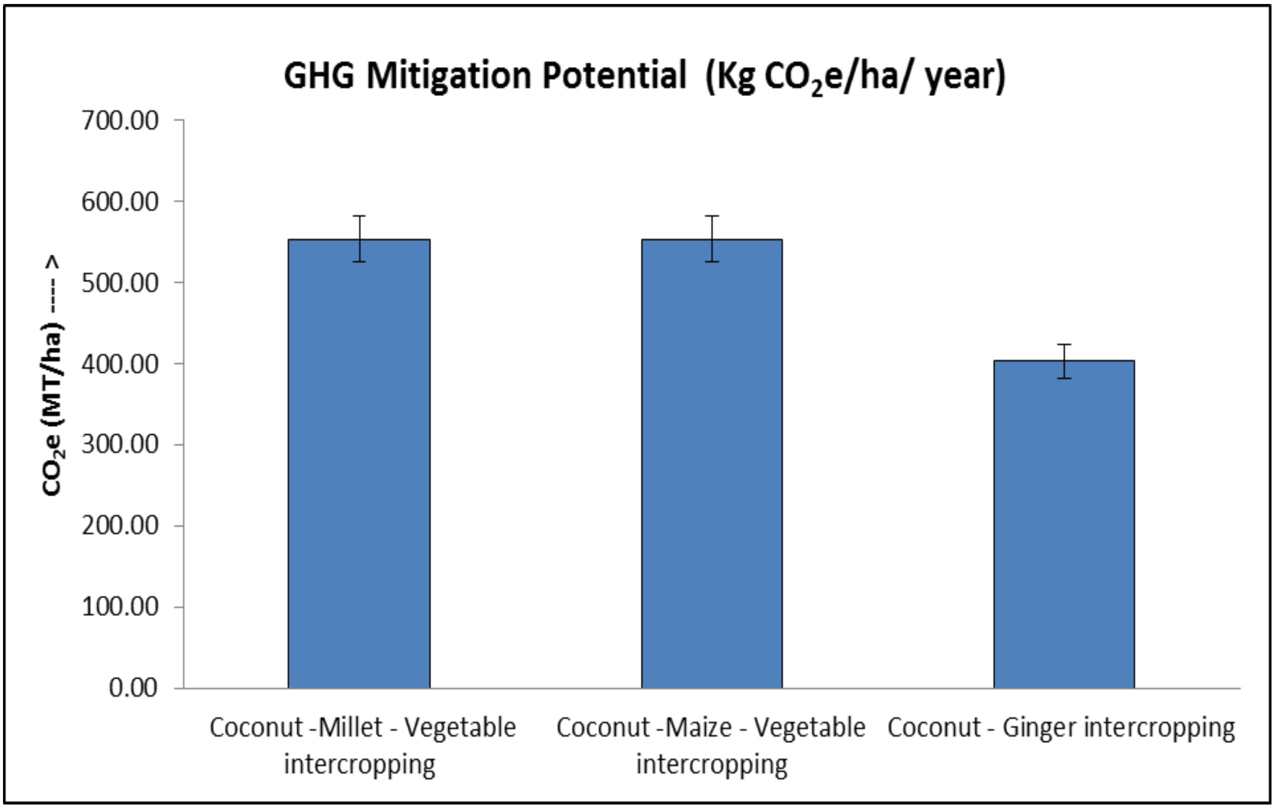
Note : Approx 60 % area was utilized under other crop in coconut intercropping



Comparative study of coconut equivalent yield (CEY) showed that there was highest increase (23.9 %) of CEY (kg/ha) was in case of coconut – ginger inter-cropping practice with adoption of Clean Food Net Zero program. However in other two model also showed significant increment of CEY under the program which might be due to adoption of Inhana Rational Farming (IRF) Technology as experienced under different crop under IBM-IORF sustainability program irrespective of Agro-ecological zone.



Comparative study of farm income showed that it was highest under coconut – ginger inter-cropping practice (Increase of farm income was Rs 209360 /ha/year) with adoption of Clean Food Net Zero program.



Comparative study of GHG mitigation potential under Clean Food Net Zero program in comparison to conventional farmers practice revealed that highest GHG mitigation potential was under coconut –maize –vegetable intercropping (553.49 MT CO_2e / ha/year). The study reveled that adoption of Clean Food Net Zero program have the potential for meaningful contribution towards climate change mitigation.

Coconut – millet intercropping as part of coconut based circular bio-economy model at Mandya, Karnataka

Impact of coconut based circular economy (CE) models on Soil Quality

In the study focused on soil health management within coconut-based circular economy (CE) models, soil samples were collected both at the outset of the research and at the conclusion of the harvesting phase to assess the impact of the initiative. Despite the somewhat rushed nature of the endeavor to draw definitive conclusions, the aim was to glean insights from the program. Initial findings revealed significant deficiencies in soil carbon levels, fertility status, and microbial activity. Moreover, the presence of small to medium-sized gravel particles exceeding 50% of the soil's weight rendered it largely unsuitable for cultivating sensitive crops. These observations underscore the pressing need for interventions to address soil health issues within the context of circular economy models in coconut based intercropping.

Soil Physical Quality Evaluation of Coconut based Circular Economy (CE) Model, in the Project area at Mandya ,Karnataka

Sl. No.	Land Use	Soil Gravels %	Sand %	Silt%	Clay%	Texture
1	CE 1 : Coconut based Millet - Vegetable intercropping plot	57.89	72.00	16.00	12.00	Loamy Sand
2	CE 2: Coconut based Maize - Vegetable intercropping plot	63.29	82.00	5.00	13.00	Loamy Sand
3	CE 3: Coconut based Ginger intercropping plot	59.55	74.00	15.00	11.00	Loamy Sand

Novcom Coirpith Compost at Mandya, Karnataka

Impact of coconut based circular economy (CE) models on Soil Quality

Soil Physico-chemical Parameters Evaluation of Coconut based Circular Economy (CE) Model, in the Project area at Mandya ,Karnataka under IBM-IORF Sustainability Project, Phase III

Sl. No.	Major Land Use	pH	EC (1:5) dSm^{-1}	Org. C %	Av NO_3 (ppm)	Av-N (kg/ha.)	Av P_2O_5 (kg/ha.)	Av. K_2O (kg/ha.)	Av- SO_4 (kg/ha.)
1	CE 1 : (Pre Management Soils)	6.06	0.054	0.55	22.00	163.64	61.14	603.12	410.32
	CE 1 : (Post Management Soils)	6.12	0.051	0.71	20.00	210.26	72.19	627.29	350.23
2	CE 2: (Pre Management Soils)	6.23	0.049	0.59	34.30	181.26	11.92	539.27	391.22
	CE 2: (Post Management Soils)	6.27	0.044	0.77	24.29	203.12	13.46	538.29	383.17
3	CE 3: (Pre Management Soils)	6.19	0.056	0.36	31.26	159.23	24.22	460.39	472.19
	CE 3: (Post Management Soils)	6.29	0.048	0.46	28.26	196.37	31.27	471.23	453.22

Coconut – vegetable intercropping as part of coconut based circular bio-economy model at Mandya, Karnataka

Soil microbial properties Evaluation of Coconut based Circular Economy (CE) Model, in the Project area at Mandya ,Karnataka under IBM-IORF Sustainability Project, Phase III

Sl. No.	Major Land Use	MBC (microgram C/gm soil)	FDA (µg/g dry soil)	Bacteria X 10^4	Fungi X 10^3	Actinomycetes X 10^3
1	CE 1 : (Pre Management Soils)	30.12	17.61	62	27	12
	CE 1 : (Post Management Soils)	50.72	21.22	72	20	11
2	CE 2: (Pre Management Soils)	28.37	13.67	41	19	10
	CE 2: (Post Management Soils)	47.29	18.19	76	37	14
3	CE 3: (Pre Management Soils)	21.62	12.11	21	18	12
	CE 3: (Post Management Soils)	42.46	17.62	29	42	42

Note: Soil MBC : *Soil Microbial Biomass (µg.CO_2.C/gm dry soil);* ***FDAH :*** *Fluorescein di-acetate hydrolyzing activity (FDAH) (µg/gm dry soil)*

Evaluation of soil quality under Coconut based 'Net Zero' Intercropping pre and post experimentation revealed no considerable changes in soil pH and EC. However, slight increase (28% - 30%) in organic carbon was noted which was mainly due to application of Novcom coir pith compost @ 40 ton/ha. Available N, P, K showed increasing trend though the difference is not significant.

Soil micro-organisms play a significant role in regulating the dynamics of organic matter decomposition and availability of plant nutrients.. Comparatively higher value of soil microbial pollution, soil MBC and its activity (indicated by FDAH activity) etc. post soil analysis indicated the favourable role of Novcom coir pith compost towards soil micro flora rejuvenation. This was probably due to very high (one trillion billion microbes / ton compost) self generated microbial presence in Novcom coir pith compost, which post application helps to regenerate microbes in soil in speediest manner. Overall offsetting of synthetic fertilizers and pesticides also helps to create a toxicity free favourable condition for increasing microbial population.

In summary, the study found that implementing coconut-based intercropping systems within the CFNZ program, alongside adopting IRF Technology, enhances soil properties and productivity. This is achieved by maintaining a dynamic equilibrium among biotic and abiotic components of the soil, sustaining biochemical processes, and rejuvenating soil microflora. Diverse species under coconut trees contribute to continuous nutrient replenishment through recycling and addition, leading to improved crop productivity compared to conventional farming practices.

Red loamy soils of Mandya, Karnataka

Preparation of different organic concoctions towards rejuvenation of soil microbes at Mandya, Karnataka

CONCLUSION

A circular, bio-based economy stands as the most comprehensive pathway towards a sustainable future, prioritizing the health and regeneration of our ecosystems. By avoiding non-essential products, minimizing waste, and utilizing renewable energy sources, this approach emphasizes the importance of biomass streams for meeting basic human needs while prioritizing sustainability.

In the context of the IBM-IORF Sustainability project in Mandya, Karnataka, we have successfully developed a coconut-based circular bio-economy model through the adoption of Inhana Rational Farming (IRF) technology. This model not only enhances crop productivity and increases farm income but also improves soil health and mitigates greenhouse gas emissions.

The development of this Coconut-based Circular Economy (CE) Model serves as a benchmark study for formulating sustainable agricultural programs, particularly in the context of climate change mitigation. It showcases the potential of integrating innovative technologies and circular economy principles to create resilient and environmentally friendly agricultural systems.

Coir pith is most underrated and unaccounted Agro Industry waste which is a potent source of Soil & Water pollution and Methane emitter but hard to recycle without an Effective Technological Intervention

Present of high lignin part in coirpith which contains aromatic and aliphatic components and various functional groups, including phenolic, hydroxyl, carboxyl, benzyl alcohol, methoxy, and aldehyde groups, which can cause phytoxicity when applied untreated in agricultural soil. The present practices / mal practices in many parts of South India with application of these materials as organic manure with no /little intervention enhance the threats – which needs an established mechanism for proper recycling and agricultural usage.

About 1000 ton of Coir Pith was bio-converted to produce Novcom Coir pith compost and utilized for elimination of synthetic fertilizers, especially Nitrate Fertilizers, through sustainable Soil Health Management towards maintenance of 25.2 ha. Clean Food Net Zero Model for development of SAFEST food – 'Clean Food Net Zero' and for full proof validation in terms of Crop Sustainability. About 40 MT of NOVCOM compost was given, which essentially infused 40 trillion billion self generated diversified microbial population into the soil.

GHG ABATEMENT through Inhana Soil Health Management (ISHM)

On- farm produced **Novcom Coir pith Compost** at 40 ton/ ha as well as various organic concoctions were used for **SOIL HEALTH MANAGEMENT** towards **elimination of Nitrate Fertilizers.** Elimination of N- fertilizers means **stoppage of N_20 Emission- another critical GHG**, while Restoration of Soil Biological productivity, through Novcom Compost application can initiate the regeneration process of **Soil-C Sequestration Potential-** a critical step towards GHG abatement .

Bioconversion of raw Coir Pith – a landfill waste, especially a prolific Methane emitter – using Novcom Composting Technology demonstrated GHG OMISSION FROM SOURCE while converting this Waste into a Stable, Mature and Non-phytotoxic compost within the shortest period of 30 days.

Novcom composting Technology developed by IORF, has enabled bioconversion of **2000 ton of Coir pith (in 2022-23 & 2023-24) to Safe–Stable-Mature Compost rich in self generated microflora** (one trillion billion Microflora per ton Novcom compost) **within 30 days –** Bioconversion of Toxic Methane Emitter to an Excellent Resource for Soil- C Sequestration .

The Study indicated that bioconversion of coir pith under Novcom Composting Technology, can enable a **Methane mitigation of about 6000 ton CO_2 eq.** per 1000 ton waste

SOIL HEALTH MANAGEMENT UNDER IRF TECHNOLOGY

Soil health plays an important role in agricultural productivity, food quality, environmental resilience, and ecosystem sustainability as HEALTHY SOILS PRODUCE HEALTHY CROPS that in turn nourish life on earth. In 2023-24, as part of the IBM-IORF Sustainability Project Phase-III, Inhana aimed to assess the potential of each individual crops /seed in terms of productivity and their impact on farmers' livelihoods. This assessment focused on utilizing the IRF Technology, a sustainable crop production approach. A comprehensive plant and soil health management strategy were implemented to achieve Net Zero Clean Food Cultivation.

Novcom Coirpith Compost @ 40 tons./ha. as well as various organic concoctions (CDS & P5 etc.) was applied as a Safe and Quality Compost in Soil. The application of this compost not only enhances soil quality but also facilitates the elimination of synthetic chemical fertilizers. By adopting such practices, the agricultural sector can progress towards achieving Clean Food 'Net Zero' objectives, promoting sustainability and environmental responsibility in food production.

Using NOVCOM Composting Technology of IORF, to convert coir pith into compost is a great step towards reducing environmental pollution. The utilization of biologically activated and potentized NOVCOM (CP) Solution were used for creating an ideal environment for enhancing the effectiveness of the composting process. This approach not only addresses the issue of waste management but also harnesses the potential of natural elements to create a beneficial product for agriculture. It's exciting to see innovative solutions like this being implemented to tackle environmental challenges.

Novcom Coirpith Compost prepared under IBM-IORF Sustainability Project at Mandya, Karnataka

QUALITY OF NOVCOM CP COMPOST

Analyzed under IBM-IORF Sustainability Project (2023-24), *Mandya, Karnataka*

Physicochemical properties, fertility parameters and lignin content of 30 days Novcom coir pith compost utilizing Novcom Composting Technology.

Test Parameters	Novcom Coirpith Compost made using NOVCOM Technology under IBM-IORF Sustainability Project
PHYSICOCHEMICAL PARAMETERS	
Moisture (%)	68.4 – 74.2
pH (H_2O)	6.26 – 6.67
EC (dSm^{-1})	2.04 – 2.44
Ash Content (%)	44.22 – 47.29
Volatile Solids (%)	52.71 - 55.78
Organic carbon (%)	27.67 – 30.24
NUTRIENT & NUTRIENT DYNAMICS	
Total N (%)	0.96 – 1.07
Total P_2O_5 (%)	0.16 – 0.19
Total K_2O (%)	3.14 – 3.44
C:N	27: 1 - 30:1
CMI	1.49 – 1.57
BIOLOGICAL PARAMETERS	
Bacteria (c.f.u. per gm moist compost)	(37 – 49) X 10^{16}
Fungi (c.f.u. per gm moist compost)	(11 – 27) X 10^{16}
Actinomycetes (c.f.u. per gm moist compost)	12 X10^{16}
STABILITY, MATURITY & PHYTOTOXICITY PARAMETERS	
CO_2 Evolution Rate ($mgCO_2$–C/g OC/day)	1.41 -1.78
Seedling Emergence (% Over Control)	103.7 – 108.7
Root Elongation (% Over Control)	107.1 – 112.5
Germination Index (Phytotoxicity Bioassay)	0.97 – 1.24
LIGNIN DEGRADATION STUDY	
Acid soluble lignin (ASL)%	0.79 – 0.91
Acid insoluble lignin (AIL)%	22.65 – 22.91
Total lignin %	23.64 - 23.84

QUALITY ANALYSIS OF NOVCOM COIR PITH COMPOST

Due to high lignin content and high C:N ratio, coir pith when left untreated can take decades to decompose, which not only leads to environmental pollution but most importantly methane emission, thereby contributing to climate change. However, once composted, coir pith can transform into an effective soil rejuvenator, considering its utility towards amelioration of especially marginal/ agriculturally degraded soil and improvement of soil productivity.

Novcom coir pith compost was produced under Novcom Composting Technology of Inhana, within a period of 30 days with 2 turnings of the compost heap on 10^{th} & 20^{th} day. Physicochemical and fertility status of compost resembled the standard set by different international composting councils, while its total nitrogen (0.96 – 1.07 %) content was much higher than coir pith compost produced using other composting processes. The high value of nitrogen might be due to intense biodegradation process, which lowered the potential for N loss and favourably influenced atmospheric- N fixation through naturally generated autotrophic microflora within compost heap. The finding was corroborated by the high population of microbes (10^{14} to 10^{16} c.f.u. per gm moist compost) within compost, which were generated naturally during the composting process. Maturity and phytotoxicity bioassay tests confirmed that Novcom coir pith compost was mature and free from phytotoxic effect. The study concluded that Novcom composting method could be an effective and economical process for speedy conversion of coir pith into a valuable input for organic soil management.

Novcom coir pith compost at Mandya, Karnataka under IBM-IORF Sustainability Project, 2023-24

IBM-IORF Sustainability Project : Soil Health Management in 25 ha (25%) of Project Area utilising Novcom Coir Pith Compost.

From Phase- II of the IBM-IORF Sustainability Project, at Mandya, Karnataka; IBM had provided extra project allocation towards **Soil Health Management using Novcom Coir pith Compost in about 25 ha Project Area towards the objective of Developing Clean Food 'NET ZERO'. This is perhaps the Best Model for Climate Action (both Mitigation and Adaptation)** utilizing **bio-converted landfill waste; which impacts the crucial SDG-2**. Moreover with this single additional intervention the outcome will be phenomenal. Single project will accomplish the objectives of Seven SDG's- 1,3,11,12,15, apart from SDG-2 and 13.

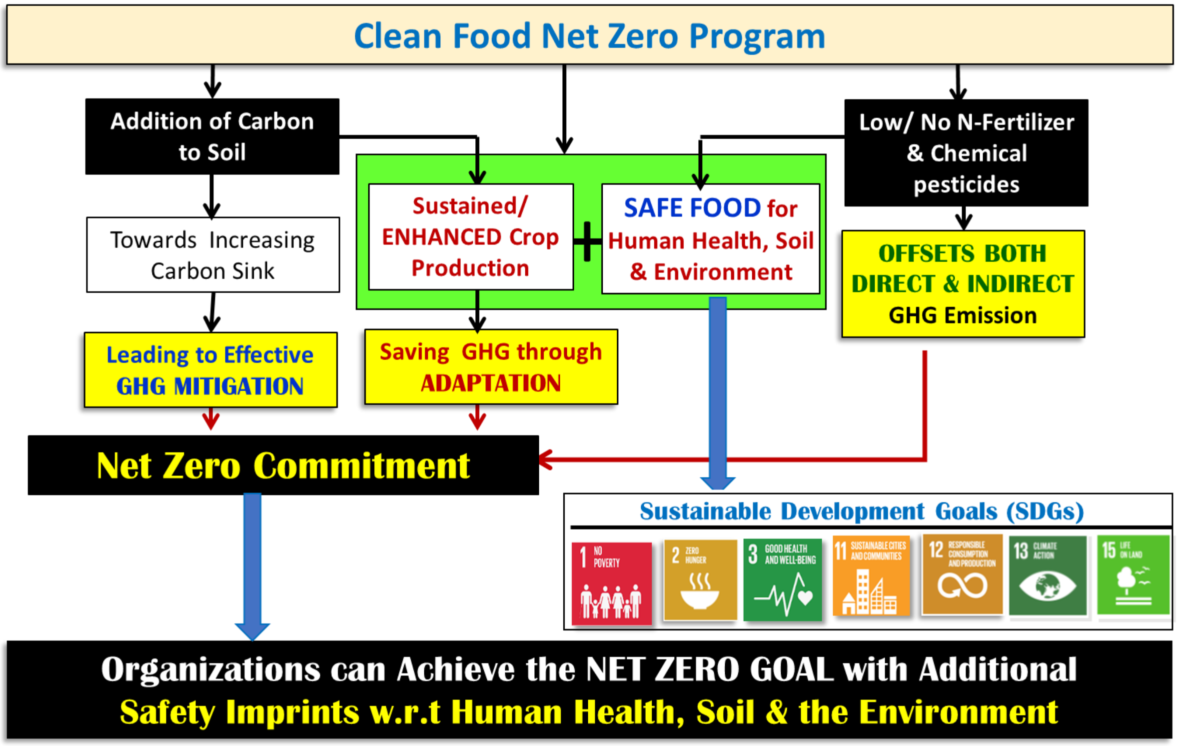
The program helped to develop a Unique Model for conversion of Waste to Wealth, i.e., a potential GHG Emitter and Pollutant to a Safe and Quality Organic amendment for Safe and Sustainable Crop Production, through the utilization of Novcom Composting Technology. This is important especially in the context of Methane (CH4) Mitigation, which is at the enter stage of discussion in any Climate Action Program This is because Offsetting Methane is the fastest way of bringing down the rate of Global Temperature Rise but one of the Hardest Program to Execute.

Moreover, Methane with GWP value of 75 with an atmospheric time period of 24 years is one of the most dangerous GHG, considering that it can generate three potential GHG's; i.e., Carbon-di-oxide, Water vapour and Ozone. And Coir pith is a very strong Methane Emitter which emits more than 6.0 ton CO2-eq. per ton. The IBM-IORF Sustainability Project has already demonstrated >99% Omission of Methane from Source through adoption of Novcom Composting Technology.

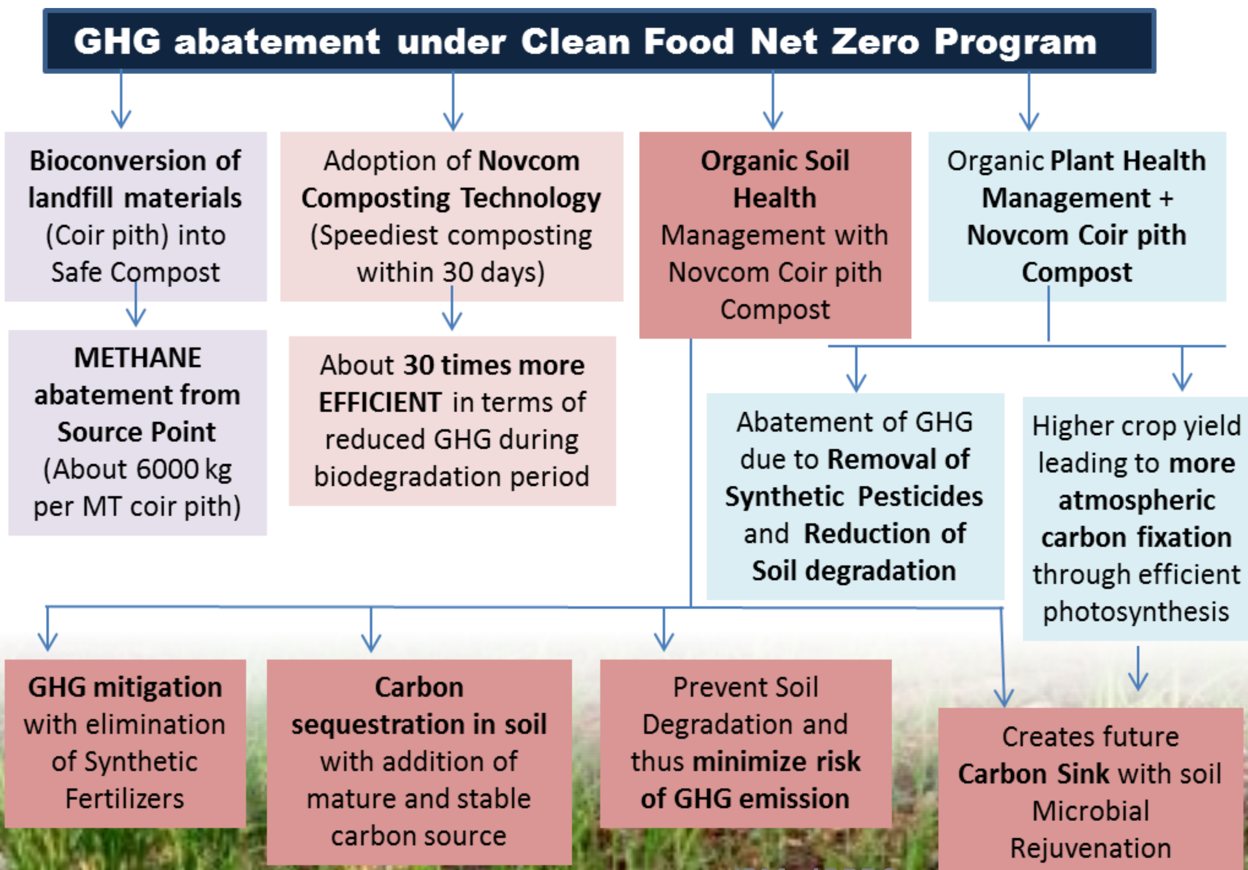
This is important not only w.r.t. the Climate Commitment in line with SDG-13; but is also crucial in the pretext of Degraded Soil Reclamation and Sustenance/ Improvement of Crop Yields; which forms the key for livelihood sustenance of the Project Farmers in Mandya, Karnataka. This program will also ensure mitigation of Nitrous Oxide (N2O) which emits from Urea application to a tune of 1.3 ton CO2-eq. per hectare.

Finally Clean Food 'NET ZERO', perhaps the Best Endeavor in respect of Climate Action and the Highest Form of Sustainability in a Tangible Manner. 'NET ZERO' signifies that it is not just Stoppage of Omission from Source (that is otherwise considered un-abatable) but also Sequestration of about 2.0 ton Carbon per hectare. The program can ensure a Total of about 250 MT CO_2-eq. Negative Carbon Footprints per ha.

How Clean Food Net Zero Program can at a time attend the Net Zero Commitment & Sustainable Development Goals (SDGs) ?



Inhana Clean Food Net Zero (CFNZ) Program for GHG Mitigation at Karnataka



Under Clean Food 'Net Zero' program at Mandya, Karnataka under IBM-IORF Sustainability Project with the adoption of IRF Technology, bio- conversion of coir pith (Landfill WASTE from coir industry) was taken up through utilization **of Novcom Composting Technology in order to transform it into Safe and Mature Novcom Coir pith compost. This was to serve the dual objective of soil health management and elimination of N- fertilizers. This approach actually provided three way benefits in respect of GHG mitigation.** Firstly, bioconversion of landfill materials, cut off the METHANE emission potential directly from SOURCE POINT. Secondly, bioconversion of the material through Novcom Composting Technology, reduced the GHG emission by about 30 times than the average GHG emission recorded under any biodegradation process. Thirdly, Novcom coir pith was utilized for soil health management towards elimination of synthetic fertilizers specially N fertilizers, which on one hand stopped N_2O emission while also enabling soil carbon sequestration.

Organic Plant Health Management under IRF Technology, ensure elimination of synthetic pesticides that enabled reduction of indirect GHG emission. Moreover, adoption of IRF Technology improved crop productivity, which meant higher atmosphere carbon fixation through efficient photosynthesis.

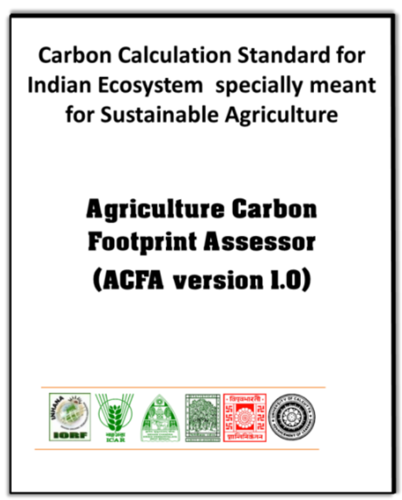
Comparative study of GHG Emission under Conventional farmer's Practice and Clean Food 'Net Zero' Program

Adoption of CFNZ Model in the 25 ha Project Area has enabled GHG Abatement of approx. 6300 MT CO2 eq. through Stoppage of GHG emission from Source Point and GHG mitigation through elimination of Synthetic Fertilizers. Moreover, Adaptation to Climate Change is exhibited through higher crop yields; that also indicated higher atmospheric C- capture; along with SAFEST FOOD production.

GHG Footprint evaluation in respect of seven major crops production under Clean Food Net Zero program (CFNZ) in 25.2 ha. area in Mandya, Karnataka, was done through ACFA (Version 1.0) tool and it was found that replacing conventional farmers' practice with CFNZ Program has the potential to mitigate about 250.39 Mt CO_2 equivalent per ha..

What is 'ACFA (Agriculture Carbon Footprint Assessor)'?

ACFA, Agriculture Carbon Footprint Assessor is a tool for Assessment of Carbon Footprint in Agriculture (An Evaluation Protocol based on "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories" and latest IPCC Assessment Report 6 (AR6), released in August 2021.)


Carbon Calculation Standard for Indian Ecosystem specially meant for Sustainable Agriculture

Agriculture Carbon Footprint Assessor (ACFA version 1.0)

What are new in 'Agriculture Carbon Footprint Assessor (ACFA)'?

- Specifically developed for assessing the GHG footprints from Sustainable Agricultural Practices.
- Considered **ALL THE POSSIBLE** alternative Specific Input components under these calculations.
- These calculations involve more detailed and specific data and specific emission factors of individual inputs that can provide more accurate estimates of GHG Footprint.
- Inhana felt the need for development of more precise & accurate tool for assessing the greenhouse gas inventories (as per IPCC Guideline) that are crucial for understanding the contributions of different agricultural activities to climate change and for tracking progress toward emission reduction targets. Hence, the calculations have been made as per IPCC Tier 3 methods that are the most advanced and precise, involving specific measurements and more sophisticated models.
- In the calculations for **'Agriculture Carbon Footprint Assessor',** Inhana has taken the specific values of process emission for different on-farm composts/organic soil inputs. Even Specific scope for Agricultural Waste Compost & Land fill compost is separately being kept under these calculations.
- While No scope of input biological parameters (most important quality components for sustainable soil health management) of on – farm compost in All other available calculators, Inhana trying to establish the correlation with the sequestration potential of compost with its microbial strength (As per Inhana Logic) in **'Agriculture Carbon Footprint Assessor (ACFA)'.**
- **ACFA** considers all the possible input specific embodied energies.
- In ACFA overall scope for specific/ detailed inputs for resource recycling towards Sustainable Farming is **much innovative as well as relevant.**
- In the calculations of ACFA, focused & considered the **micro- environment factors into the assessment** so that it can enhance the accuracy and relevance of the results and facilitate the development of targeted and context-specific climate action plans in a specific region.
- Additionally, ACFA can aid in measuring progress and the effectiveness of mitigation efforts within a particular micro-environment over time.
- **ACFA** will provide a comprehensive report that outlines the carbon footprint of the agricultural operation: breakdowns of emissions by activity or emission source, identification of hotspots, and potential mitigation strategies.
- **ACFA** will have more synchronization with Indian conditions and recommendation from the findings having impact on sustainability initiatives.

Components of Agricultural Operations considered for GHG Calculation

GHG Emission / mitigation are associated with most of the Agricultural Operations. In general more GHG emission occurs due to the farm level activities taken up under Conventional Agriculture. In contrast, under sustainable/ organic farming practice, both GHG emission and mitigation occurs. The relevant Agricultural Operations are listed below in a broader class for Conventional Farmers Practice, Sustainable Agriculture and in the Clean Food Net Zero (CNFZ) Model under IRF Technology.

Sl. No.	Farm Operations under Conventional Farmers Practice	Farm Operations under Sustainable Agriculture	Farm Operations under Clean Food Net Zero (CNFZ) Model under IRF Technology
1	Seed*	Seed*	Seed*
2	Seed Treatment	Seed Treatment - Alternate Bio agents.	Seed Treatment - Under IRF Technology.
3	Nursery Management	Nursery Management	Nursery Management
4	Land Preparation	Land Preparation	Land Preparation
5	Irrigation	Irrigation	Irrigation
6	Weed Management	Weed Management.	Weed Management.
7	Cultural Practice	Cultural Practice	Cultural Practice
8	Crop Nutrient management - Chemical Fertilizer Application	Crop Nutrient Management - Compost Application/ Bio fertilizers.	**Inhana Soil Health Management (Under CFNZ)** - Novcom compost application.
9	Crop Protectants (Chemical Crop Protectants)- Clemical Fungicides, Insecticides .	Crop Protectants - Bio pesticides, Bio fungicides.	Inhana **Plant Health Management (Under CFNZ)** - 1st & unique concept introduced under IRF Technology
10	Other Inputs (if any) - Synthetic Growth Promoters etc.	Other Inputs (if any) -Organic Growth Promoters	Other Inputs (if any) -On Farm Concoctions made under the guideline of IRF Technology
11	Harvesting	Harvesting	Harvesting

*Note: *No standard reference of individual seed GHG available so far for GHG emission due to Seeds.*

Excluding the Highlighted blocks (Operations related to Soil & Crop Management/ Protections) all inputs/ components remains almost same for any Agricultural Practices. On the other hand these highlighted blocks are the major components for GHG Emission/ Mitigation.

Table 1 : GHG emission in different crop cultivation under conventional farmers practice at Mandya, Karnataka

Sl. No.	Farm Operations	Ragi	Maize	Vegetables	Ginger	Sugarcane (2nd year)	Coconut
		kg CO_{2e}/ ha					
1	Seed Treatment, Bed Preparation & Nursery Mgt.	6.787	0.315	2.348	34.17	-	-
2	Land Preparation	110.54	110.54	120.714	120.714	-	-
3	Transplanting	13.565	0	13.565	13.565	-	-
4	Irrigation	56.91	71.14	256.1	142.28	170.74	156.51
5	Chemical Crop Nutrients Management	*958.48*	*1212.74*	*2271.59*	*1948.6*	*4021.57*	*1378.68*
6	Chemical Pest management	-	-	*17.943*	*40.135*	*64.137*	-
7	Weed Management	2.226	7.156	1.507	30.839	15.767	3.626
8	Cultural Practice	-	-	-	-	-	-
9	Carbon from Biomass	-	-	-	-	-	-3183.25
10	Harvesting	0.446	0.446	-	6.782	2.79	-
11	Total GHG Emission (kg CO_{2ee} / ha)	1149.0	1402.3	2665.8	2297.0	4210.9	-1644.4

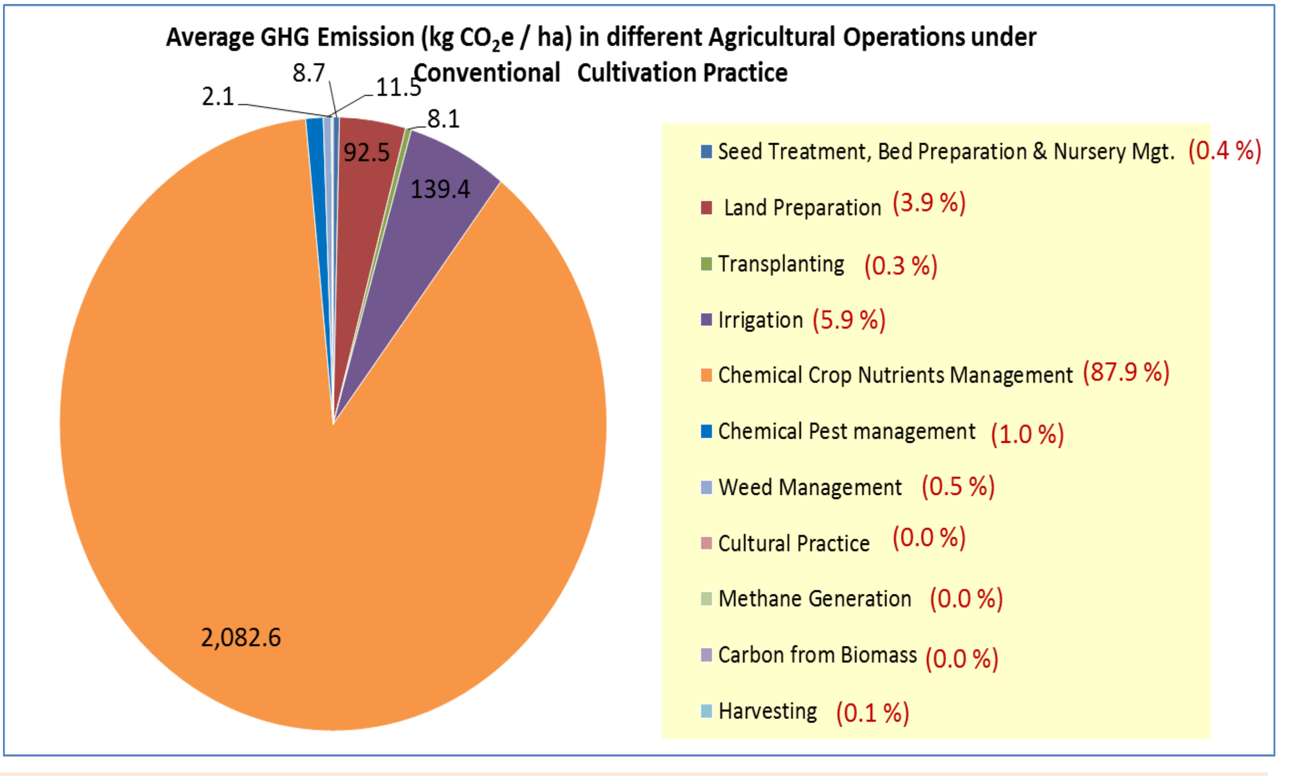


Fig 1 : Average GHG emission (KgCO_2e /ha) of different agricultural operations at Mandya, Karnataka studied under IBM-IORF Sustainability Program

Table 2 : GHG emission in different crop cultivation under Clean Food Net Zero Program at Mandya, Karnataka

Sl. No.	Farm Operations	Ragi	Maize	Vegetables	Ginger	Sugarcane	Coconut
		kg CO_{2e}/ ha					
1	Seed Treatment, Seed bed Preparation & Nursery Mgt.	6.029	0.027	0.944	1.02	-	-
2	Land Preparation	110.54	110.54	120.714	120.714	-	-
3	Transplanting	13.57	0.00	13.57	13.57	-	-
4	Irrigation	56.91	71.14	256.1	142.28	170.74	156.51
5.	Inhana Soil Health Management (ISHM) with Novcom Coir pith Compost	-248872	-248872	-248872	-248872	-248872	-248872
6	Inhana Plant Health Management (IPHM)	3.77	3.77	6.47	7.54	4.31	3.77
7	Weed Management	0.67	0.67	1.507	1.507	1.507	0.67
8	Carbon from Biomass	-	-	-	-	-	-3183
9	C- Sequestration due to Land Use Change	-1130	-1130	-1130	-1130	-1130	-1130
10	Cultural Practice	-	-	-	-	-	-
11	Harvesting	0.446	0.446	0.000	6.782	2.790	0.000
12	Total GHG Emission (kg CO_2 / ha)	-249810	-249815	-249602	-249708	-249822	-249841

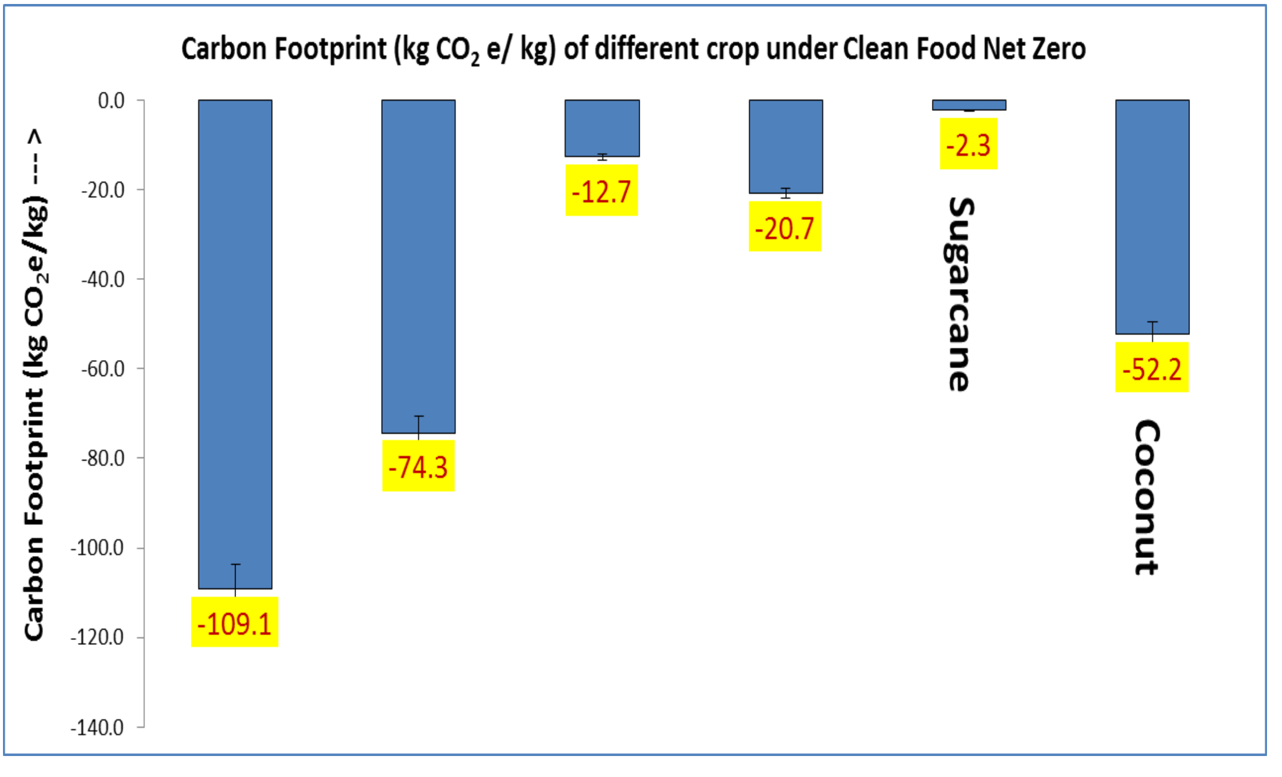


Fig 2 : Carbon footprint of different crop under Clean Food Net Zero Program, IBM-IORF Sustainability Project at Mandya, Karnataka.

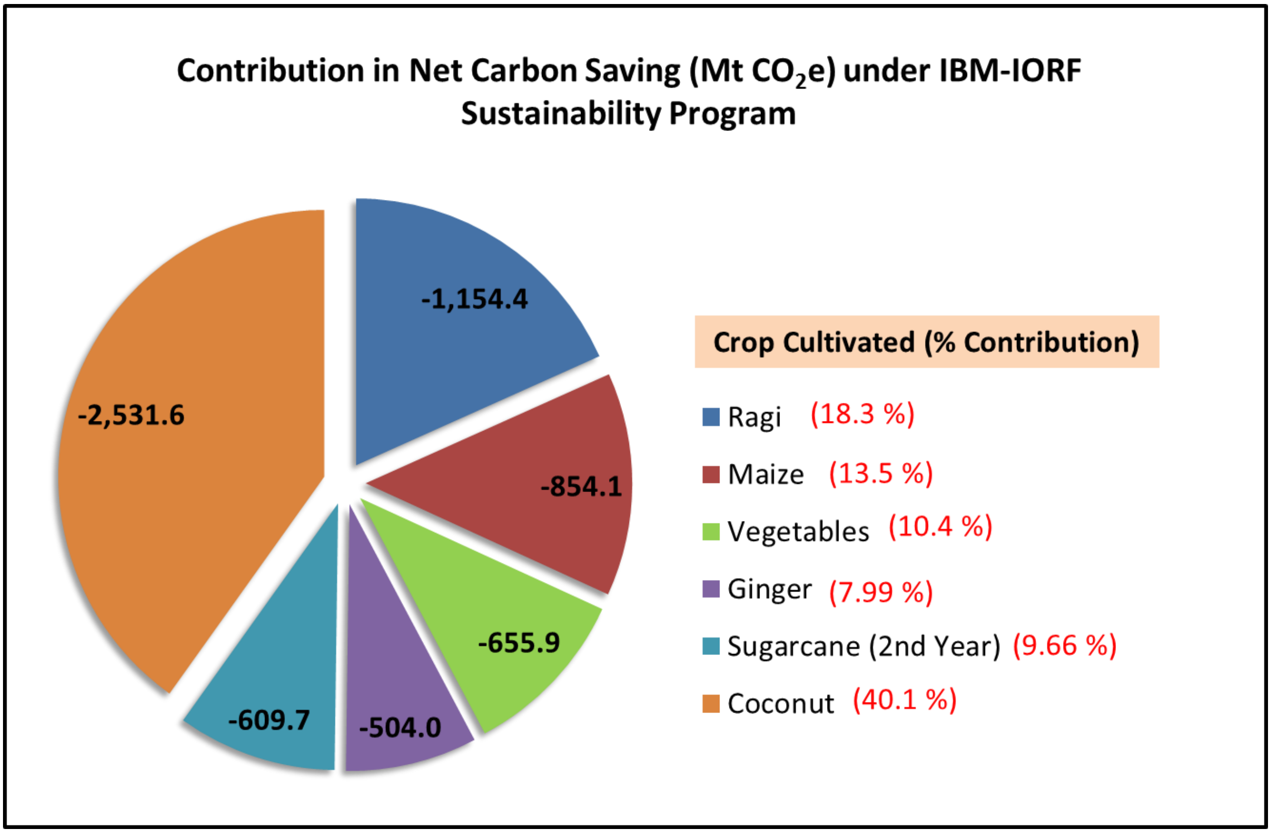
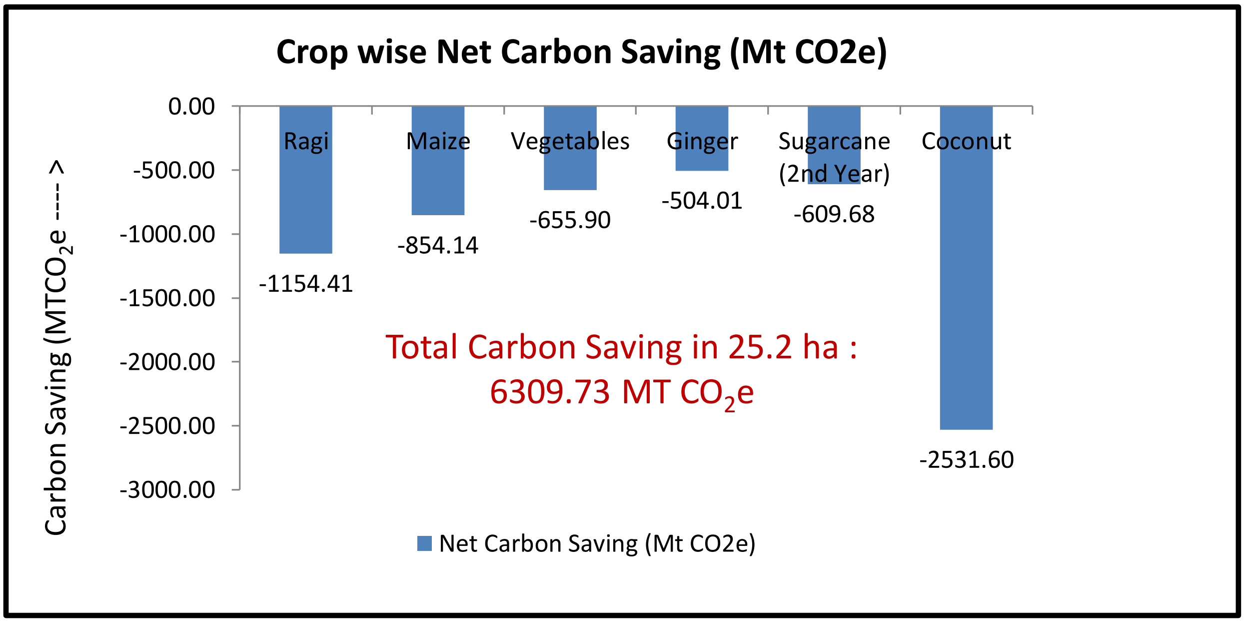


Fig 3 : Net Carbon Saving under under Clean Food Net Zero Program, IBM-IORF Sustainability Project at Mandya, Karnataka.

Net carbon saving under Clean Food Net Zero Program



Under Clean Food Net Zero Program, total GHG mitigation was 6309.73 MT CO_2e or 250.39 MT CO_2e /ha. Thus Clean Food Net Zero (CFNZ) program could be the best Demonstrative Model for IBM's Compliance and commitment of Net Zero GHG Emission by 2030

Conclusion

This is probably the **1st Ever Sustainable Agricultural Model** which can sustain crop productivity, create opportunities for employment and sustain farmer livelihood, provide Safe Food to all Without deteriorating the Soil and Environment; while providing the Road Map for attaining NET ZERO Goal and making significant impact w.r.t. Seven Crucial SDGs

Annexure

Inhana Rational Farming (IRF) Technology

INHANA ORGANIC RESEARCH FOUNDATION (IORF)

INHANA Founded by Dr. P. Das Biswas, is a Research Foundation based in Kolkata, that works as the ‘Sustainability Enabler’ for the Organic Stakeholders and the Conventional Farming Community; who are seeking pathways to Reduce the Chemical load in Crop Production. INHANA is a Knowledge Center for Organic Agriculture and aims to bring forth India’s rich agricultural heritage, which was abandoned as obsolete like many other valuable traditions; in its true scientific avatar before the entire agricultural world. The sustainability gizmo is its own development namely Inhana Rational Farming (IRF) Technology, which applies the ‘Energy Management’ Principle to maintain the promise of Sustained Crop Yields and Safe End Product irrespective of the crop type or the agro-ecological conditions.

INHANA from initiation has tried to be the change we wanted to see; abolishing the unscientific input based chemical farming and departing from the substitution based organic farming concept; to develop a scientific nature harnessed pathway.

Its breakthrough pathway in compost production, namely Novcom Composting Method – is the speediest (completes in just 21 days) process with no raw material specificity; and forms an Efficient Tool for Energy Saving and GHG Mitigation. Its post soil application effectiveness in terms of soil health regeneration and crop support is ensured by the self- generated native microflora (population in the order of 10^{16} c.f.u).

During the last two decades IORF has established the World’s 1st and only Carbon Neutral Tea Estate, enabled Sustainable Organic Conversion of about 3.0 million kg Teas, Reduction of Pesticide Footprint in about 5 million kg Teas, Sustainable Organic Seed (Paddy & Vegetables) Development, Safe & Sustainable- ‘Clean Food’ production and may more.

Inhana realized the necessity of a well-equipped own laboratory for performing different analyses in the most scientific manner (as there has always been a dearth of the same) for the documentation, interpretation and to show the interrelatedness of the various qualitative components and how they behave in true Sustainable Management system, which is closer to their philosophy.

IORF has a small but dedicated laboratory for Soil, Compost and Tea quality analysis, which strives to infuse a scientific basis into the crop production system. It is perhaps the only laboratory pan India that analyzes compost for its stability, maturity and phytotoxicity status (as per 32 parameters). IORF has also developed a complete set of scientific indices (Soil Quality Index, Soil Development Index, Compost Quality Index, Pesticide Pollution Index, Biodiversity Marker etc.) to support and to measure the post adoption sustainability quotient of any crop production system at the farm level; as well as for effective resource management.

INHANA RATIONAL FARMING TECHNOLOGY

Inhana Rational Farming (IRF) Technology – The Major Technological Intervention towards Safe & Sustainable 'Clean Food' Production

Philosophical Thought Process is Universal.

In France, F. Chaboussou thought about Healthy Plants against the popular beliefs on chemical way of crop cultivation. Miles away in India, Dr. P. Das Biswas, an Indian Scientist; researched to re-establish two lost qualities of the plant kingdom i.e., Self-Nourishment & Self- protection.

Both the visionary men thought about development of Healthy Plant for amelioration of causative factors behind plant signaling towards higher pest/disease infestation.

They concluded that alleviation of biotic and abiotic factors, which depress plant metabolism require a prolonged step wise program and might not be still completely manageable.

On the other hand focusing on Plant Health Management to activate the metabolic processes along with other curative measures can deliver time bound results in terms of lowering of pest pressure thereby pesticides use and lead towards crop sustenance.

Self- Nourishment for growth and Self- Protection from pest/disease are two sides of the same coin – The inherent Quality of Healthy Plants

In the race of globalization where international agro research and development corporations want to patent seeds, crops or life forms, Dr. P. Das Biswas, initiated an effort to protect Biodiversity and promote Scientific Organic Farming. His constant effort to provide Toxicity Free Environment for Healthy Food Production laid the Foundation of INHANA and led to the development of Inhana Rational Farming (IRF) Technology – A beautiful blend of Ancient Wisdom and Modern Science.

Dr. Das Biswas's in-depth research on Vedic Philosophy for last two decades and its logical sublimation with Modern Science revealed that Elements are essential components of all living beings and responsible for equilibrium in plant functioning. They are Not deficient, just de-activated under chemical bombardment.

But there is scope for Re-activation of elements; provided a process of ENERGY INFUSION was adopted. This led to development of 'Energy Solutions' in the backdrop of Element–Energy–Activation (E.E.A.) Principle, which provided cure for individual problems related to soil & plant.

But it was soon realized that for Sustainable Agriculture a Composite Approach towards 'Soil' and 'Plant' will be requisite; for Systemic Relief. IRF Technology was in affirmation to this very science.

The Journey of Inhana Organic Research Foundation (IORF) started in the year 2000 in Tea; and now covers every item of the Food Basket.

IRF Technology converted West Jalinga T.E., the largest tea estate in Assam (India); into demonstrate **'Sustainable Organic' and established the garden as World's First & Only 'Carbon Neutral' Tea Estate**.

MOU with State Agricultural University and several Scientific Projects with Visva Bharati University, State Agricultural University and, Krishi Vigyan Kendras (ICAR); were all focused towards demonstration and lab to land Technology Transfer for Ecologically & Economically Sustainable Organic Crop production as well as Safe & Sustainable 'Clean Food' Production

IORF has opened up a new panorama in FOOD SAFETY called 'CLEAN FOOD PROGRAM' (*Complete Elimination of Chemical Pesticides & Low Nitrate fertilizers*), that ensures SAFE & SUSTAINABLE end product Without Any Crop Loss or Raising the Cost of Production. The Program has been Empowered by the 'IBM Sustainability Accelerator' from 2021.

The organization also pioneered the 'CLEAN TEA MOVEMENT' in India in 2014 and demonstrated that with Effective Technological Intervention (IRF Technology) and a Programmed Approach; Safe & Sustainable Tea production is possible even while remaining under conventional farming – it launched the Concept of **'CLEAN TEA'.**

In the course of its Journey IRF Technology has Vividly Demonstrated :

- **Consistently Best Performance as compared to Conventional farming in terms of Crop Yield with Lowest Cost of Production – The International FAO-CFC-TBI Project.**
- **Sustainable Organic Seed production for Paddy & a wide variety of Vegetable Crops**
- **Organic Crop Production encompassing all Varieties of Agri-horti Crops, without Crop Loss or Raising the CoP.**
- **'Sustainable Agriculture Model' for all Agro –Ecological Zones.**
- **Potential GHG Model for Achieving Net Zero.**

IORF LABORATORY

(*1st of Kind in India that adopts National & International Standards*)

- 26 Parameters Soil Quality Analysis
- 32 Parameters Compost Quality Analysis

IORF developed Scientific Tools & Indices to adjudge the Sustainability Quotient of any Agricultural Practice.

- Soil Physical Index (PI)
- Soil Fertility Index (FI)
- Microbial Activity Potential (MAP)
- Soil Quality Index (SQI)
- Soil Development Index (SDI)
- Compost Quality Index (CQI)
- Pesticide Pollution Index for Crop & Soil (CPPI & SPPI)
- Biodiversity Index (BDI)

IORF was formed to disseminate the Research Findings of Inhana Biosciences among the Farming Communities (*especially the resource poor small and marginal farm holders*) to enable Safe & Sustainable Food Production and Economic Prosperity, under the existential Climate Change Impact. The organization is Committed to reach out directly to the farmers without the dependence on conventional dissemination process in order to enable them the benefits of cost.

VISION

Inhana envisions a possibility of quality- clean food for every plate and Sustainable Livelihood irrespective of the farmers' class. Equipped with a Nature Harnessed Farming Pathway i.e. Inhana Rational Farming (IRF) Technology and with the Scientific Tools for Sustainable Agriculture'; Inhana welcomes agriculturists for ecologically and economically sustainable crop production ventures; to make the vision a reality.

MISSION

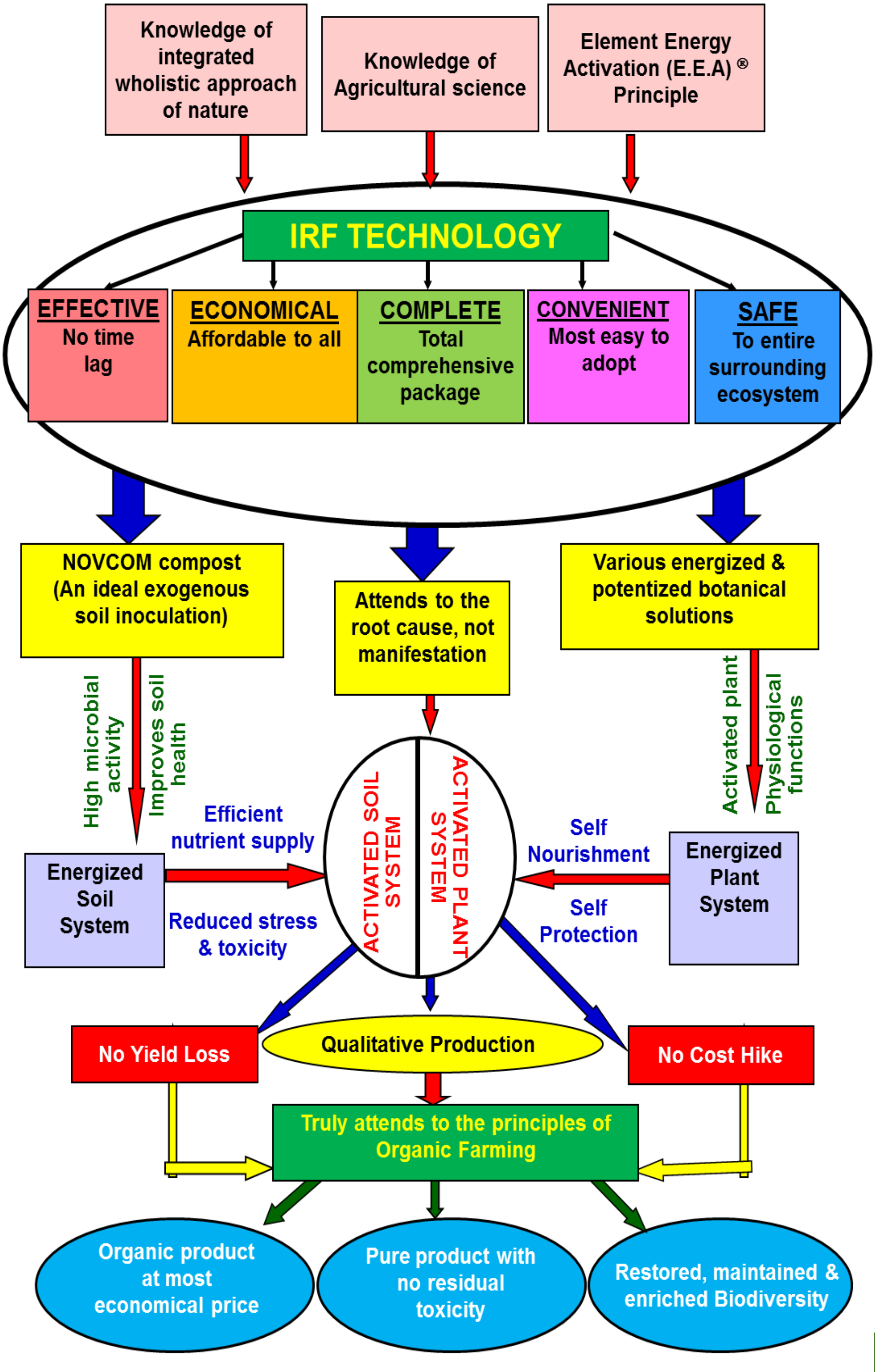
India's Traditional Wisdom stressed that 'Nature is not only Holistic, it is WHOLISTIC. . . . Once broken down, nature cannot be returned to its original state. . . . Union is always superior to the division . . the undifferentiated always superior to the differentiated'.

Inhana was founded to act as a knowledge repository for organic farming; and aims to bring forth India's rich agricultural heritage, which was abandoned as obsolete like many other valuable traditions; in its true scientific avatar before the entire agricultural world.

Inhana's mission is to bring scientific but adoptable pathways for the masses in order to enable ecologically and economically sustainable production of all types of crops, in all agro-ecological regions and irrespective of the climate change impacts.

INHANA RATIONAL FARMING(IRF) TECHNOLOGY

An Ideal Organic Farming Methodology

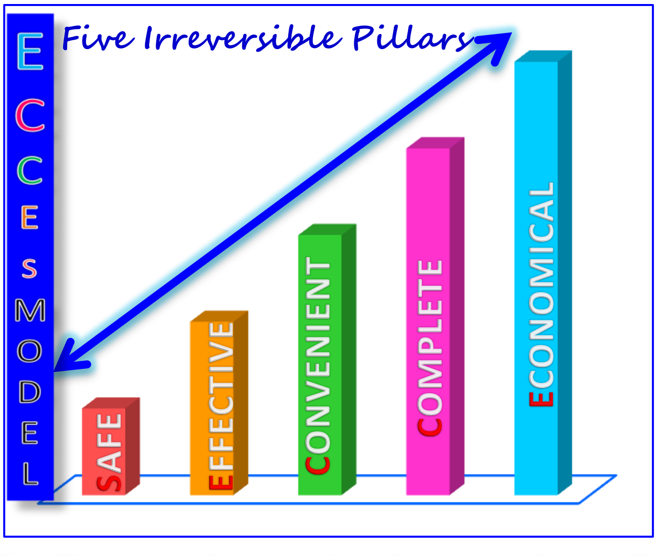


IRF TECHNOLOGY works on the 'Energy Element Activation (E.E.A.) Principle' towards Energy Infusion into the Soil and Plant so as to enable Ecologically & Economically Sustainable Crop Production. The objective of Plant Health Management is to reactivate the two inherent qualities of the plant system, i.e. (i) **Self-Nourishment** & (ii) **Self-Protection**.

Energization of Soil System is aimed at enabling the soil to function naturally as an effective growth medium for plants. Soil Energization aimed at rejuvenation of soil micro-flora, is primarily attended by application of on-farm produced Novcom compost (*that contains a rich population of self-generated micro flora in order of* 10^{16} *c.f.u*); different types of on- farm produced Soil Energizers and adoption of Sustainable agricultural practices. However, the technology emphasizes plant health management as a precursor for resilient plant system that can ensure sustainability even under the changing climatic patterns.

Energization of Plant System is aimed at enabling higher nutrient use efficiency alongside better bio-chemical functions that leads to activation of the plants' host defense mechanism. Plant Energization under this technology is a systemic approach that utilizes a set of potentized and energized botanical solutions developed under Element Energy Activation (EEA) Principle. Details about the technology in terms of working principles and spraying protocols of the solutions had been done according to the workers who have followed this technology for organic crop production (Chatterjee *et al*., 2014 and Barik *et al*., 2014).

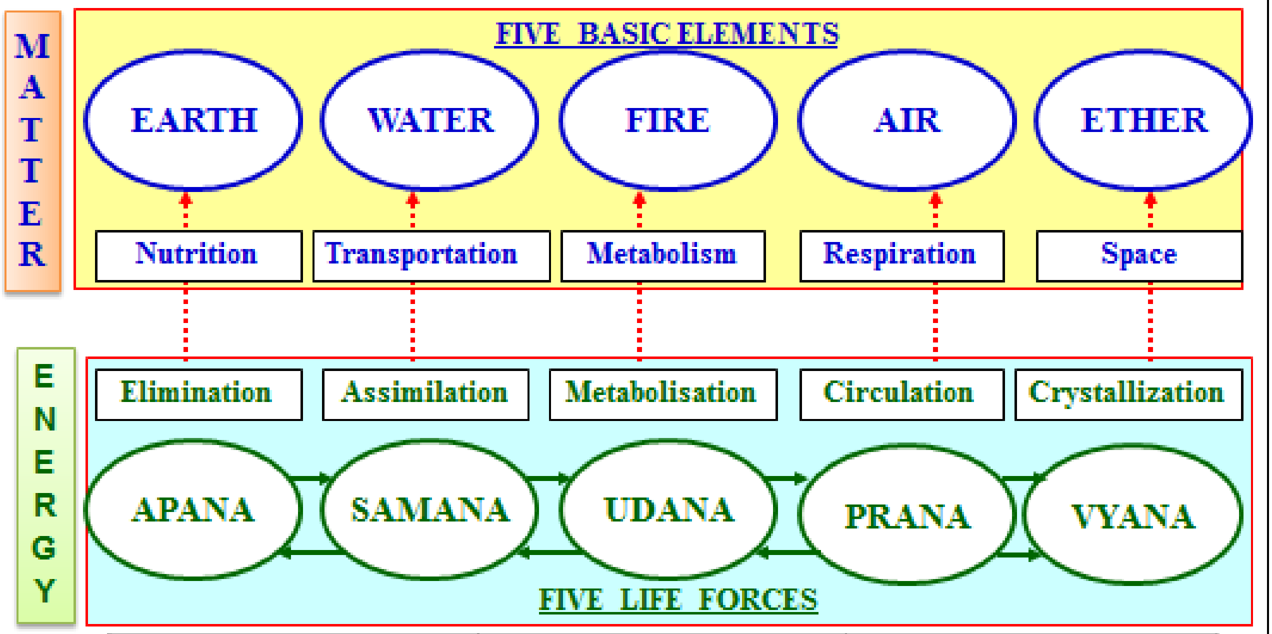
The uniqueness of this Crop Technology is that it is based on the **ECCES Model; i.e., Effective, Complete, Convenient, Economical and Safe;** that ensures Ecologically and Economically Sustainable and Safe crop production for the marginal and resource poor farmers which should be a prime criteria for any sustainable agro-technology.



Five Elements - Cosmic ether, Cosmic air, Cosmic fire, Cosmic water, Cosmic earth are the basics of manifestation. Their different proportion distinguishes one life form from the other. These elements remain undistorted till any interference and by the intelligent mixture of five cosmic elements, the universe is born. Each element has a specific function in the living system and these work both independently and interdependently.

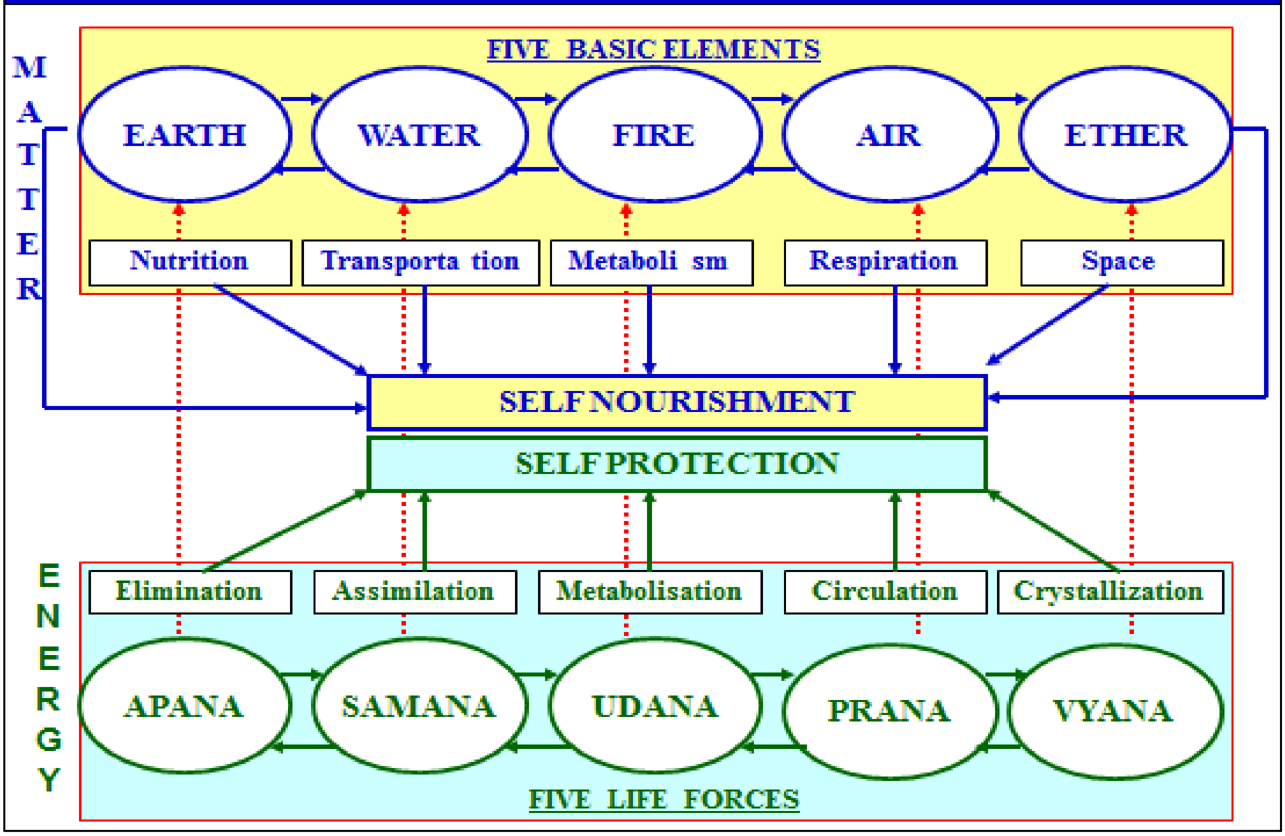
These five basic elements take care of **Self-Nourishment.**

Working Mechanism of E.E.A Principle



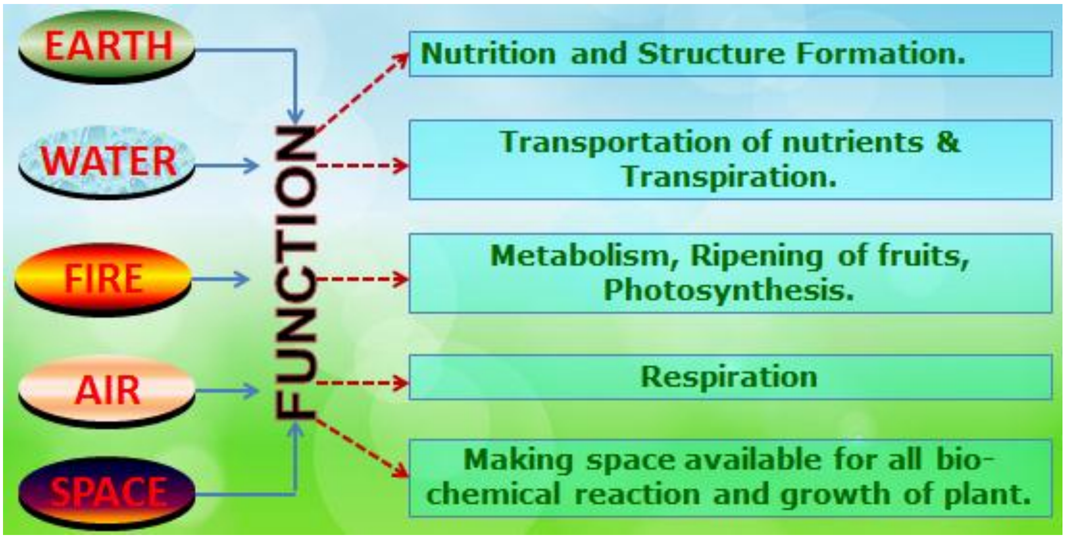
LIFE FORCES/ ENERGY	PREDOMINANT AREAS	BASIC ELEMENTS
APANA	ROOTS	EARTH
SAMANA	AERIAL PARTS	WATER
UDANA	LEAVES	FIRE
VYANA	WHOLE PLANT BODY	AIR
PRANA	CELLS	ETHER

IRF Technology is based on the Element Energy Activation (E.E.A) Principle



The Mechanism of Self- Nourishment in Plant System

Five basic elements (Panchamahabhutas) Soil, Air, Water, Fire and Space take care of nourishment. Till time we Humans do not interfere with these qualities, it perform without any problem. The individual element responsible for specific mechanism of nourishment :

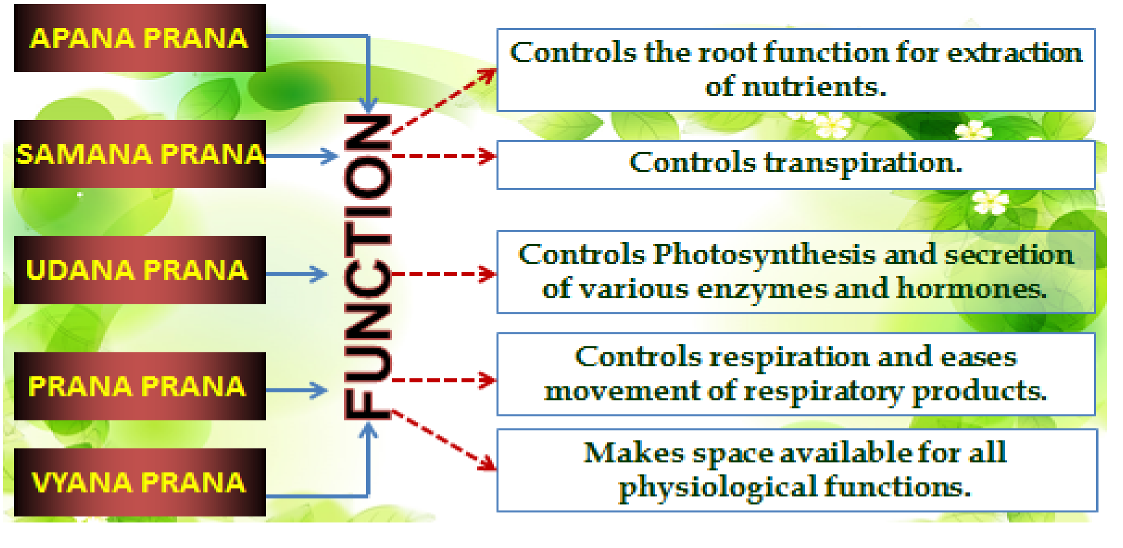


There are five different life forces or energies in all living bodies as well as in the plant system originated from the Basic Life Force i.e. Solar Energy. The **Self-Protection** mechanism is controlled by the Life Forces and they are also the vehicles of the basic elements and movement of nutrients is impossible without them.

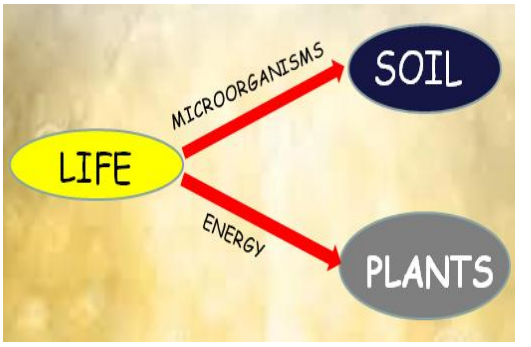
In plant system being 'PURE NATURE', energies directly activates on the matter or elements. Here Life Forces or Energies work as the power of expressing the former and moving the latter.

The Basic Life Force is the Solar Energy. The Five Life Forces or Prana Shakti originated form Basic Life Force controls Self - defense mechanism. LIFE FORCES ARE ACTUALLY VEICHLES OF THE BASIC ELEMENTS AND MOVEMENT OF NUTRIENTS IS IMPOSIBLE WITHOUT THEM.

The Mechanism of Self- Protection in Plant System



IRF Technology enables Enlivenment of Soil & Plant Health towards the Goal of Sustainability



With application of IRF Technology in Agriculture, Dr. P. Das Biswas could define the Two Pointers for Non- Sustainability.

1. **DE-ACTIVATED SOIL**
2. **DE-ACTIVATED PLANT SYSTEM**

Hence **IRF Technology** was tuned to **RE-ACTIVATE SOIL & PLANT HEALTH by just infusing the Required ENERGIES.** He developed **Novcom Composting Method** (21 days Biodegradation Process) that produces **Quality Compost with rich self- generated microflora (10^{16} c.f.u./ gm compost).** To enable **speedy regeneration of native soil Microbes**, towards **natural restoration of all soil functions**.

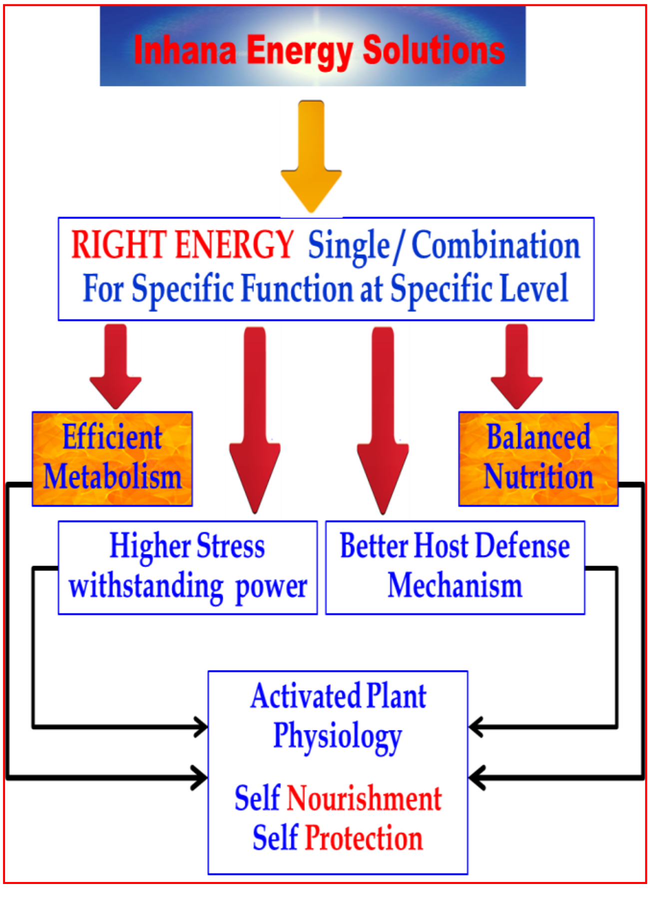
But He also realized that due to Resource Scarcity large scale Soil Rejuvenation will be a Long Term process. But REACTIVATION OF PLANT can be a CHOICE under IRF Technology and its Package of 'ENERGY SOLUTIONS' can be the TOOL for that.

VEHICLES OF IRF TECHNOLOGY – INHANA SOLUTIONS

'Inhana solutions' are developed on 'Element Energy Activation (E.E.A.)' Principle. These solutions are vastly different from any other herbal formulation considering that they contain Energy Components in Activated Forms.

Radiant solar energy is stored in plants and this binding stored energy components are extracted from energy rich plant parts by a specific extraction procedure and subsequently potentized in the order of 10^3 to 10^4, so that the Activated Energy Forms Release the Energy Components when Sprayed on the Plant System

Hence, these potentized and energized botanical extracts do not add any element from outside but only provide the necessary <u>ENERGIES</u> for activation of plant physiology, towards Better Nutrient Uptake/ Utilization and Better Host- Defense mechanism of the plant system.



HOW INHANA SOLUTIONS WORK?

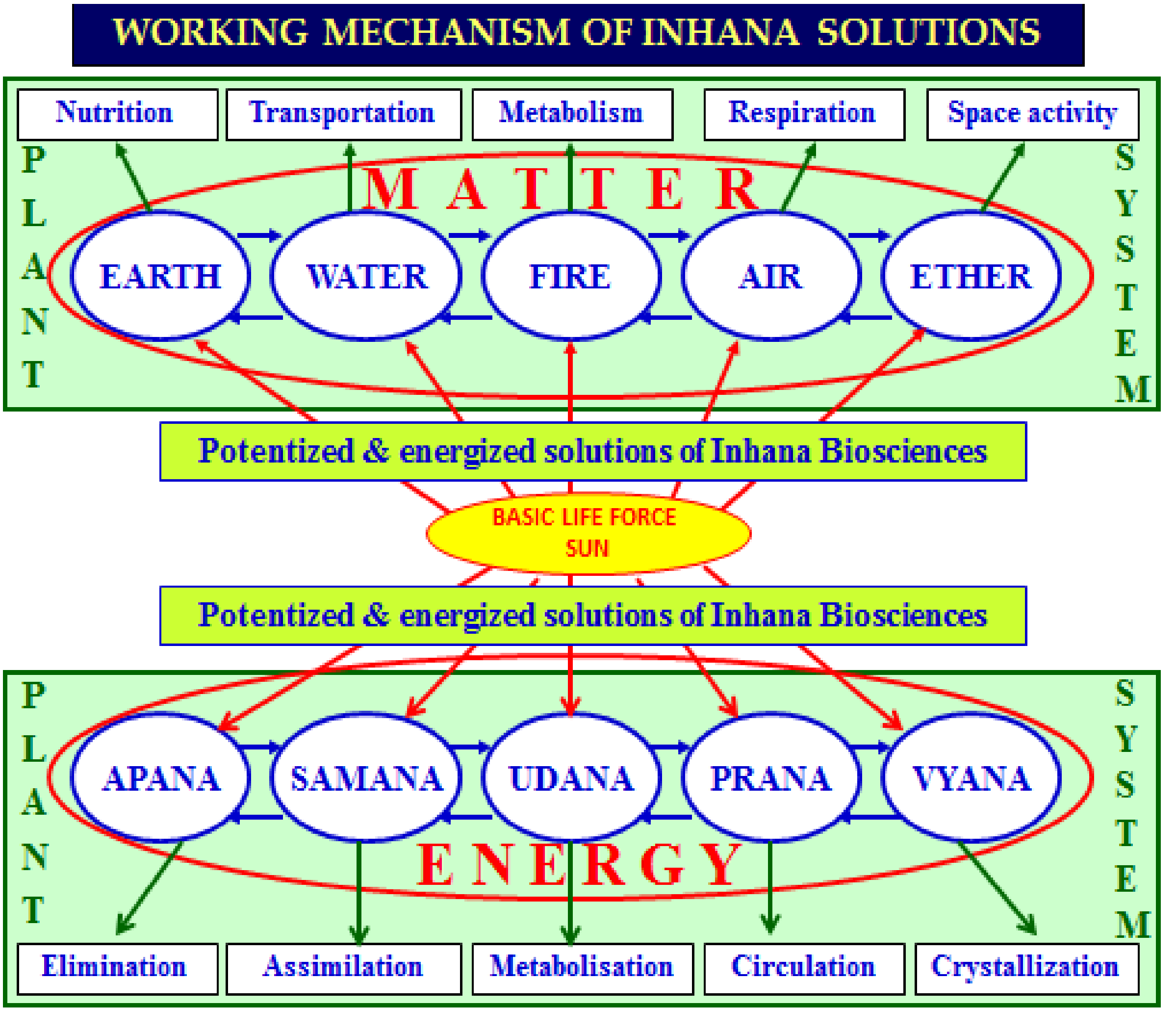
i. When Inhana Solutions are sprayed on the plants they just provide the necessary energy components that invigorate the various biochemical reactions.

ii. As for example, better biochemical responses aimed at better protein synthesis shall not only lead to a healthy plant but it also means that there shall be lesser pools of free amino acids and sugars that will negatively impact pest incidence.

iii. Better biochemical responses also mean activation of the biochemical and structural defenses of the plant.

Energy solutions are extracted from specific energy rich plants as per lunar calendar, energized & potentized to reach and re-activate the functional sites in plant system.

Subtle Energy in the solutions is quickly absorbed by the Plant System, and Activates the Metabolic Functions leading to 'HEALTHY PLANT'



REACTIVATION OF SOIL HEALTH THROUGH NOVCOM COMPOST

Novcom Compost is an Ideal Exogenous Soil Inoculation that is used for Soil Health Management under Inhana Rational Farming (IRF) Technology

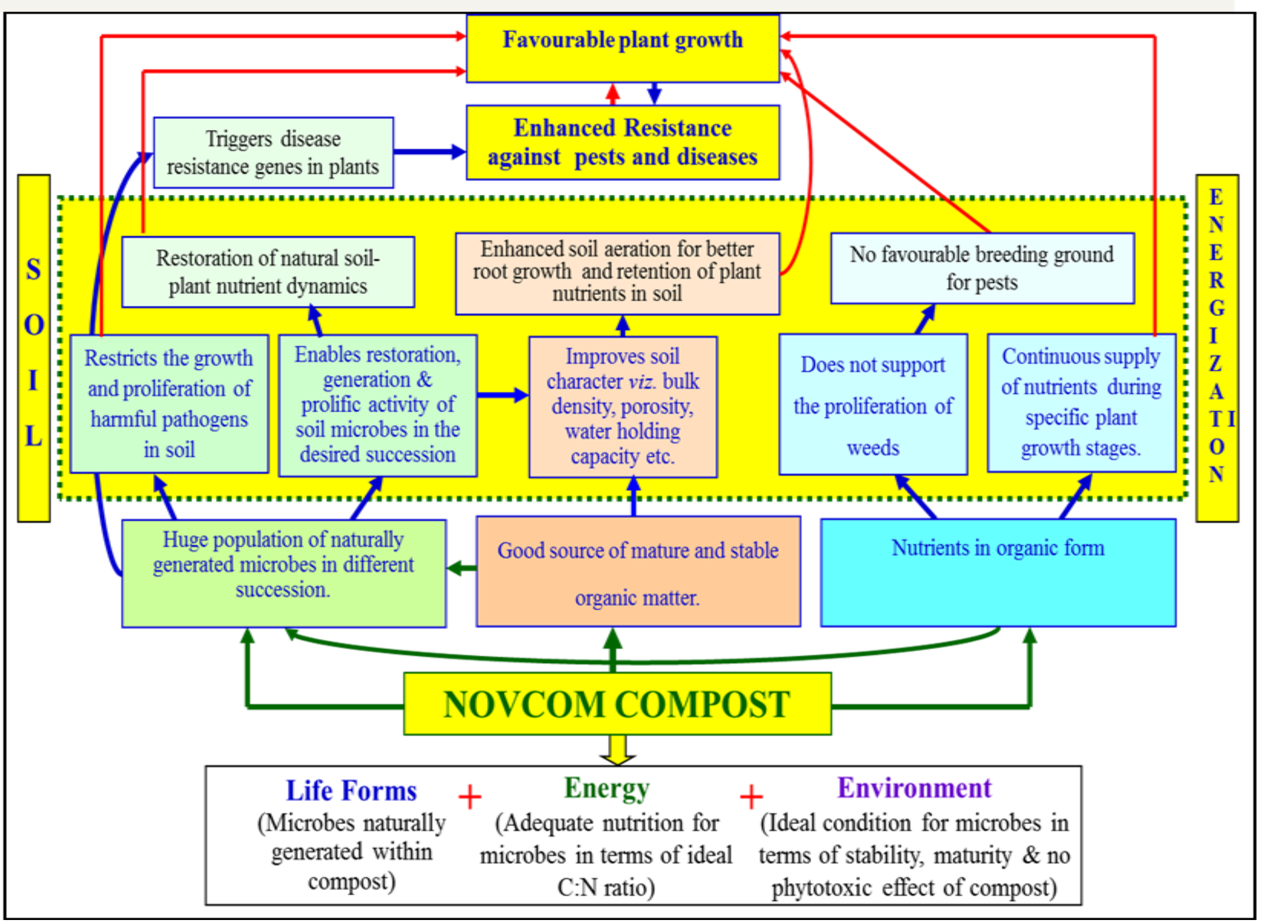
FACETS OF NOVCOM COMPOSTING TECHNOLOGY

- **Fastest composting method, quality compost gets ready in just 21 days.**
- **No raw material specificity, any type of biodegradable material as raw material.**
- **No specific infrastructure required.**
- **1/3rd Dose of Application; Superior quality ensures lower requirement as compared to any other organic manure.**
- **Most economic production cost as compared to any other organic manure.**

Novcom Compost Quality is ensured through Stability, Maturity & Phytotoxicity Analysis of End product following National & International Protocol

More than 15 Research Papers published in different National & International Journals/ Seminars/ Workshop….

SOIL ENERGIZATION by NOVCOM COMPOST & Its Effect On Plant System



THREE WAY ACTION of NOVCOM Compost

- It improves the Physical Properties of soil viz. Soil Aggregates, Porosity, Bulk Density, Water Holding Capacity as well as gradually reduces Soil Erosion.
- Enables proper growth by ensuring balanced supply of Nutrients to plant at the desired time and in required quantity, through **ACTIVATION OF SOIL NUTRIENT DYNAMICS.**
- Eradicates soil pathogens and encourages enhancement of beneficial Soil Microflora to increase inherent Soil Productivity.

Novcom Compost contains atleast 10,000 times higher Microflora population (*Self Generated*) than any Good Quality Compost – the primary drivers towards time specific rejuvenation of soil health.

Novcom Compost – Its potential towards Efficient Carbon Foot Print Management

1/3rd Biodegradation Time – ***Less GHG Emission Potential***

Minimum involvement of Mechanization – ***Low Energy Intensive Method.***

Higher N Appreciation – ***Lower Energy Consumption to Sustain Productivity***

Higher Microbial Population – ***Faster Soil Rejuvenation Leads to Higher GHG Trapping Potential.***

Stable, Mature compost with High Org. C – ***Higher potential of C Sequestration***

All Roads lead to Lower GHG Emission/ Efficient Carbon Foot Print Management

Most conclusively attended by:

NOVCOM COMPOSTING METHOD

(Validated Time & Again in different environments with different raw materials)

Brief scientific details of the development of Inhana Solutions

Inhana solutions are botanical extracts containing energy components in activated forms, so that they can perform in desired order when applied on the plant system (matter). Specific plant parts viz. roots, stem, leaf, root hair, leaf vein etc. are taken for Extraction of the energy components, which are extremely subtle and abstract in nature and simultaneously need a medium (matter) to perform. Hence, during and after extraction they are transferred to a medium which is less subtle and at the same time has higher surface tension and Ethyl alcohol serves as this medium.

The next step Energization is the process through which energy components are isolated from their gross forms and stabilized in alcoholic medium. However, both extraction and energization process operate simultaneously as the extracted gross components should be immediately transferred to a medium for storage.

This step is followed by Potentization, through which the extracted bind energy is activated for enhancement of their liberating potential, so that these energy components can perform in desired order when applied in plants. In this process the medium used is pure filtered water free from heavy particles. The potentization is done in the order of 10^3 to 10^4 times according to the individual energy component and the specific objectives.

Process Flowchart of Inhana Solutions under E.E.A Principle

Collection of specific plants (According to defined parameters)

↓

Alcoholic Extraction (Specific plant parts as per specific time and procedure)

↓

Energisation (Isolation of Energy Components)

↓

Potentization (Release of Bind Energy in the order of 10^3 to 10^4 times)

↓

Combination of the individual activated, potentized and energized extracts

ADDRESSING THE SUSTAINABILITY ISSUES WITH IRF TECHNOLOGY

Through the dual approach of Plant Health and Soil Health Management, the Technology works towards reactivation of the inherent Physiological, Metabolic & Biochemical Functions of the Plant System for aiding Better Nutrient Utilization as well as Enhanced Immunity against pest and disease.

Soil Health Management under IRF Technology

- An Effective and Economic solution which can be easily adoptable by farmers community irrespective of socio-economic consideration and Agro-ecological Diversity.

Soil Health Management is Primarily done using Novcom compost, a Technological innovation for better and speedy effectiveness, and economic viability

Novcom Composting Method

- Enables Quality Compost within 21 days
  When most of the composting method take 60 to 120 days, Novcom composting method takes only 21 days

- Ensured Post Soil Application Effectiveness through 10,000 times Higher Self-generated Microbial Population
  When most of the composts have microbial population in the order of 10^{10} to 10^{12} c.f.u /gm moist compost, compost prepared under Novcom composting Technology have a microbial population in the order of 10^{16} c.f.u / gm moist compost – which ensures speedy microbial rejuvenation in soil and enhances soil-plant nutrient dynamics towards higher crop production without any time loss.

- Wider Applicability with Less Application Requirement
  Novcom Composting Method can use any type of biodegradable waste including complex materials like press mud, poultry litter, coir pith, paper mill waste, Municipality Solid waste; as raw material Qualitative superiority of Novcom Compost ensures lesser application dosage for similar crop target w.r.t. other conventional compost.

- 1/10th GHG emission w.r.t. windrows composting method
  Higher biodegradability potentials enable less GHG emission under Novcom composting process – makes it suitable for any GHG Mitigation Program

- 1/3rd cost of vermi compost
  With no infrastructure requirement, lesser sensitivity, lesser monitoring time and better recovery percent, the cost of Novcom compost is less than 1/3rd of vermi compost making cost.

ADDRESSING THE SUSTAINABILITY ISSUES WITH IRF TECHNOLOGY

Through the dual approach of Plant Health and Soil Health Management, the Technology works towards reactivation of the inherent Physiological, Metabolic & Biochemical Functions of the Plant System for aiding Better Nutrient Utilization as well as Enhanced Immunity against pest and disease.

Plant Health Management with IRF Technology

- 1st Ever approach for attending the Plant Health through Energy Infusion that activates plant physiological functioning.

- **Restoration of the Deficient Energies in Plant System lead to Activated Plant Physiological functioning leading to Plant Health Development.**

This is primarily done through application of a Package of 'ENERGIZED & POTENTIZED' Botanical Solutions, which are developed on the 'Element Energy Activation' (E.E.A.) principle. The Solutions contain Isolated Energy Forms extracted from Energy Specific Plant Sources which store the Radiant Energy or the Basic Life Force in differential forms. The Isolated Energy Forms are easily Absorbed by the Plant System and Deliver the deficient energies to the specific sites within the Plants that control the different Metabolic & Bio-chemical functions.

- **Activate Plant's Immune System.**

Activated Plants with higher Photosynthetic Efficiency produce Complex carbohydrates like Pectin, which reduces Susceptibility to soil borne pathogens. Activated Plants also store the surplus energy in the form of lipids which aids in formation of the phospho-lipid cell membrane, the plant's mechanical barrier especially towards air borne pathogens. Activated Plants means desirable secretion of phenolic compounds which invoke the Bio-chemical Defenses against Disease Infections.

Different Inhana Solutions used under IRF Technology

12 Inhana Solutions are suggested for plant physiology development either singly or in combination. Combination of solutions or their schedule is prepared based on specific criteria viz. soil and climatic condition, management practice, bush health and other factors.

Plant Health Management (for plant physiological development)			
Sl No	Solution Name	Biologically activated & potentised extract of	**Role in Plant Physiological Development**
1.	IB 1	Hyoscyamus niger, Ficus benghalensis & Dendrocalamus strictus Nees.	**Organic growth promoter, activator and regulator** **Energizes and stimulates the plants system for the best use of nutrients both applied and stored in the soil. Regulates every stage of the Grand Growth Period influencing growth correlation.**
2.	IB 2	Ocimum sanctum, Calotropic procera R. & Cynodon dactylon	**Silica induced immunity against fungal attack** **Activates plants' host defense mechanism through silica management providing structural defense against fungal pathogens.** **It also stimulates plants immune system by activating the biosynthesis of different phenolic compounds having fungi-toxic property.**
3.	IB 3	Adhatoda vasica Nees, Zingiber officinale Roscoe & Embellia ribs.	**Organic solution for potash absorption and utilization** **Increases the efficiency of potash uptake through energized root capacity, so that gradual reduction in application is ensured.** **It activates suction pressure by influencing diffusion pressure deficit.**
4.	**IB 4**	*Calotropis Procera R., Dendrocalamus strictus Nees & Bombax malabaricum D. C.*	**Ensures biological absorption of atmospheric-N directly by plant.** **Helps the plant to utilize the atmospheric nitrogen. It also balances the quantity of nitrogen in the plant system at the right time, thereby preventing deleterious effect on quality of the produce.** **Ensures gradual reduction of chemical nitrogen application.**

Different Inhana Solutions used under IRF Technology

Plant Health Management (for plant physiological development)			
Sl No	Solution Name	Biologically activated & potentised extract of	**Role in Plant Physiological Development**
5.	IB 5	*Cynodon dactylon & Calotropic gigantean.*	**Energizes the various biochemical process of plant resulting in harmonious grand growth period.** **Regulates and stimulates the cellular oxidation process. Energizes the phloemic function resulting in encouraged translocation of organic solutes. Stimulates the hydrolysis of starch to D-Glucose units by enhancing the enzymatic activity.**
6.	IB 6	*Hyoscyamus niger & Solanum Verbascifolium*	**Energizes and activates respiration and photosynthesis activity and plays complementary role of solution-I** **1. Energizes respiration by activating the protoplasmic factors and the concentration of respiratory substrate.** **2. Stimulates the rate of photosynthesis by quick translocation of carbohydrates.**
7.	IB 7	*Ocimum sanctum*	**Stimulates the root function, activates root growth/ penetration and energizes soil in the root zone thus improves soil-plant relationship.** **1. Develops the CEC of soil.** **2. Energizes the production of micro-flora and bio-flora around the root zone.** **3. Improves the degree of base saturation to the desired level.** **4. Enhances the Root Cation Exchange Capacity.** **5. Stimulates the root growth and penetration by activating the Contact Exchange Capacity of the Root.**
8.	**IB 8**	***Solanum verbascifolium, Prosopis spicigera & Ocimum bascilicum.***	**Organic solution for termite management.** **1. It has both controlled and contained action. It restricts the movement of termites.** **2. Repels termite activity by influencing thermostatic environment of the soil.**

Different Inhana Solutions used under IRF Technology

Plant Health Management (for plant physiological development)			
Sl No	Solution Name	Biologically activated & potentised extract of	**Role in Plant Physiological Development**
9.	IB 9	*Albizzia maranguihses, Biscifia javanica &* *Erythrina Variegate Linn.*	**Ensures enhanced photosynthesis and balances respiration** **It influences the action spectrum and absorption spectrum of plants.** **It enhances or activates Xanthophills.**
10.	IB 10	*Costus specicus sm. & Typhora indica mer.*	**Improves plant transport by deliberating essential substances to the various internal mechanism.**
11.	IB 11	*Solanum xanthocarpum schard & Aristolochia indica Linn.*	**Improves the movement of solutions by providing systemic presence to give structural integrity.**
12.	**IB 12**	***Sida Cordifolia Linn. & Barberis asiatica Roxb. Ex. De.***	**Improves the plant's capacity for starch synthesis.**

Different Inhana Solutions used under IRF Technology

Inhana Solutions for PEST MANAGEMENT THROUGH PLANT MANAGEMENT			
Sl No	Solution Name	Biologically activated & potentised extract of	**Role in Plant Physiological Development**
1.	IB 13	*Ficus racemosa Linn. & Calotropuc procera R.*	**Activates hypersensitive defense system by disintegrating the hypha.**
2.	IB 14	*Ocimum sanctum & Costus specicus sm.*	**Improve root health and activates apoplastic and symplastic mechanism.**
3.	IB 15 CDS - F	*Veronica cineria Less. & Solanum verbascifolium (Root &stem)*	**Improves and fortifies the cow dung and cow urine concoction towards better toxicity removal and plant sanitization effect.**
4.	IB 16 CDS – G	*Veronica cineria Less. & Solanum verbascifolium (Root)*	**Improves and fortifies cow dung and cow urine concoction for faster organic activity in the surface soil.**
5.	IB 17	*Prosopis spicigera & Costus specisus sm.*	**Activates karanj seed and cow urine concoction for anti-ovulatory effect on Helopeltis Theivora.**
6.	IB 18	*Barberis asiatica Roxb. Ex. De., Ficus racemosa Linn., Ocimum sanctum & Cynodon dactylon*	**Influences the cell wall swelling, thereby inhibits host penetration and infection by pathogens.**
7.	IB 19	*Bombax malabaricum D.C., Calotropic procera R & Ocimum bascilicum.*	**Organic pest management** **An organic pest repellant with anti-feedant action.** **It activates the Plants Host Defense Mechanism.** **It enhances Environmental Resistance and reduces the Biotic Potential.**
8.	**IB 20**	***Bombax malabaricum D.C., Calotropic procera R, Ocimum bascilicum. & Biscifia javanica***	**Activates plant system for enhanced secretion of phytoalexins particularly pisatin and orchinol.**

Are Inhana Solutions SAFE?

All the 'Inhana Solutions' are aqueous based in which more than 99% is water (free from heavy particles). Hence there can't be any thing more safer than these solutions. Naturally these are most Natural. Any toxicity can be only associated with matter. Energies can't have any toxicity.

There are three ingredients in any Inhana Solution where Active Ingredient ranges 0.001 - 0.006 percent, in the form of potentized energy, Auxiliary Ingredient ranges 0.01 – 0.06 percent in the form of Ethyl Alcohol and balance 99.8 percent is water. Hence, these solutions do not cause any harm if consumed by human.

The concentration of the active ingredients is in the range of 0.001 to 0.006 percent in any Inhana Solution and they are nothing but the NON – MATERIAL LIFE FORCE. The Solvents are used for the extraction of the plant extracts is 99.8% pure Standard quality Ethyl alcohol (C_2H_5OH). 0.01 – 0.06 percent Ethyl Alcohol is present in these solutions which is used as auxiliary ingredient.

Ingredients of Inhana Energy Solutions In Short

1. Active Ingredient: (Biologically Activated Potentised & Energized Botanical Extracts)

Range of 0.001 to 0.006 percent in any Inhana Energy Solution (nothing but the NON – MATERIAL LIFE FORCE.)

2. Auxiliary Ingredient: (Ethyl alcohol)

Range of 0.01 – 0.06 percent

3. Inert Ingredients : (Water)

Balance 99.8 – 99.9 percent

Since Active Ingredients are only up to 0.006% in any Inhana Energy Solutions, that too are in the Potentised & Energized form, two things thus substantiates;

1. There is no material substances but only exist as NON- Material Life Force or Energy.
2. There can't be anything safer than these solutions.

No other inert ingredient like stabilizers, emulsifiers etc. are added to the formulation because the process does not allow such additions during preparation of the solutions or during their application on plants.

According to law of Avogadro in all probability no molecule remains when a substance is diluted beyond 6 X 20 power minus 23. Hence, all the Inhana Solutions always reach the point of No – SUBSTANCE ANYMORE. Hence, according to the theory of relativity, massless particle travels at the speed of light. These massless particles possesses momentum and energy but no rest mass.

Inhana solutions becomes massless when subjected to potentization, which have no mass but only energy. Since everything in the Universe is made out of energy nothing is purer than Energy, Inhana solutions supply the specific energies in the free form. As any form of toxicity related to matter (mass), the massless Energy Solutions do not possesses any form of toxicity.

However for the convenience in the documentation process simple rinse with clean water recommended for the 0.01 – 0.06 percent Ethyl Alcohol, in case of any contact with eyes, face etc.

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Clean Food' through Adoption of Ecologically and Economically Sustainable Farming Technology with Special Focus on Soil & Plant Health Management

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Clean Food' through Adoption of Ecologically and Economically Sustainable Farming Technology with Special Focus on Soil & Plant Health Management

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A B S T R A C T

Today it is no longer a debatable issue that since the "green revolution" of the 1960s has been touted as solutions to the global hunger problem by focusing only on the potentiality of high crop yields have come at the cost of environmental degradation and lowered sustainable food and nutritional security over the long term. Especially in the crop intensified zones, rampant use of chemical fertilizer and pesticides made the soil and overall environmental quality to an alarming stage. Thus, shifting focus towards ecologically and economically sustainable crop cultivation is the only option left for future crop sustainability. In this background, pesticide free 'Clean Food production' with adoption of various good agricultural practices (GAP), mechanical and biological practices amalgamated with innovative organic approach (IRF technology) specially focused towards soil and plant health management have been adopted in some villages of Fathepur Gram Panchayat in the Haringhata Block, Nadia district of West Bengal from 2020. Analysis of soil samples in the study area clearly indicated soil quality depletion with very low organic carbon (< 0.60 %), very poor biological properties, poor microbial biomass carbon (<200 µg.CO2.C/gm dry soil) and poor FDAH (< 50 µg/gm dry soil). Comparative evaluation of crop productivity under Clean Food programme vis-a-vis conventional farmers' field indicated increase in crop yields even in the 1st year of program adoption. Analysis of pesticide residue indicated presence of pesticides residue in less than 4% of the vegetable samples, while in the rest the same were below detection limit (< 0.01 ppm). Post production soil development index indicated enhancement in soil quality which was majorly due to the activation of soil biological properties through the application of compost as well as reduction in the use of herbicides and chemical pesticides. The Clean Food program can be a practical option for sustainable agriculture towards crop sustainability, environmental preservation and empowerment of the small and marginal farmers.

Keywords: Clean Food, Inhana Rational Farming Technology, Soil Resource Mapping, Novcom Compost, Plant Health Management, Colorometric Pesticide Assay Test, Energy Use Efficiency, GHG Mitigation, Soil Quality Development

1. Introduction

Intensification of chemical agriculture, over the years; has led to overall degradation of the fragile agro-ecosystem. High cost of production and diminishing economic returns from agricultural practices are affecting the socio-economic condition of the farmers. Loss of soil fertility, erosion of soil, soil toxicity, diminishing water resources, pollution of underground water, salinity of underground water, increased incidence of human and livestock diseases, and the risk of food toxicity enhances with indiscriminate and disproportionate use of Agro-chemicals (Rahman, 2015).

Application of Chemical fertilizers induced higher crop productivity but at the same time they also led to the alteration of soil physicochemical and biological properties, decline of soil organic matter (SOM) content coupled with a decrease in the quality of agricultural soil (Pahalvi, 2021). On the other hand application of chemical Pesticides caused significant changes in the composition, diversity and basic functioning of important soil micro-flora (Riah et al., 2014), reduced the abundance and diversity of soil organisms, impairing the reproductive capacity and survival of earthworms (Lo, 2010), interfering with enzyme production, altering the soil fertility, nutrient cycling and metabolism and hindered nitrogen fixation due to inhibition of the molecular communication between plants and rhizobia (Ahemad & Khan, 2013).

Thus the depletion of soil productivity and the impaired soil-plant nutrient relationship weakens plant's inherent capacity to sustain biotic and abiotic stress. Application of chemical pesticide further weakens the plant physiological functioning and impairs the metabolism, creating ready food source for the pest and pathogens. Now to overcome the present challenges and constraints there is need to undertake sustainable crop management for which focus has to be imparted towards development of soil and plant health.

In the present Clean Food development project, different good agricultural practices (GAP), various mechanical and biological practices amalgamated with innovative organic approach (IRF technology) for the energization of soil and plant system in order to activate the self-nourishment and self-protection mechanism of plant system. The study aims to mitigate the root cause of un-sustainability which will not only help towards crop sustenance, but also create an environment for gradual reduction of the pest & disease infestation leading to the development of pesticide free 'Clean Food' aiming at livelihood sustenance of the farming community

2. Materials and Methods

A collaborative program was initiated by Nadia Krishi Vigyan Kendra, BCKV, ICAR and Inhana Organic Research Foundation (IORF), Kolkata towards developing pesticide free 'Clean Food'. The program has been ongoing at Fatepur gram panchayat, in the Haringhata block of Nadia district since 2020 with an aim to introduce sustainable crop management, towards development of pesticide free end product with better marketability potential that will enable livelihood sustenance of the farming community specially small and marginal. Factually, they are the worst affected under the ensuing climate change impact and the vulnerable market economy threat during Covid-19 pandemic. In the year 2022, IBM, India came forward to support the objectivity of this Clean Food Initiatives and development of pesticide free safe and sustainable food production.

2.1 Clean Food Program

The program initiated with grid based soil sampling followed by detailed investigation of soil quality and resource mapping (Fig 1 & 2). On-farm production of Novcom compost as a part of soil health management was also started. An integrated approach of plant health management was developed side by side towards sustainable crop growth, higher crop production and gradually reducing the pest/ disease infestation. IRF Plant Health Management was introduced towards activation of the plant physiology for building up plant resilience towards the climate change impact, develop plant immunity and its host-defense mechanism, which is crucial for sustained/ higher crop performance and for reducing the interference of pest and disease. This Unique Approach under IRF Technology activates Plants' Metabolism & Photosynthetic Efficiency in order to curtail the accumulation of ready food source for the pests in the plants' cell sap, so as to curtail the pest infestation and thereby the dependency on chemical pesticides (Bera et al., 2021).

Fig 1 : The 'GOAL' of Clean Food Movement

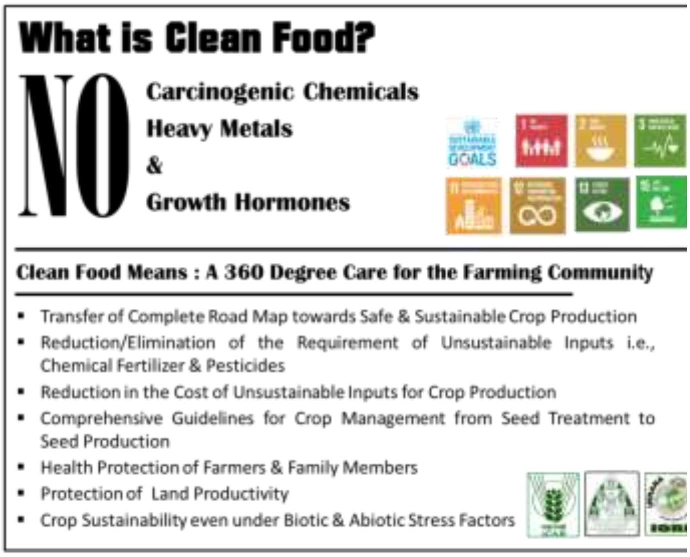

Fig 2 : A Brief note on activity under Clean Food program

2.2 Inhana Rational Farming (IRF) Technology

The Technology works on the 'Energy Element Activation (E.E.A.) Principle' and works towards Energy Infusion into the Soil and Plant so as to enable Ecologically & Economically Sustainable Organic Crop Production. The objective of the plant health management is to reactivate the two inherent qualities of the plant system, i.e. (I) Self-Nourishment & (II) Self-Protection. For this a Focused Approach is undertaken towards Soil & Plant Health Management that simultaneously deflates the pest pressure due to alleviation of factors responsible for pest – parasite interactions.

Energization of Soil System is aimed at enabling the soil to function naturally as an effective growth medium for plants. Soil Energization aimed at rejuvenation of soil micro-flora, is primarily attended by application of on-farm produced Novcom compost (that contains a rich population of self-generated micro flora); different types of herbal concoctions and adoption of cultural practices (Fig 3 & 4). However, the technology emphasizes plant health management as a precursor for resilient plant system that can ensure sustainability even under the changing climatic patterns.

Energization of Plant System is aimed at enabling higher nutrient use efficiency alongside better bio-chemical functions that leads to activation of the plants' host defense mechanism. Plant Energization under this technology is a systemic approach that utilizes a set of potentized and energized botanical solutions developed under Element Energy Activation (EEA) Principle. According to EEA Principle, radiant solar energy is stored in plants and the bound or stored energy components from energy rich plants are extracted on specific day, time, by specific extraction procedure and subsequently potentized so that energy components can be effectively received by plant system for activation of various metabolic functions. Details about the technology in terms of working principles and spraying protocols of the solutions had been done according to the workers who have followed this technology for organic crop production (Chatterjee *et al*., 2014 and Barik *et al*., 2014).

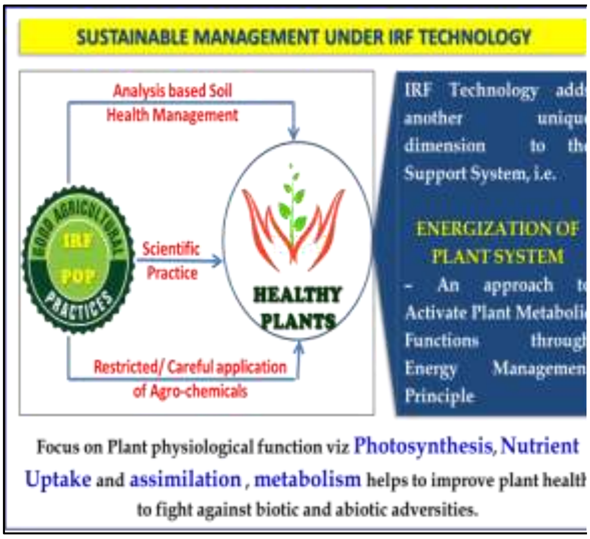

Fig 3 :Flow diagram of IRF Package of Practice towards development of Healthy Plants. (figure was reproduced with the permission from IORF, Kolkata)

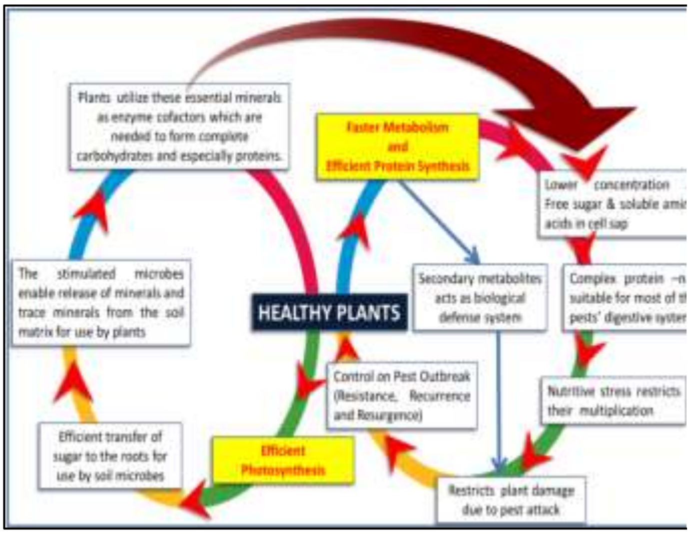

Fig 4 : Pest management through plant management - How the Concept Work under IRF Technology (figure was reproduced with the permission from IORF, Kolkata)

2.3 Novcom Composting Method

Novcom composting, a well recognized scientific method of compost preparation through use of Novcom solution, a biologically activated and potentized extract of Doob grass (Cynodon dactylon), Bel (Sida cordiflolia L.) and common basil (Ocimum basellicium). In this method good quality matured compost was produced on farm by using common farm waste and cow-dung at 80:20 ratio within a period of 21-25 days as per the procedure documented by Bera et al., 2013a. (Fig 5 & 6)

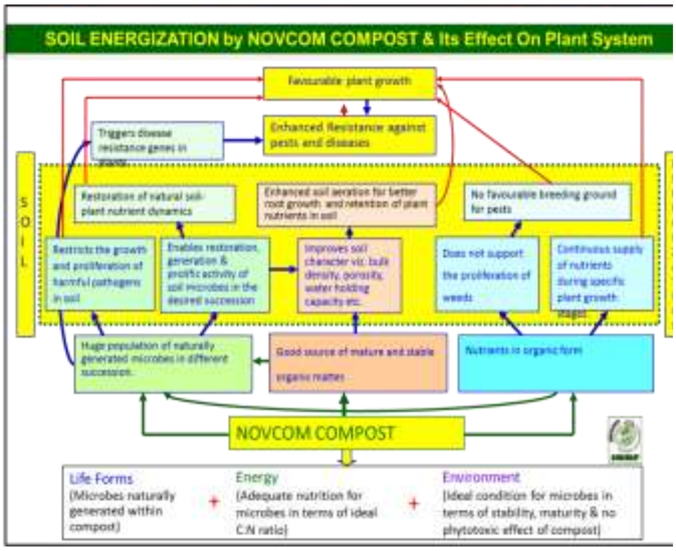

Fig 5 : Soil Energization by Novcom Compost (figure was reproduced with the permission from IORF, Kolkata)

Fig 6 : Demonstration of Novcom compost at Nadia as part of Women training program

2.3.1 Mechanism of Novcom Composting Method under E.E.A.® principle

If the mechanism of Novcom Composting Method is interpreted through E.E.A.® principle, it gives an unique, novel but most convenient system. It is known that all objects of the earth is composed of five elements. Hence, in the first stage of degradation process the elements are to be broken into their individual identity. Then the temperature need to be rise up to 65-70°C by activating the fire element with the help of Apana Prana. In this stage the unfriendly bacteria, fungi or the seeds of unwanted plants are destroyed and thermophillic bacteria start growing up. After a span of time the acinomycyte group of micro-organisms come and break the degraded material into the smaller particles. This function is facilitated by the Space element utilizing Vyana Prana. The process continues at various levels with the help of Fire element and finally the stage of lignin degradation comes. In the complete process Air element plays a very important role by providing the oxygen for respiration of the numerous micro-organisms engaged in the conversion process. The entire process is rapid, intense and programmed that it finishes within 3 weeks only. The technology promises to give solution with the variation of different organic waste and functions in any place anywhere. This does not require any microbial inoculation because the necessary microbes are generated with the ideal environment. Moreover, microbial inoculation is also an unscientific process because these strains are first experimented individually but in the practice, is given in combination. Since, each microbe has individual biological cycle and behaviour that can never match when that is given in combination with other microbes. As a result, very naturally the process does not complete in less than three — four months. Moreover, biodegradation is a natural process where one stage only comes when the previous one is completed. Hence, any effort for preponing any stage will always make the process a complex one. The compost developed with Novcom composting technology provides the energized environment for the regeneration of the soil fauna, as a result application of small quantity of this compost brings a change in the soil in the shortest possible time. Finally one thing is to be remembered that microbes also need the adequate environment to grow and function. Hence, to provide the environment is more necessary than to inoculate them directly in the soil. Novcom only works for that objectivity.

2.4 Soil and Compost Analysis Protocol:

Analysis of compost was done as per standard International protocol (Trautmann and Krasny, 1997). Soil samples were collected from individual treatment plots, air dried, sieved and analyzed for physico-chemical, fertility and microbial status as per standard procedure (Black, 1965).

2.5 Standardization of Colorometric Pesticide Assay Test for evaluation of pesticide residue in vegetables

Colorimetric Assay Test of 5 major groups viz. Organochlorine, Organophosphate, Carbamate, Synthetic Pyrethroids and Nicotinoids will serve to authenticate the non-presence of every single variant out of more than 650 pesticides formulations covering major insecticides, fungicides and Herbicides; whose presence in food products have been indicated round the globe. Not only the pesticide, but also the presence/ absence of Harmful heavy metals viz. Hg2+, Cd2+, Cu2+ and Pb2+ can also be done using the colorimetric qualitative test. Apart from that Triazines, Paraquat and many other known and unknown toxic substances which inhibit our central and peripheral nervous system; if present in food product can also be brought under the scanner through the colorimetric assay test. Through this assay test, pesticide residue can be visually detected up to 0.01 ppm level and up to 0.003 ppm level using the spectrophotometer (Fig 7 & 8). Colorimetric assay tests were done as per the methodology of (i) Organochlorine (Paulini & Rurbaud, 1957), (ii) Organophosphate & Carbamate (Mahaed E. et al. 2014), (iii) Synthetic Pyrethroid (Suate et al., 2020, Mahaed E et al, 2014), (iv) Nicotinoids (Nwanisobi & Egbana, 2015), (v) Heavy metals (Cu, Zn. Hg. As, Cd, Pb) (Mahaed E. et al., 2014), (vi) Phenylpyrazole, Triazine and Paraquat (Mahaed E et al., 2014; Lionetto, 2013).

Fig 7 : Colour Development under Colorometric Pesticide Assay Test at Inhana laboratory, Kolkata.

Fig 8 : Colorometric Pesticide Assay Test done jointly by Nadia KVK and IORF, Kolkata

2.6 Energy Use Efficiency and GHG Emission:

Energy use efficiency, energy productivity, specific energy, energy intensiveness and net energy were calculated as per the standard methodology (Banaeian *et al*., 2011). In order to calculate the potential for greenhouse gas emission, we used ACFA –version 1.0 which was developed by IORF, Kolkata (Bera et al, 2022).

Fig 9 : Landscape view of the project area

Fig 10 : Clean Cabbage cultivation in the project area

3. Results and discussions

3.1 Soil quality and Impact of Intensified Chemical Agriculture:

The soil samples were collected grid wise and analyzed for the various quality parameters (Table 1, 2 & 3) primarily in IORF laboratory at Kolkata. Table 1 represented the soil physical characteristics of the study area (Fig 9 & 10). The soils of the area were mostly sandy clay loam to silty loam. The soils were basically light soils with no limitation in terms of soil depth, coarse fragment, bulk density and aggregate stability.

Table: 1. Soil Physical Properties of the study area

Grid No.	Particle Size Distribution			Texture	[1]SIC	[2]AS	[3]BD	[4]SD	[5]CF	[6]PI
	Sand	Silt	Clay							
1	17.2	65.4	17.4	[7]sl	1.5	[9]MS	1.45	> 150 cm	No	22
2	17.3	68.5	14.1	sl	2.6	MS	1.48	> 150 cm	No	22
3	16.4	68.2	15.4	sl	0.3	MS	1.47	> 150 cm	No	22
4	18.2	68.2	13.6	sl	1.4	MS	1.45	> 150 cm	No	22
5	17.2	65.4	17.4	sl	3.9	MS	1.44	> 150 cm	No	22
6	25.3	50.4	24.2	sl	4.6	MS	1.45	> 150 cm	No	22
7	17.2	65.4	17.4	sl	3.4	MS	1.46	> 150 cm	No	22
8	17.2	65.4	17.4	sl	1.2	MS	1.46	> 150 cm	No	22
9	15.5	64.0	20.5	sl	1.3	MS	1.47	> 150 cm	No	22
10	18.3	65.8	15.9	sl	3.7	MS	1.47	> 150 cm	No	22
11	18.0	65.0	17.0	sl	2.1	MS	1.48	> 150 cm	No	22
12	16.2	67.4	16.4	sl	0.3	MS	1.46	> 150 cm	No	22
13	17.5	64.1	18.4	sl	0.3	MS	1.47	> 150 cm	No	22
14	17.2	62.5	20.3	sl	0.2	MS	1.45	> 150 cm	No	22

15	17.8	63.2	19.0	sl	1.7	MS	1.43	> 150 cm	No	22
16	36.2	52.2	11.6	[8]scl	2.9	MS	1.42	> 150 cm	No	22
17	37.6	53.1	9.3	scl	0.1	MS	1.43	> 150 cm	No	22
18	35.3	54.3	10.3	scl	5.3	MS	1.45	> 150 cm	No	22
19	35.2	53.0	11.8	scl	0.1	MS	1.45	> 150 cm	No	22
20	35.4	54.0	10.6	scl	0.2	MS	1.46	> 150 cm	No	22
21	36.0	55.7	8.3	scl	0.4	MS	1.45	> 150 cm	No	23
22	37.3	56.4	6.3	scl	0.4	MS	1.46	> 150 cm	No	24
23	38.3	56.6	5.1	scl	0.3	MS	1.46	> 150 cm	No	25
24	37.8	56.2	6.0	scl	0.2	MS	1.46	> 150 cm	No	26
25	38.1	56.0	5.9	scl	0.2	MS	1.44	> 150 cm	No	27

Note : [1]Slaking Index Coefficient, [2]Aggregate Stability, [3]Bulk Density, [4]Soil Depth, [5] Coarse Fragment, [6]Physical Index, [7]Sandy Loam, [8]Sandy Clay Loam,

3.2 Soil Quality Indices

Physical index (PI) value indicate in terms of soil physical quality, it was good to very good for agricultural crops. Soil physico-chemical and fertility parameters study (Table 2) indicate that in terms of soil fertility index (FI), soils were moderate to moderately high in terms of nutrient availability in most of the area. However, interpretation of the analyzed database in details indicate impact of heavy load of chemical fertilizer as average value of Av. NO3 was 111.8 and the ratio of Av NO3 and KMNO4 extractable N was 0.36 which was unusually high (commonly the ratio was < 0.10). Similarly average value of available phosphate was 274 which were also abnormally high. At the same time the organic carbon status was low to very low with average of 0.60 %. Under intensive chemical farming and lack of organic amendments in the soil management program make the soil most vulnerable for future crop sustenance.

Table 2: Physico-chemical & fertility parameters of the study area

Grid No.	**Physicochemical Parameters**								**FI***
	pH	**EC (1:1)**	**Org. C %**	**NO_3^-**	**Av-N**	**Av P_2O_5**	**Av. K_2O**	**Av- SO_4**	
				< --------------------kg./ha ---------------------- >					
1	6.05	0.381	0.60	119.48	326.14	239.51	189.73	252.98	23.0
2	5.70	0.347	0.44	108.82	288.51	329.82	149.07	164.17	15.0
3	6.15	0.709	0.63	222.34	297.92	338.19	203.28	446.74	23.0
4	6.84	0.198	0.79	62.09	329.28	340.46	162.62	166.86	27.0
5	6.62	0.232	0.46	72.76	263.42	184.47	121.97	118.41	15.7
6	6.72	0.193	0.57	60.53	329.43	297.34	149.07	153.40	21.4
7	7.37	0.330	0.68	103.49	297.92	232.34	162.62	247.59	24.0
8	6.52	0.320	0.35	100.35	263.42	292.38	271.04	199.15	19.7
9	6.33	0.398	0.74	124.81	316.74	394.11	420.11	285.27	27.0
10	6.99	0.285	0.44	89.38	291.65	318.13	271.04	250.29	21.4
11	7.31	0.274	0.46	85.93	344.96	313.43	298.14	161.47	21.4
12	6.49	0.981	0.55	307.64	291.65	311.57	447.22	269.12	25.0
13	6.88	0.367	0.95	115.09	257.15	313.22	352.35	368.70	26.0
14	7.03	0.211	0.71	66.17	244.61	297.95	203.28	158.78	25.0

15	5.85	0.340	0.30	106.62	250.88	353.43	325.25	148.02	18.9
16	7.10	0.175	0.63	54.88	266.56	312.19	182.95	145.33	25.0
17	7.00	0.385	0.65	120.74	266.56	350.98	176.18	161.47	23.0
18	6.59	0.472	0.55	148.02	310.46	279.18	271.04	196.46	25.0
19	6.68	0.311	0.55	97.53	269.70	286.61	311.70	228.76	25.0
20	6.11	0.254	0.52	78.232	310.46	412.74	474.32	411.76	26.0
21	5.89	0.59	0.79	181.72	398.27	44.58	528.53	503.35	26.0
22	6.43	0.29	0.63	89.32	354.37	157.43	433.66	652.32	27.0
23	6.36	0.32	0.63	98.56	348.10	151.02	433.66	769.69	26.0
24	6.93	0.213	0.77	65.604	332.42	158.26	433.66	550.75	27.0
25	6.98	0.107	0.69	32.956	341.52	142.20	420.45	510.4	26.0

Note : *FI : Fertility Index

Soil biological properties were also studied in depth to investigate the soil biological functioning under such intensive chemical agriculture. Soil microbial biomass (MBC) value indicated low to very low microbial population. Microbial quotient (qMBC) which was the ratio of Cmic/Corg, has been used as an indicator for future changes in organic matter status that might occur in response to alterations in land use and low to moderate status in the study area indicated stress in the microbial world due to intensive usage of synthetic fertilizer and pesticides. The stress factor was further supported by the high values of qCO_2 which usually indicated a stressful condition in disturbed systems.

Fig 11 : Soil sampling from the project area

Fig 12 : Soil Analysis in IORF laboratory at Kolkata

Table 3: Soil Biological properties and Soil Quality Index (SQI) in the study area

Grid No.	Soil Biological Parameters									[10]SQI
	[1]Soil MBC	[2]SR	[3]FDA	[4]qMBC	[5]qCO_2	[6]qFDA	[7]SIR	[8]Qr	[9]MAP	
1	51.49	0.40	38.67	0.86	5.98	0.64	1.28	0.08	3.33	0.38
2	59.06	0.48	39.62	1.34	5.98	0.90	1.47	0.12	8.00	0.37
3	53.87	0.52	39.62	0.86	5.94	0.63	1.34	0.24	3.00	0.37
4	79.59	0.48	43.32	2.15	6.66	0.55	1.23	0.07	8.67	0.55
5	86.72	0.41	20.97	1.49	6.00	0.46	1.15	0.04	7.00	0.41
6	101.46	0.51	39.62	1.81	6.99	0.70	2.27	0.12	9.33	0.48
7	85.04	0.49	20.64	1.69	6.49	0.30	2.80	0.10	6.00	0.45
8	74.61	0.44	18.07	1.42	6.50	0.52	5.73	0.06	6.00	0.47

9	107.06	0.42	46.06	1.53	6.17	0.62	2.34	0.03	8.67	0.55
10	69.32	0.43	17.99	1.01	6.00	0.41	1.83	0.03	6.00	0.50
11	89.15	0.67	27.97	1.76	7.07	0.61	1.42	0.12	6.30	0.50
12	73.84	0.42	29.03	1.98	6.80	0.53	1.08	0.03	8.67	0.56
13	61.61	0.46	39.62	2.86	6.60	0.42	1.91	0.02	4.33	0.55
14	73.10	0.46	28.74	3.56	6.02	0.40	2.84	0.02	5.33	0.53
15	86.30	0.33	16.93	1.04	6.00	0.56	2.69	0.06	4.00	0.46
16	126.41	0.68	27.23	2.96	3.66	0.43	3.34	0.13	8.67	0.52
17	71.34	0.69	20.16	2.64	6.66	0.31	2.11	0.05	8.67	0.49
18	54.13	0.41	28.09	3.89	6.00	0.51	1.24	0.03	4.33	0.53
19	122.68	0.37	39.62	2.23	2.99	0.72	3.90	0.09	4.00	0.51
20	50.66	0.72	22.16	3.01	3.32	0.43	1.20	0.07	8.67	0.53
21	73.84	0.42	29.03	1.98	4.80	0.53	1.08	0.03	8.67	0.56
22	61.61	0.46	39.62	2.86	5.60	0.42	1.91	0.02	4.33	0.55
23	73.10	0.66	28.74	3.56	6.02	0.40	2.84	0.02	5.33	0.53
24	86.30	0.43	16.93	1.04	6.00	0.56	2.69	0.06	4.00	0.46
25	73.84	0.42	29.03	1.98	6.80	0.53	1.08	0.03	8.67	0.56

Note : [1]MBC; Microbial biomass carbon (microgm biomass C/gm dry soil/hr), [2]SR:Soil Respiration, [3]FDA : Soil Fluorescein diacetate hydrolysis activity (µg/gm dry soil), [4] qMBC :Microbial Quotient, [5]qCO2: Metabolic Quotient, [6]qFDA : Total enzymatic activity per unit organic carbon, [7]SIR : Substrate induced respiration, [8]Qr: Microbial Respiration Quotient, [9]MAP : Microbial Activity Potential, , [10]SQI : Soil Quality Index

3.3 Soil Resource Mapping and development of Soil Health Management Outline

Soil resource mapping in terms of soil fertility map, soil quality index map etc will help to develop a suitable soil management policy for the area (Fig 13 & 14). As the study already indicates that the soils in the study area became most venerable with low organic carbon, high fertilizer salt concentrations, low soil microbial presence and the stress condition of the existing microbial pool, it required a sustainable management plan and the resource maps could be an important tool. Inhana Organic Research Foundation in collaboration with Howrah KVK (ICAR) developed Soil Quality Index (SQI) suitable for Indian condition which is the function of soil physical index (PI), soil fertility Index (FI) and soil microbial activity potential and it was calculated as the area of a triangle. Soil Quality Index (SQI) of the soil in the Project Area was moderate (0.46 – 0.60) in majority of area (72.4 % area) followed by poor status in 22.2 % area and moderately high status only in about 5.4 % area.

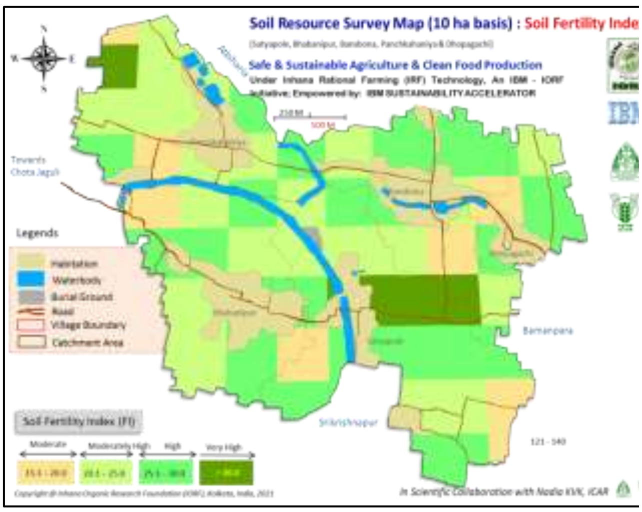

Fig 13 : Soil Fertility Index (FI) map

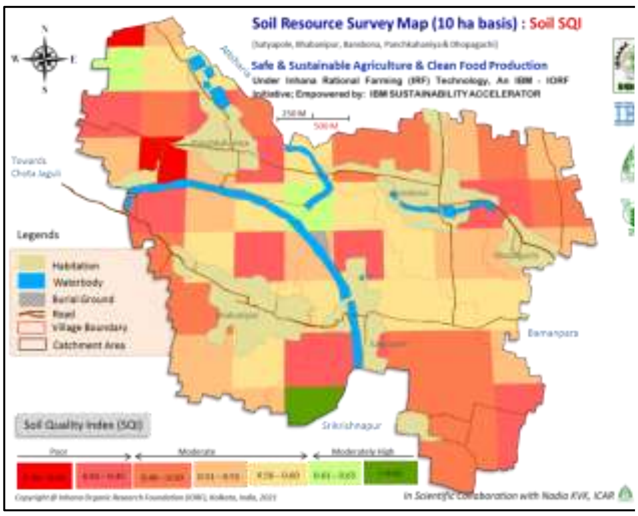

Fig 14 : Soil Quality Index (SQI) map

3.4 On-farm Novcom Composting and its quality components

Novcom compost was prepared in the project area using farm waste and crop residue as the major components. Compost samples were analyzed as per National (FAI, 2007) and International Standards (Australian Std.1999, Thompson *et al*, 2002). All the compost samples appeared dark brown in colour with an earthy smell, deemed necessary for mature compost (Epstein, 1997). Average moisture in compost samples varied from 45.23 to 58.78 percent, which may be placed in the high value range (40 to 50) (Evanylo, 2006). Evaluation of Novcom compost in terms of pH, organic carbon, nutrient value and C:N ratio indicated quality compost as also found by other workers (Seal *et al*., 2012; Bera *et al* 2013b; Bera *et al* 2013c). Compared with the standard suggested range for N, P, K (Alexander, 1994), the value obtained for Novcom compost were in the upper range, which clearly authenticated its rich nutrient status (Fig 15, 16).

Fig 15 : Development of Novcom poultry compost

Fig 16 : Application of Novcom compost in the project area

Table 4: Quality parameters of Novcom compost

Sl. No.	Parameter	Novcom compost	Sl. No.	Parameter	Novcom compost
1.	Moisture present (%)	61.40	7.	Total Microbial Count[1]	32 x 1016
2.	pH_{water} (1 : 5)	7.74	8.	CO_2 evolution rate ($mgCO_2$–C/g OM/day)	2.04
3.	EC (1 :5) dS/m	2.15			
4.	Organic carbon (%)	28.40	9.	Germination Index (phytotoxicity bioassay)	1.02
5.	Total NPK (%)	3.79			
6.	C/N ratio	13.1 : 1	10.	Compost Quality Index (CQI)	5.41

[1] per gm moist soil;

Total microbial count in the order of 10^{16} signified high generation of microbial population indicating the compost to be of rich quality. Speedy biodegradation within 21 days and comparatively high nutrient content of Novcom compost was influenced by the high and diversified microbial population that was generated naturally within the compost heap during the biodegradation process (Seal *et al.*, 2012). Assessment of phyto-toxicity in terms of Germination index (> 1.0) indicated that the compost enhanced rather than impaired germination and radicle growth (Trautmann and Krasny, 1997).

3.5 Plant Health Management and its Impact on Crop Productivity & Economics:

Productivity of the vegetables under the ‘Clean Food’ project was documented and compared with the zonal productivity range of the respective vegetables under the conventional farmers’ practice (Table 5). Productivity of almost all the vegetables under clean food program was higher than the average productivity of the same under conventional farmers’ practice. The findings indicated that adoption of different sustainable management practices helped in increasing the crop productivity even in the 1st year of adoption; which nullified the general myth of crop loss in the absence of any chemical pesticide in crop production. This initiative could be a benchmark study for sustainable management of vegetables and the technological advancement can be transferred to the farmers’ field in order to facilitate crop production even in an intensified cropping zone like Nadia, where excessive use of fertilizers and pesticides enhances the risk of soil health deterioration as well as the surrounding ecology.

The cost of vegetable production under the ‘Clean Food’ program was also compared with that under the conventional farmers’ practice which is shown in Table 5. According to the documented data base, the production cost of clean vegetables per ha, was comparable with the cost of conventional farming and in some cases, even lower than that of conventional farmers’ practice. However, when assessed in terms of cost per kg cost of cultivation under the

'Clean Food' program (Fig 17 & 18) was found to be lower than that recorded under the conventional farmers' practice; considering that crop productivity under the adopted sustainable practice was higher than the average productivity under conventional farmers' practice.

Fig 17 : Brinjal production under clean Food program at the project area

Fig 18 : Clean vegetable production in the project area

Table 5: Productivity and Economics of major vegetables under Clean Food Development Program vis-a-vis Conventional Practice

Vegetables	Productivity (ton/ha)		Cost of Production of Vegetables (Rs. in Lakh /ha)		Average Cost of Vegetable Production (Rs./kg)		Average Farmers price (Rs/kg) (Source : Sufal Bangla)
	Under Clean Food Program	Under Farmers Practice	Under Clean Food Program	Under Farmers Practice	Under Clean Food Program	Under Farmers Practice	
Brinjal (*Solanummelongena*)	24.0 – 28.4 ton	19.0 – 25.0 ton	1.40 -1.70	1.32 -1.75	4.90 – 7.10	5.30 – 9.20	11 – 35 (Avg. 20)
Chilli (*Capsicum frutescens*L.)	16.2 - 17.5 ton	14 – 18 ton	1.30 -1.40	1.20 -1.38	7.40 – 8.60	6.70 – 9.90	25 – 50 (Avg. 37)
Okra (*Abelmoschu sesculentus)*	9.9 – 10.4 ton	8.0 – 11.0 ton	0.50 – 0.75	0.62 – 0.85	4.80 – 7.60	5.60 – 10.60	14 – 60 (Avg 37)
Tomato (*Solanum lycopersicum*)	18.6 – 20.4 ton	15.0 -18.4 ton	0.60 – 0.80	0.60 – 0.85	2.50 – 4.30	3.30 – 5.70	7 – 40 (Avg. 20)
Bottle gourd (*Lagenaria siceraria*)	28.4 – 33.5 ton	24.2 – 32.0 ton	0.70 – 1.05	0.70 – 1.10	3.60 – 5.40	2.20 – 4.60	7 – 25 (Avg. 11)
Bitter gourd (*Momordica charantia*L.)	18.5 – 22.2 ton	15.0 – 20.0 ton	0.80 – 1.00	0.85 – 1.10	3.10 – 3.90	4.30 – 7.30	22 – 60 (Avg. 35)
Pumpkin (*Cucurbita moschata*(Duch.) Poir)	28.0 – 32.0 ton	25.2 – 30.0 ton	1.00 – 1.10	1.10 – 1.25	2.70 – 3.40	3.70 – 5.00	6 – 20 (Avg. 12)
Red Amaranth (Amaranthus cruentus)	13.4 – 16.8 ton	10.2 – 15.0 ton	0.45 – 0.50	0.40 – 0.50	2.70 – 3.70	2.70 – 5.00	8 – 26 (Avg. 14)
Spinach (*Spinacia oleracea)*	24.4– 27.0 ton	15.0 – 25.0 ton	0.55 – 0.60	0.50 – 0.65	2.00 – 2.50	2.00 – 4.30	6 – 30 (Avg. 14)
French Bean (*Phaseolus vulgaris* L)	11.4 – 12.8 ton	8.0 – 12.0 ton	0.85 – 1.00	0.80 – 1.05	6.60 – 8.80	6.70 – 13.10	14 – 50 (Avg. 40)

3.6 Pesticide residue analysis under colorimetric assay test

Pesticide residue analysis was done as per the colorimetric assay test and the results indicate that under Clean food program, except brinjal, chilli and okra, most of the samples found free from pesticide residue (Fig 19). And most importantly where traces of pesticide is found in vegetable samples under clean food program, that is far less than the EU standard for vegetable and upto 80 % lower than that of from Market source (Fig 20, 21 & 22).

Fig 19 : Pesticide free safe and sustainable cxrop production under 'Clean Food' Program

Table 6: Comparative Pesticide Residue in vegetables grown under Clean Food program vis a vis conventional market vegetables

Vegetables	Major Pesticide Groups							
	Organo Chlorine		Organo-Phosphate		Synthetic Pyrathroids		Nicotinamides	
	< ------------------------- ppm ------------------------- >							
	[1]CF	[2]MV	CF	MV	CF	MV	CF	MV
Brinjal	BDL	BDL	0.016	0.042	0.010	0.044	0.012	0.065
Chilli	BDL	BDL	BDL	0.040	0.012	0.039	0.021	0.031
Okra	BDL	BDL	0.014	0.034	0.012	0.028	BDL	0.021
Tomato	BDL	BDL	BDL	0.021	BDL	0.018	BDL	0.019
Bottle gourd	BDL	BDL	BDL	0.012	0.024	0.021	BDL	0.012
Bitter gourd	BDL	BDL	0.011	0.012	BDL	0.016	BDL	0.014
Pumpkin	BDL	BDL	BDL	0.011	BDL	0.014	BDL	0.012
Red Amaranth	BDL	BDL	BDL	0.011	BDL	BDL	BDL	0.014
Spinach	BDL	BDL	BDL	0.011	BDL	BDL	BDL	0.012
French Bean	BDL	BDL	BDL	0.011	BDL	0.012	BDL	0.024

[1]CF : Vegetables under Clean Food program, [2]MV : Conventional vegetables sourced from Market; Note : Values are avg of only those samples having residue over BDL

Fig 20 : Pesticide residue analysis of vegitable samples through colorimetric assay test under 'Clean Food' Program

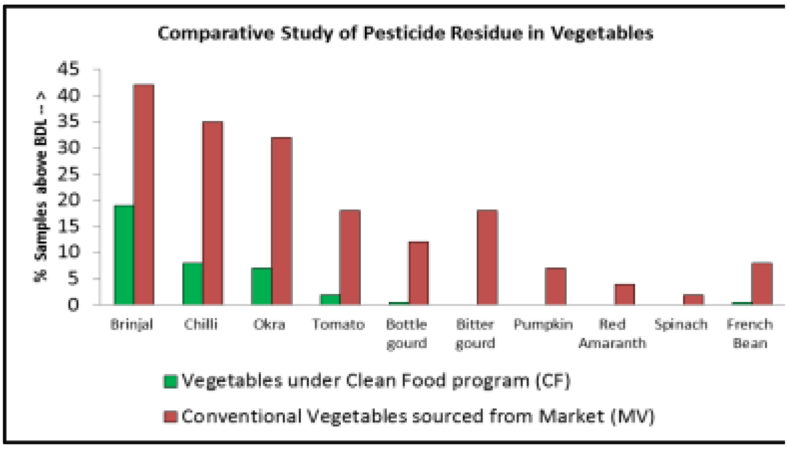

Fig 21: Comparative study of presence of pesticide residue above Below Detectable Limit (BDL < 0.01 ppm).

Fig 22 : Colorimetric assay test at IORF Laboartory, Kolkata.

3.7 Energy Use Efficiency and Reduction of GHG Emission Potential

Agriculture itself is an energy consumer and energy producer in the form of renewable energy. Crop productivity and profitability are closely related with energy consumption. Efficient use of these energies helps to achieve higher production and productivity, and contributes to the economy, profitability and competitiveness of agricultural sustainability (Singh, 1990). In the present study average energy use efficiency under clean food program was about 31 % higher (18 % to 60 % with different crop) than the farmers practice (Fig 23).

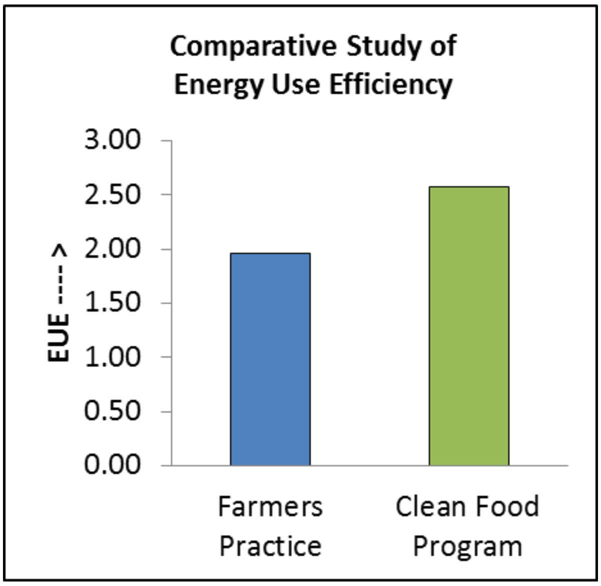

Fig 23: Comparative Study of Energy Use Efficiency under Clean Food Program vis a vis Farmers Practice.

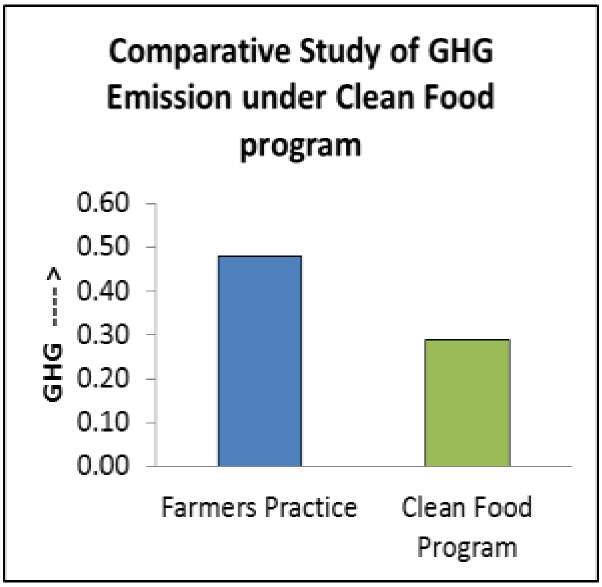

Fig 24: Comparative Study of GHG Emission Potential under Clean Food Program vis a vis Farmers Practice using ACFA –Version-1.0 carbon assessment tool..

In the context of increased emission of greenhouse gases and the abrupt climatic change, energy budgeting in terms of carbon usage has become a point of concern for any industry. It is widely recognized that greenhouse gas emissions from agricultural practices are largely driven by the synthetic fertilizers and the fossil fuels that are used for the different agricultural operations. In the present study the GHG emission potential under the different vegetables were evaluated using ACFA –Version-1.0 carbon assessment tool. (Bera et al,2022). The study showed that total GHG emission potential was significantly lower (40 %) under Clean Food Program primarily due to reduction of N-fertilizer and chemical pesticides (Fig 24).

3.8 Soil Quality Development

Study of soil quality for pre and post experimentation showed increase in soil microbial activity potential and soil quality index under Clean Food program which might be due to application of Novcom compost along with reduction in application of chemical pesticides and herbicides in the area (Fig 25 26, 27 & 28).

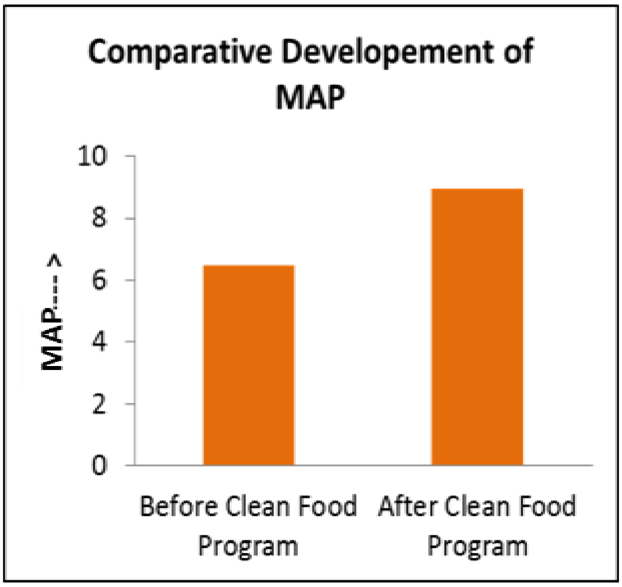

Fig 25 : Comparative study of soil microbial activity potential (MAP) before clean food program and after 1 year of program at the study area

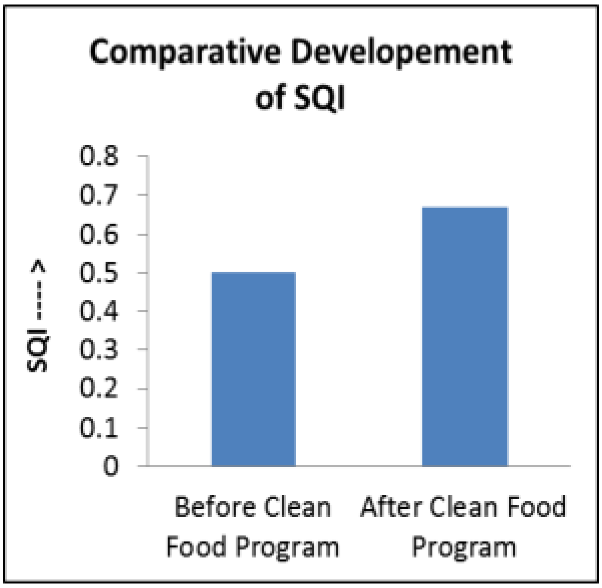

Fig 26 : Comparative study of soil quality Index (SQI) before clean food program and after 1 year of program at the study area

Fig 27 : Distribution of Soil Health Cards to the project farmers under 'Clean Food Program'

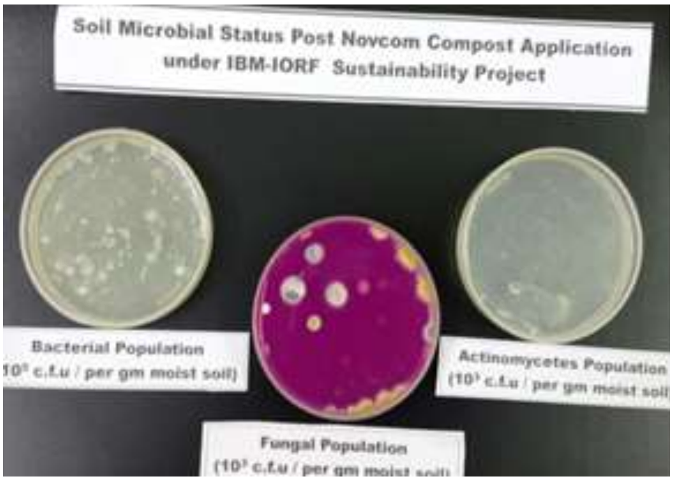

Fig 28 : Analysis of soil microbial population post compost application in the project area.

4. Conclusion

Injudicious use of chemical inputs along with intensive farming system made the soil most vulnerable and need a sustainable management practice for future crop security and sustainability. Clean Food Development program could be the most effective approach looking at the improvement of crop productivity along with improvement of soil quality, reduction of risk of pesticide residue in food, preservation of environment and most importantly creating opportunity for higher income generation.

5. Award and Recognitions

The 'Clean Food' Program has received 4 Recognitions in 2022 viz (i) Winner in the Category ENVIRONMENT under 8th CSR Impact Awards – CSR Box & Dalmia Bharat Foundation, (ii) Winner – Excellence in Climate Change Mitigation under CSR & Sustainability Summit & Awards – ASSOCHAM Southern Region, (iii) Bronze in Category LIVELIHOOD under National CSR & Summit Awards – Vision India Forum & CMAI and (iv) Winner in the Category 'Best Innovative CSR Project' under Corporate Responsibility Summit & Awards – UBS Forums (Fig 29).

Fig 29 : Innovativeness and impact of this 'Clean Food Program' on farming community has been recognized by different forum.

5. Acknowledgements

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'CLEAN FOOD': A MODEL FOR SAFE AND SUSTAINABLE AGRICULTURE TOWARDS ACCOMPLISHMENT OF CIRCULAR ECONOMY

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ABSTRACT

The core concept of Circular Economy (CE) in Agriculture is targeted towards better sustenance through higher use of renewable sources and facilitating the restoration and regeneration of system resources. However, dearth of effective crop-technology/ies that can ensure the above while sustaining crop yields; form the major bottleneck towards facilitation of CE in agriculture.

The Safe and Sustainable 'Clean Food' (CF) Model can perhaps serve as the best fit road map towards the objective. Driven by Inhana Rational Farming (IRF) Technology this model focuses 'Plant Health Management' and utilizes the safe, cost-effective, waste bio-converted Novcom compost for Soil Health Management to deliver safe food, without crop loss and without raising the cost of production.

The model when evaluated in respect of all the basic principles of circular agriculture; revealed its potential towards improving (by up to 19.5%) crop yield while reducing/ eliminating non- renewable inputs like chemical fertilizers and pesticides; that minimized the risk of pesticide residue in food (vegetables) by about 93%. Resource recycling through bioconversion of MSW/ landfill waste into safe compost improved soil quality by up to 27%. Most importantly, GHG Abatement of 6.4 to 11.7 kg CO_2-eq / kg food production, 64% increase in energy productivity, 16.7% higher employment generation, and about 19.7% increase in gross income (on an average); indicated that the CF Model delivered the very essence of CE in agriculture i.e., decoupling economic development from the linear dynamics of finite and non-renewable resource extraction, use, and disposal, while improving the access to safe and nutritious food for all.

Keywords: Waste recycling, IRF Technology, Novcom Compost, Safe and sustainable agriculture, GHG mitigation.

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1.0 Introduction

Modern agriculture has increased food production but the development has entailed significant cost. Prominent among these are topsoil depletion, groundwater contamination, air pollution, greenhouse gas emissions, contamination of the food chain, and disintegration of rural communities (Brodt *et al*, 2011). Thus the situation demands a paradigm shift in agriculture to ensure the availability of safe food for the rising global population while mitigating climate change and minimizing environmental pollution. Sustainable agriculture that incorporates environmental health, economic profitability, and social equity, forms the only solution. But the reality is depicted by the statement of UN, "It is currently not clear or well defined what constitutes productive and sustainable agricultural practice".

The concept of circular economy generated from the need to develop a sustainable food production system. Circular agriculture central to the growth of circular economy, focuses on the minimal use of external inputs, closing nutrients loops, regenerating soils, and minimizing the impact on the surrounding ecology. Hence, in the current context of resource scarcity, global climate change, environmental degradation, and increasing food demand, the circular economy represents a promising strategy for supporting sustainable, restorative, and regenerative agriculture.

The relevance of Sustainable Agriculture grows manifold w.r.t. India where >89% farmers are marginal and resource poor, with a land holding <0.38 hec., are therefore highly vulnerable to climate change, and compelled to use large quantity of synthetic inputs but receive very poor and inconsistent revenue.

This was the background behind development of 'Clean Food' Model, for safe and sustainable food production, empowerment of the marginal and small farming community and to showcase impactful climate action through safe food production. Under this model, induction of sustainable crop technology, composting process for effective waste bioconversion, application of waste bio-converted compost in soil and adoption of plant health management; were all aligned towards the development of safe and sustainable 'Clean Food'. Hence, the objective of the present study is to evaluate the impact of this 'Clean Food' Model in respect of crop sustainability, food safety, food quality, soil health, energy use efficiency, GHG mitigation, employment generation and farmers' livelihood; all of which are the major components of agriculture based circular economy.

2.0 Materials and Methods

Development of 'Clean Food' (CF) was initiated under IBM Sustainability Accelerator Project entitled 'Adoption of a Cluster of Villages for Agricultural Sustainability and Food Security through Clean Food Program'. The project area comprised five villages namely Satyapole, Bhabanipur, Panchkahaniya, Dhopagachi and Bansbona in the Haringhata block of Nadia district of West Bengal, India; by Inhana Organic Research Foundation (IORF); in scientific collaboration with Nadia Krishi Vigyan Kendra, BCKV, ICAR.

Months	Max. Temp (⁰C)	Min. Temp (⁰C)	Rainfall (mm)	No. of Rainy Days	Humidity %	Cloud %	Total Sun. Hours	Sunny days
January	26.6	16.2	4.8	1.8	43.6	6.4	240.6	29.4
February	30.6	19.6	25.4	3.0	40.6	11.2	222.6	25.0
March	34.8	22.8	25.7	7.0	46.0	14.8	293.4	21.4
April	38.6	27.0	110.4	12.4	55.4	24.8	277.4	12.6
May	38.6	28.2	125.4	14.0	58.4	23.2	340.2	13.4
June	37.0	29.0	122.8	23.4	63.8	46.8	286.5	5.4
July	34.0	27.4	250.5	29.2	74.0	56.8	218.4	1.0
August	33.0	27.0	289.6	28.6	78.6	53.4	230.2	2.2
September	32.6	26.4	194.2	24.2	77.6	46.4	209.6	5.0
October	31.8	24.0	111.9	14.6	70.4	29.6	254.5	15.6
November	30.0	21.0	18.3	2.6	55.0	10.8	280.2	27.0
December	26.8	17.4	4.3	1.6	48.2	11.4	221.8	29.2

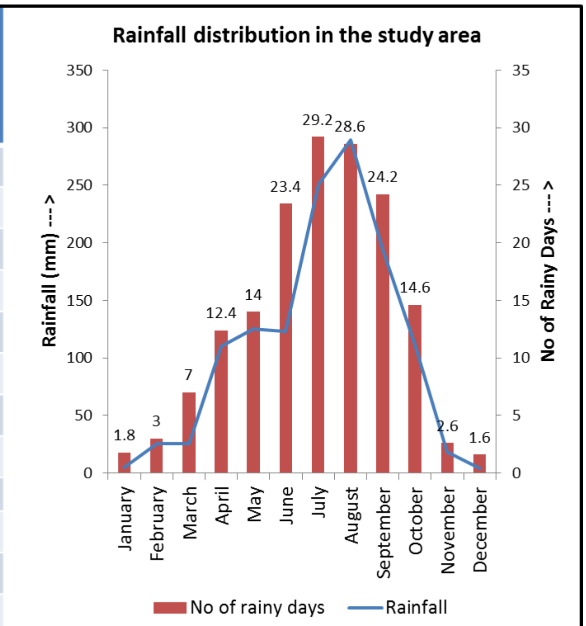


Figure 1: Climatic data of the study area (2016–2021) (Source: https://www.worldweatheronline.com)

2.1 Climatic Data of the Study Area

The study area comes under hot, moist sub humid ecological sub region (15.1) (Sehgal, 1992). The study area is characterized by hot summer, high humidity and rainfall during the monsoon. The highest mean monthly temperature is observed in April (40°C) and the lowest (17°C) in January (Fig. 1).

2.2 Land physiography and soil characteristics of the study area

The study area belongs to riverine delta zone and is formed by the materials carried by the Ganga. The area basically comes under meander flood plain (Bera *et al.*, 2021) within the new alluvial agro-climatic zone of West Bengal. The soil of the study area is very deep, imperfectly drained, fine loamy soils occurring on level to nearly level meander plain with loamy surface and moderate flooding associated with very deep, moderately well drained fine silty soils.

2.3 Hypothesis behind the concept of 'Clean Food'

Development of CF is based on a scientific hypothesis that the 'Relationship between a Plant and Pest is Purely Nutritional'. According to F. Chaboussou, a renowned French scientist, application of N-fertilizers especially when the plant metabolism is depressed, causes an enhancement of free amino acids and sugar pools in the plant cell sap; which serve as ready food for the pest. So to reduce/ eliminate pesticides, pests need to be reduced and for that the ready food source need to be cut off (Bera *et al.*, 2021). The unique approach under Inhana Rational Farming (IRF) Technology is based on this science, and serves the above objectives through activation of plant metabolism and photosynthetic efficiency, leading to higher plant immunity against pest and enhanced host-defence against disease causing pathogens. This primary approach along with sustainable field practices ensures sustenance of crop yield while lowering the requirement for chemical pesticides, leading to the development of safe and sustainable Clean Food.

2.4 Inhana Rational Farming (IRF) Technology – The major technological intervention

The CF Model is primarily driven by IRF Technology - an organic package of practice for soil and plant health management (Seal *et al*, 2017; Barik 2017). The technology is based on the 'Energy Element Activation (E.E.A.) Principle' which works towards energy infusion into the soil and plant system, leading to ecologically and economically sustainable crop production (Seal *et al*, 2017b).

Energization of soil system is primarily attended through the application of Novcom compost that is produced on-farm utilizing Novcom Composting Technology through biodegradation of any type of available resources/ waste (Seal *et al*, 2012, Bera *et al*, 2017). Novcom Composting Technology enables bioconversion of any kind of waste within a 21 days' time period and without requiring any specific infrastructure that helps towards its easy adoption by small and marginal farmers. The safety, stability, maturity and phytotoxic aspects of Novcom compost was evaluated as per the set standards of U.S. Composting Council. Evaluation revealed a rich population of self-generated micro flora in the order of 10^{16}c.f.u. per gm or one trillion billion microflora per ton Novcom Compost, which enables speedy restoration of the soil biological productivity (Seal *et al*, 2012; Bera *et al*, 2017; Mukhopadhyay *et al*, 2021). IRF Technology emphasizes plant health management as a precursor for resilient plant system. Energization of plant system is aimed at activation of plant physiology leading to higher nutrient use efficiency alongside better bio-chemical functions that lead to enhancement of plant immunity and its' host defence mechanism. It is a systemic approach that utilizes a set of potentized and energized botanical solutions developed under E.E.A Principle. The working principle and spraying protocol of the solutions are in accordance with that followed by the workers adopting this technology for organic crop production (Barik *et al.*, 2014).

2.5 Adoption of Clean Food (CF) Model

Vegetables form the major crop grown in the area with a cropping intensity of 2.8 to 3.0. The program was initiated with awareness and skill development program for local farmers followed by soil survey, on-farm demonstration of Novcom composting and development of recommendation for sustainable crop production (Fig. 2).

The CF Model is based on two primary approaches i) Soil Health Management ii) Plant Health Management. Soil health management is done through application of on- farm produced Novcom compost. Plant health management from seed sowing till crop harvest is done through application of a schedule of IRF Plant Health Management (IPHM) Solutions (Seal *et al.*, 2017).

Application of compost is the primary requirement for soil health management. But raw material scarcity for compost production is the primary bottleneck in Indian agriculture, especially in West Bengal. Hence, to overcome this limitation three types of CF Models were formulated. Plant health management was kept same for all the models, but the soil management aspect varied as per the availability of raw material for on-farm compost production.

Three CF Models were exhibited (i) CF Model - 1 (100 % Reduction of Chemical Pesticide), (ii) CF Model - 2 (50% Reduction of N- fertilizer +100 % Reduction of Chemical Pesticide) (iii) CF Model - 3 (100% Reduction of both N- fertilizer and Chemical Pesticide)

2.6 Soil quality analysis, soil quality indices and development of soil resource maps

Soil analysis was conducted before initiation of project and post crop harvest. Two different types of soil sampling were done under the project. Firstly 65 soil samples (from 0 to 30 cm soil depth) were collected from the project villages on a 10 ha grid for developing village level soil resource maps. Another set of soil samples were collected from plots where the different CF Models were demonstrated. Soil physicochemical and fertility parameters were analyzed as per standard methods (Jackson, 1973). Microbial biomass carbon was measured using the dichromate oxidation method (Vance *et al*. 1987). Soil respiration was measured through chemical titration of trapped CO_2 and Soil FDAH as per the standard methodology (Haney *et al*. 2008).

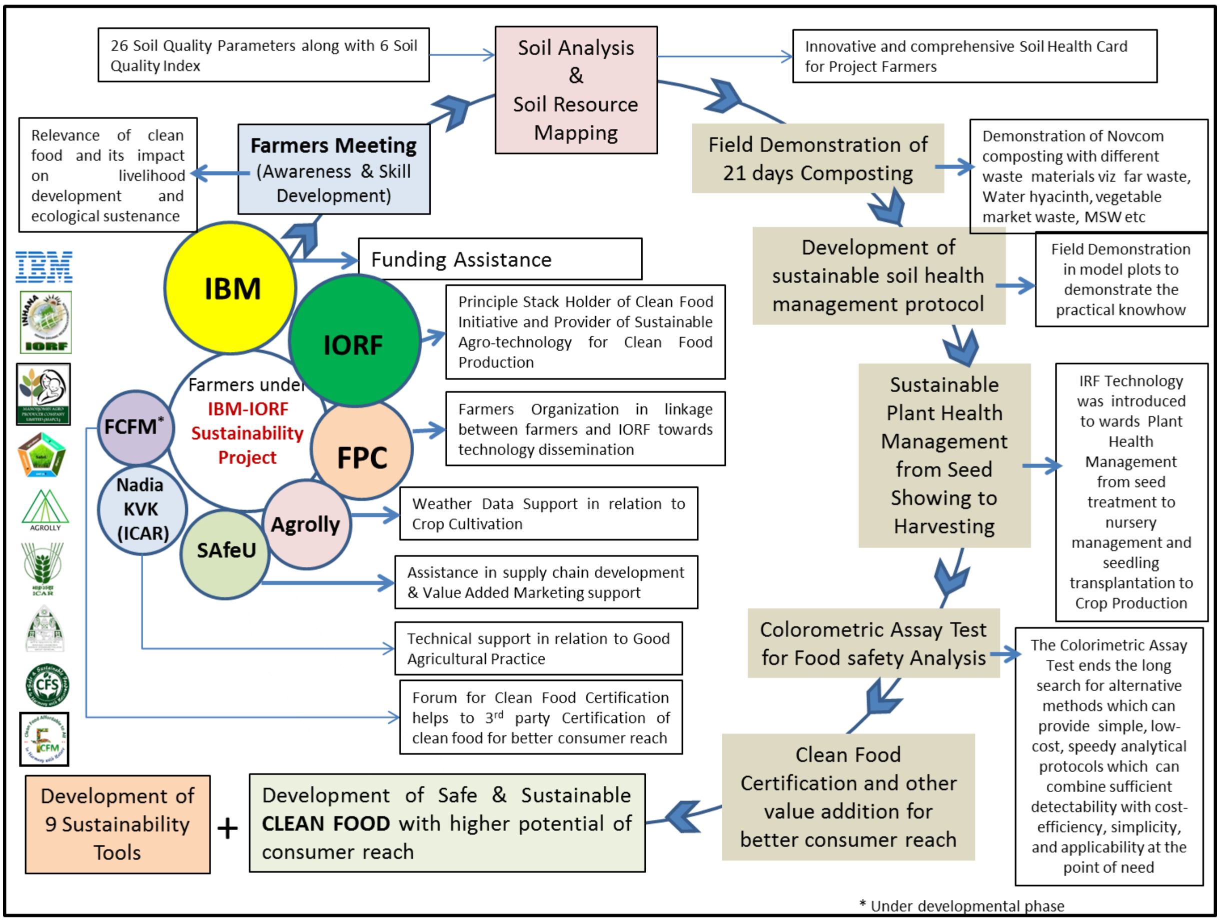


Figure 2: Flow diagram of Clean Food Program under IBM Sustainability Accelerator Project

2.7 Quality analysis of on- farm produced Novcom compost

In this project, 30 compost heaps were made on-farm utilizing different types of waste *viz.* agriculture farm waste, water hyacinth (weeds from water bodies), vegetable market waste, poultry litter (livestock waste) and Municipality Solid Waste (MSW)/ Landfill waste; utilizing Novcom Composting Technology of IORF (Seal *et al*, 2012). This technology enabled the preparation of safe and quality compost within a period of 21-30 days and the safety and quality aspects of Novcom compost was analyzed in the laboratory as per the standard methodology (Black, 1965 & Jackson, 1973).

2.8 Protocol of Colorimetric Assay Test for evaluation of pesticide residue in vegetables

The safety aspect of CF was evaluated utilizing the Colorimetric Assay Test. Pesticide residue analysis in terms of five major groups *viz.* Organochlorine, Organophosphate, Carbamate, Synthetic Pyrethroids and Nicotinoids were conducted to detect every single variant out of more than 650 pesticides formulations covering major insecticides, fungicides and herbicides. This test method can also enable detection of heavy metals *viz.* Hg^{2+}, Cd^{2+}, Cu^{2+} and Pb^{2+}. Apart from the above, Triazines, Paraquat and many other known and unknown toxic substances which inhibit our central and peripheral nervous system; was also brought under the scanner, utilizing this test method. Through this assay test, pesticide residue can be visually detected up to

0.10 ppm level and up to 0.01 ppm level using the spectrophotometer. To conduct this test the vegetable samples were extracted as per the standard QuEChERS method (Anastassiades *et al*, 2003) and Colorimetric Assay Test was done as per the methodology for (i) Organochlorine (Paulini & Rurbaud, 1957), (ii) Organophosphate, Carbamate, Synthetic Pyrethroid, Phenylpyrazole, Triazine, Paraquat and Heavy metals (Cu, Zn. Hg. As, Cd, Pb) (Mohamed E. *et al*. 2014), (iii) Nicotinoids (Nwanisobi & Egbana, 2015).

2.9 Qualitative Evaluation of CF

Quality assessment of vegetables grown under CF model *vis-à-vis* conventional farmers' practice was undertaken in respect of Vitamin– C Content (FASSI, 2015), Protein Richness (Latimer 2016) and Antioxidant Richness (Hua et al 2015).

2.10 Evaluation of Energy Use Efficiency and GHG Emission

Energy use efficiency, energy productivity, specific energy, energy intensiveness and net energy were calculated as per the standard methodology (Mittal *et al*, 1985). ACFA (Version 1.0) developed by IORF as per IPCC guideline; was used to calculate the GHG emission potential (Bera *et al*, 2023) under the different CF Models. GHG abatement from source during bio-conversion of landfill waste was estimated as per the guidelines of IPCC (2021). In the study, two different timescales were used for evaluating GHG emission. In case of CO_2 and N_2O, the usual 100 years' time frame was used, whereas in the case of methane 24 years' time frame was considered as because it is short lived in the atmosphere and also because this time horizon aligns with scenarios achieving a specific temperature goal and to best align emission metrics with the Paris Agreement 1.5 ◦C goal (Abernethy and Jackson 2022).

3. Results and Discussion

The impact study was initiated with soil resource mapping for understanding the problem and potentials of the soils in the project area w.r.t. crop production and qualitative evaluation of Novcom compost which forms the major influential component behind the different CF Models. Comparative assessment of crop yields under the major crop sequences, energy efficiency and GHG emission/mitigation potentials was also done in respect of the CF Models *vs*. conventional farmers' practice. And finally, the footprint of CF Model was evaluated in terms of soil quality improvement, employment generation and farmers' livelihood support.

3.1 Soil Resource Mapping

Soil resource mapping is crucial towards development of a suitable soil management policy for any area. Soil physical index (PI) which depicts soil physical status in terms of crop sustenance and root growth was good to very good in the project area (Fig. 3).

Soil fertility index (FI) (Barik *et al*, 2017) was moderate to moderately high in 50 percent of the project area while high FI value was obtained in the rest area (Fig. 4). Soil microbial activity potential (MAP) which depicts the presence of soil microflora and their activity in soil; was found to be very low to low in about 83 percent of the project area (Fig. 5) while a moderate value was observed in only about 11 percent of area. Soil quality index (SQI) was moderate in 72 percent area followed by poor status in 22 percent area and moderately high status was obtained for only about 5.4 percent area (Fig. 6). The study indicated the vulnerability of the soils in the project area in terms of low organic carbon, high fertilizer salt concentrations and low microbial presence, which calls for a sustainable plan for soil health management.

3.2 Compost Quality Analysis

The mature compost samples (6 samples each for specific type of compost) had dark brown colour and earthy smell, indicating compost maturity. Moisture content varied from 52.54 to 68.56 percent (Table 1) which was slightly higher than the suggested standard (40 to 50 percent) (Evanylo, 2006.). The compost samples were almost neutral in pH as indicated by the values (7.23 – 7.80).

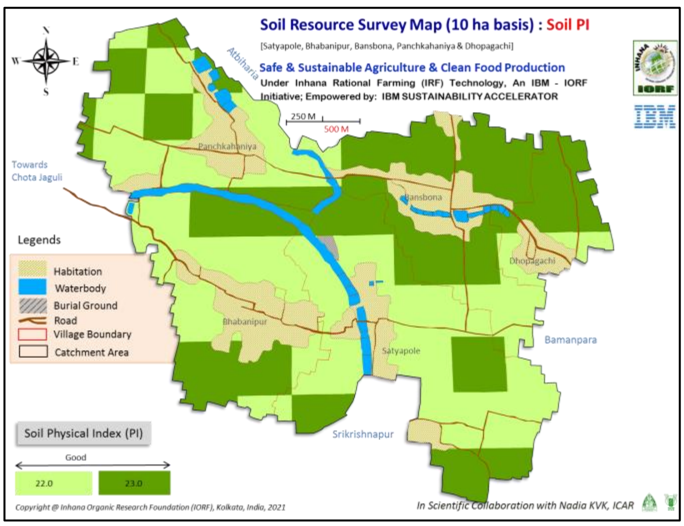


Figure 3: Thematic Map depicting variation in Soil Physical Index (PI) in the study area.

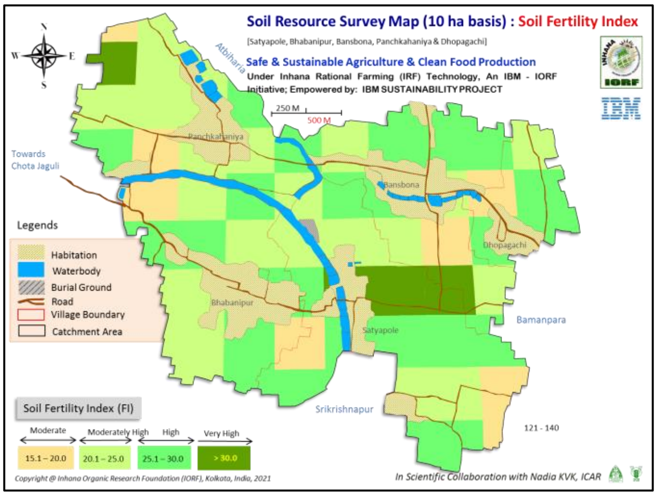


Figure 4: Thematic Map depicting variation in Soil Fertility Index (FI) in the study area.

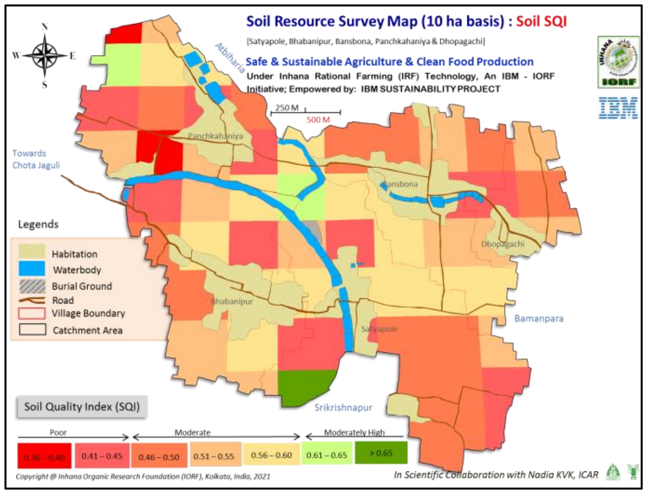


Figure 6: Thematic Map depicting variation in Soil Quality Index (SQI) in the study area

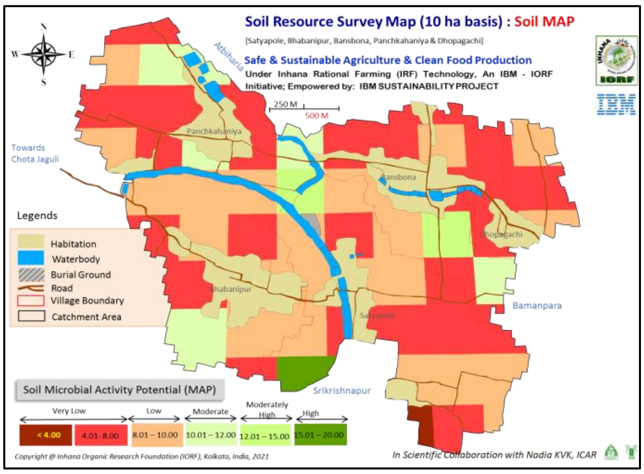


Figure 5: Thematic Map depicting variation in Soil Microbial Activity Potential (MAP)

Picture 1: Vegetable Production under 'Clean Food' Model at the Study Area

Table 1: Quality parameters of Novcom compost produced under IBM Sustainability Accelerator Project

Sl. No.	Parameter	Bio-conversion of Waste (Mean value)				
		Farm waste	Water Hyacinth	Vegetable Market Waste	Poultry litter	MSW
1.	Moisture percent (%)	60.4	63.5	65.5	62.90	52.54
2.	pH_{water} (1 : 5)	7.8	7.23	7.65	7.75	7.71
3.	Organic carbon (%)	28.80	29.8	20.48	26.30	19.96
4.	CMI[1]	1.67	1.55	3.08	2.00	3.21
5.	Total NPK (%)	4.21	4.18	3.74	4.03	2.49
6.	C/N ratio	14:1	14:1	11:1	13:1	13:1
7.	Total bacterial count[2]	$92x10^{16}$	$39x10^{16}$	$47x10^{16}$	$29x10^{16}$	$28x10^{16}$
8.	Total fungal count[2]	$48x10^{16}$	$11x10^{16}$	$31x10^{16}$	$17x10^{14}$	$12x10^{14}$
9.	Total actinomycetes count[2]	$12x10^{16}$	$8x10^{16}$	$18x10^{16}$	$11x10^{14}$	$6x10^{14}$
10.	CO_2 evolution rate (*$mgCO_2$ – C/g OM/day*)	3.8	2.16	2.71	2.74	2.14
11.	Germination index *(phytotoxicity bioassay)*	1.03	1.09	1.04	0.82	0.85

[1]*CMI : Compost Mineralization Index;* [2]*Microbial count : c.f.u. per gm moist compost.*

The compost qualified for field application as indicated by their organic carbon content (19.96 – 29.8 %) (Evanylo, 2006). The ready nutrient supplying potential of compost (CMI: 1.55 – 3.21) was well within the standard reference range as suggested by Rekha *et al* (2005). Total nutrient content of the compost samples (2.49 to 4.20 percent) was found to be within moderate to high range w.r.t. any green matter compost. C/N ratio (11:1 to 14:1) was also found to be within the set standard of ≤ 20 (FAI, 2007) as indicated for well-matured compost.

The population of bacteria, fungi and actinomycetes was highest in case of compost produced from farm waste, while the lowest values were obtained in case of MSW compost. The high generation of microflora population within the compost heaps irrespective of the nature of the waste was influenced by the ideal micro-atmosphere created within the composting heaps through the application of Novcom solution (Seal *et al.*, 2012). Respiration test of compost samples (2.14 to 3.80 $mgCO_2$–C/g OM/day) confirmed compost stability (reference range: 2.0 - 5.0 $mgCO_2$–C/g OM/day).

The absence of phytotoxicity in the final Novcom compost samples (irrespective of the nature of waste used as raw material), was confirmed by the phytotoxicity bioassay test (Reference range: 0.8 to 1.0). The findings also indicated that it was possible to eradicate whatever inherent toxicity might be present in the different types of waste, through the utilization of Novcom Composting Technology, perhaps due to the self- generation of a very high population of microflora within the composting heap (Seal *et al*, 2012).

3.3 Comparative evaluation of crop productivity

Assessment of crop performance was taken up in respect of eleven major cropping sequences, followed in the area. Crop Performance was estimated under different CF Models *vis-à-vis* conventional farmers' practice (Table 2).

The study showed that in terms of crop productivity, all the CF models performed well as compared to conventional farmers' practice. On an average the crop productivity increased by 19.5 % under CF Model- 3. The findings provided an indication that plant health management, the most ignored component under conventional farming, can actually hold the key to crop sustainability especially under the climate change impact. Enhancement of crop productivity with adoption of IRF Technology was documented by several research workers (Barik *et al*, 2017; Seal *et al* 2017b, Seal *et al* 2017c, Seal et al 2017d). The studies indicated that the dual approach of plant health management and soil health management helped to improve crop productivity irrespective of crop variety or soil or agro-ecological settings.

Rice equivalent yield was calculated for the major crops to study the comparative economic profitability of different crops and showed highest value in the case of okra followed by coriander, brinjal and tomato (Fig. 7).

Table 2: Crop Performance under Different CF Models *vs*. Conventional Farmers' Practice

Sl.	**Cropping Sequence**	**Conventional Farmers' Practice**	**Clean Food Model – 1 (**100 % Reduction of Chemical Pesticide)	**Clean Food Model – 2** (50% Redn. of N Fertilizer + 100 % Redn. of Chemical Pesticide)	**Clean Food Model – 3** (100% Reduction of both N-fertilizer & Chemical Pesticide)
		< -------------------------- **Kg/ ha**			-------------------------- >
1.	Tomato-Cucumber-Coriander	43125	48450	48113	54000
2.	Potato-Brinjal-Cauliflower	79425	86025	90300	92775
3.	Potato -Okra-Cabbage	68025	78525	80100	82125
4.	Brinjal-Frenchbean-Spinach	45450	47625	51225	53400
5.	Pumpkin-Okra-Cabbage	49050	56325	56775	58425
6.	Brinjal-Carrot	41850	42900	45975	48150

Sl.	Cropping Sequence	Conventional Farmers' Practice	Clean Food Model – 1 (100 % Reduction of Chemical Pesticide)	Clean Food Model – 2 (50% Redn. of N Fertilizer + 100 % Redn. of Chemical Pesticide)	Clean Food Model – 3 (100% Reduction of both N-fertilizer & Chemical Pesticide)
7.	French Bean - Okra-Onion	35175	40800	39000	41475
8.	Potato-Chilli-Carrot	57825	65138	68175	71325
9.	Tomato-Ridge Gourd- Spinach	52725	59325	62250	67875
10.	Peas -Yam -Cabbage	63675	70050	74100	75450
11.	Pointed Gourd - Cauliflower	50400	55125	55650	56250
	Average	**53339**	**59117**	**61060**	**63750**

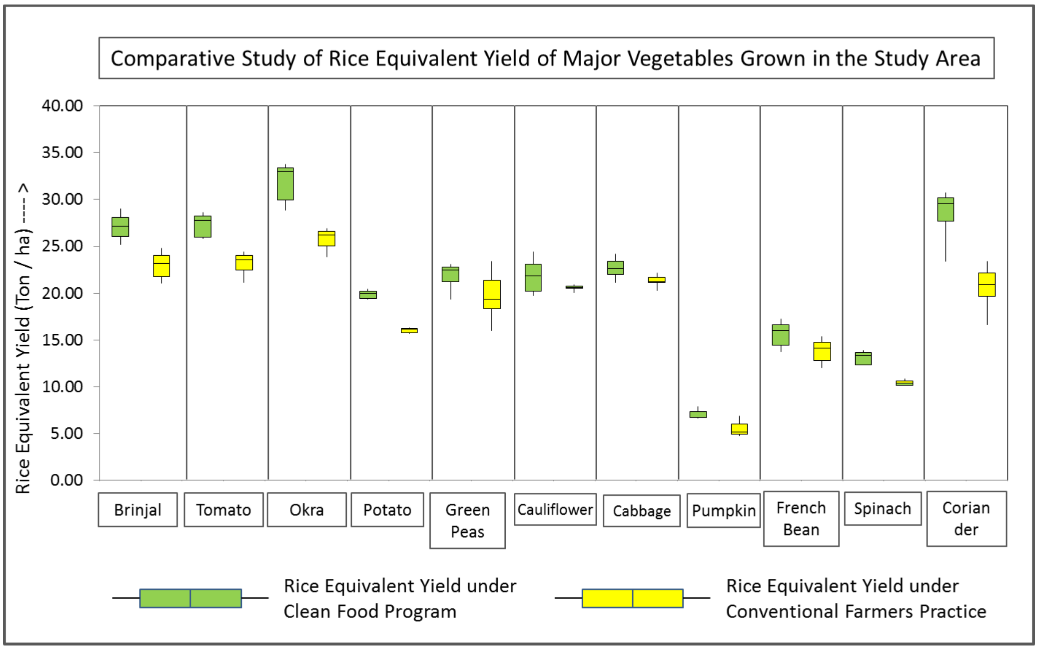


Figure 7: Box Plot diagram of Rice Equivalent Yield of Major crops grown under Clean Food Model (100% Reduction of both N- Fertilizer & Chemical Pesticides) *vis a vis* Conventional Farmers' Practice

3.4 Comparative study of pesticide residues in vegetables.

Safety aspect of 'Clean Food' was evaluated following the regulation of Codex Alimentarius Commission (CAC) and the Food Safety and Standards (Contaminants, Toxins And Residues) Regulations (2011); developed by Food Safety and Standards Authority of India (FSSAI); according to which the maximum residue limit (MRL) for vegetables is 0.1 ppm (*for individual pesticides*). However, for 'Clean Food', 0.1 ppm was considered as the MRL for the total presence of residues (*irrespective of the number of pesticides groups present*), for more stringent evaluation of its safety aspect.

The Colorimetric Assay Test (Bera *et al.*, 2022) was used for pesticide residue analysis. This test method was jointly standardized by IORF, Kolkata and KVK (Nadia)- ICAR, in technical collaboration with Dept. of Environmental Science, Tezpur University and Agricultural and Ecological Research Unit, ISI (Giridih). This initiative was especially taken up under this project to enable food safety authentication in real time and in the most economic manner.

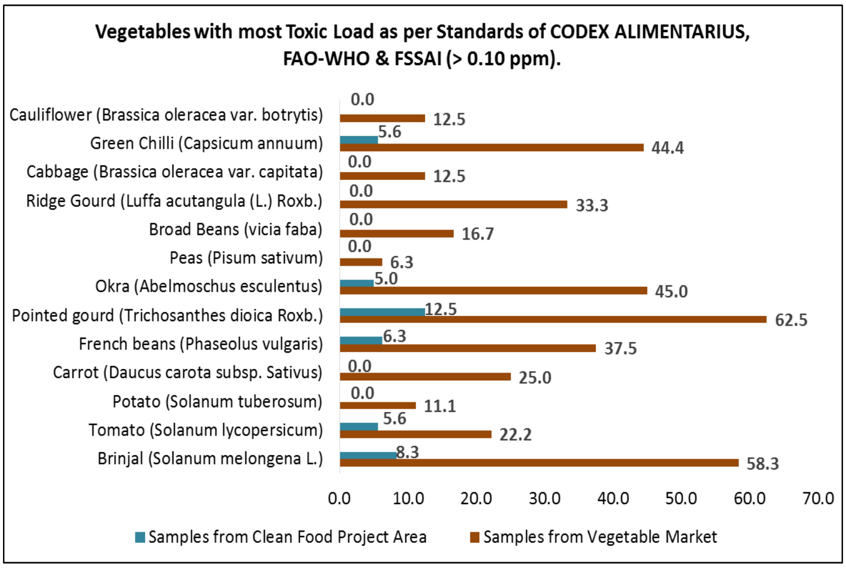


Figure 8: Comparative Analysis of different vegetables w.r.t. most toxic load as per the Standards of CODEX ALIMENTARIUS FAO-WHO & FSSAI (> 0.10 ppm).

Periodical and batch wise testing for pesticide residue was done in respect of 13 major vegetables from the study area (Fig. 8). 226 samples each were collected from the project area and the vegetable market source respectively; for the purpose of residue analysis.

In the case of vegetables like cauliflower, cabbage, ridge gourd, broad beans, peas, carrot, and potato; MRL was found below the stipulated standard of 0.1 ppm, in 100 percent of the tested samples grown under CF Model. However, for these same types of vegetables collected from market source, MRL above 0.1 ppm was recorded in 16 percent of the tested samples.

Crops like green chilli, okra, pointed gourd, French beans, tomato and brinjal, are generally considered to be high risk crops in respect of pesticide contamination, as also confirmed by the presence of residue above 0.1 ppm in 45% of the samples collected from vegetable market source. In stark contrast these same vegetables when grown under CF model were found to be relatively residue free with MRL >0.1 ppm detected in only about 7.2% of the tested samples.

3.5 Comparative Study of CF Quality

Food can boost up immunity only when it is naturally rich in anti-oxidants, minerals, vitamins and other qualities. 'Only healthy plants can produce healthy food'. Hence, food grown under conventional chemical farming i.e., using synthetic fertilizers and pesticides usually does not serve this objective. Quality analysis of 'Clean Food' was done to assess whether and to what extent the plant health management approach under IRF Technology impacts food quality. Comparative study of vitamin C, protein and antioxidant was done for the different vegetables as per specific relevance (Table 3). The comparative study provided a general indication regarding the qualitative advancement of crops grown under CF Model. The use of synthetic pesticides slows down plant defence mechanisms against pathogens, consequently favouring primary metabolism while organic management influences the reallocation from primary metabolism to secondary metabolite production resulting in higher ascorbic acid (vitamin C) and phenolic compounds (antioxidants) (Ceglie, 2016). Enhancement of these quality components under CF model might be attributed to the elimination of synthetic pesticides along with plant health management under IRF Technology, which served towards activation of plant physiology leading to higher production of secondary metabolites, which on one hand formed the quality component of food, while also enabling higher biochemical defense against the pests/ pathogenic organisms.

3.6 Comparative Study of Soil Health Development

Soil samples were collected from both conventional farmers' plot and plots under the different CF Models. For comparative analysis soil samples were collected before initiation of the project and after completion of a cropping sequence.

Table 4 : Soil Physical Properties under Different CF Models *vs*. Conventional Farmers' Practice

Sl.	Cropping Sequence	Conventional Farmers' Practice	Clean Food Model – 1	Clean Food Model – 2	Clean Food Model – 3
Soil Physicochemical Properties					
1.	Sand (%)	21.6	22.4	23.5	22.8
2.	Silt (%)	51.2	54.2	56.2	54.4
3.	Clay (%)	27.2	23.4	20.3	22.8
4.	Texture	Silt Loam	Silt Loam	Silt Loam	Silt Loam
5.	Soil Aggregates	MS[1]	MS	MS	MS
6.	Bulk Density	1.40	1.41	1.43	1.41
7.	Soil Depth (cm)	>150	>150	>150	>150
8.	Coarse Fragments	No	No	No	No
9.	Physical Index (PI)	22.0	22.0	22.0	22.0

MS[1] : Moderately stable

Table 4 represents the soil physical characteristics of the project area. The soils were mostly silt loam with light texture and no limitation in terms of soil depth, coarse fragment, bulk density and aggregate stability. Thus physical index (PI) value indicated that in terms of soil physical quality, it is good to very good for agricultural crops.

Soil Fertility Index (FI) (Table 5) indicated a high availability of nutrients in the soil solution, and the status was found to be similar in all the plots. Detailed study of the soil biological properties was done to investigate the soil biological functioning under different management practice. Soil microbial biomass (MBC) value indicated low to very low microbial population. Microbial quotient (*q*MBC) which is the ratio of microbial biomass carbon to soil organic carbon was low to moderate which indicated stress for soil micro flora due to intensive usage of synthetic fertilizer and pesticides. This was further supported by the very low FDAH value indicating low microbial activity in the soil and very low qDFA value which indicated that quality of organic matter was also not very good in terms of microbial richness. Microbial activity potential (MAP), which is an index for comprehensive assessment of the soil microbial status also came out low to very low for all the soils.

However, soil analysis post crop harvest, showed an increasing trend of soil biological functioning, which might be attributed to the application of quality compost in soil along with elimination of toxic synthetic inputs.

Soil Quality Index, which is calculated as the function of soil physical index (PI), soil fertility index (FI) and soil microbial activity potential (MAP); showed an increasing trend under the CF Models as compared to soils under conventional farmers' practice.

The study indicated that under CF Model– 1 **(**100 % Reduction of Chemical Pesticide), there was no such significant improvement of soil quality as compared to the soil receiving conventional chemical management. However, an increasing trend of soil microbial activity was noticed under this Model, which might be attributed to the elimination of chemical pesticides. However, in the cases of both CF Model – 2 (50% Reduction of N-Fertilizer &100 % Reduction of Chemical Pesticide) and CF Model – 3 (100 % Reduction of both N- Fertilizer and Chemical Pesticide) an improvement in soil quality indices was documented especially w.r.t. microbial activity; as indicated by the microbial activity potential (MAP) value.

Table 5 : Soil physicochemical, fertility and microbial properties under Different CF Models *vs*. Conventional Farmers' Practice

Sl.	Cropping Sequence	Conventional Farmers' Practice	Clean Food Model – 1	Clean Food Model – 2	Clean Food Model – 3
Soil Physic-chemical Properties					
1.	pH (H_2O)	6.38 (6.35)	6.42 (6.45)	6.39 (6.51)	6.42 (6.52)
2.	Org. C %	0.72 (0.72)	0.74 (0.75)	0.69 (0.75)	0.73 (0.79)
3.	NO_3^- (ppm)	55.18 (56.62)	54.32 (50.24)	56.31(47.12)	59.14 (50.16)
4.	Available N (Kgha^{-1})	334 (339)	346 (342)	329 (332)	345 (351)
5.	Available P_2O_5 (Kgha^{-1})	112 (114)	110 (110)	108 (107)	112 (110)
6.	Available K_2O (Kgha^{-1})	340 (345)	365 (369)	342 (345)	389 (401)
7.	Available SO_4 (Kgha^{-1})	87.6 (80.1)	87.2 (90.1)	95.2 (98.4)	96.2 (97.8)
8.	Fertility Index (FI)	26 (27)	27 (28)	27(28)	26(28)
Soil Microbial Properties					
9.	Soil MBC[1]	139 (137)	142 (151)	137 (156)	139 (162)
10.	Soil SR[2]	0.18 (0.21)	0.19 (0.18)	0.21 (0.23)	0.21 (0.26)
11.	Soil FDA[3]	30.51 (27.62)	26.35 (38.62)	28.62 (35.62)	27.47 (37.61)
12.	qMBC[4]	1.93 (19.90)	1.92 (2.01)	1.99 (2.08)	1.90 (2.05)
13.	qCO_2[5]	1.29 (1.53)	1.34 (1.19)	1.53 (1.47)	1.51 (1.60)
14.	qFDA[6]	0.42 (0.38)	0.36 (0.51)	0.41 (0.47)	0.38 (0.48)
15.	SIR[7]	3.46 (3.41)	3.54 (3.76)	3.41 (3.89)	3.46(4.04)
16.	QR[8]	0.05 (0.06)	0.05 (0.06)	0.06 (0.06)	0.06(0.06)
17.	MAP[9]	5.50(5.50)	5.50(8.67)	5.50(8.67)	5.50(8.67)
Soil Quality Index (SQI)					
18.	Soil Quality Index (SQI)	0.46(0.48)	0.48(0.56)	0.48(0.56)	0.46 (0.56)

[1]MBC; Microbial biomass carbon (micro gm biomass C/gm dry soil/hr), [2]SR:Soil Respiration, [3]FDA : Soil Fluorescein diacetate hydrolysis activity (µg/gm dry soil), [4] qMBC :Microbial Quotient, [5]qCO_2: Metabolic Quotient, [6]qFDA : Total enzymatic activity per unit organic carbon, [7]SIR : Substrate induced respiration, [8]Qr: Microbial Respiration Quotient, [9]MAP : Microbial Activity Potential.

Note : Values in parenthesis depict the value before initiation of the project

3.7 Energy Use Efficiency under CF Model

Crop productivity and profitability are closely related with energy consumption. Hence, the energy requirements of different crops were evaluated under the different CF Models as well as under conventional farmers' practice.

Comparative study of net energy showed 29,000 to 40,000 MJ/ha Energy gain under different CF models (Fig. 9) which indicated higher sustainability under these models.

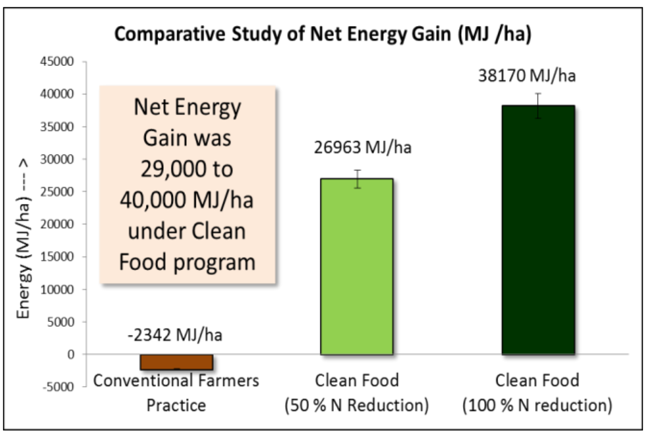


Figure 9: Comparative study of Net Energy gain (MJ/ha) under different CF Models

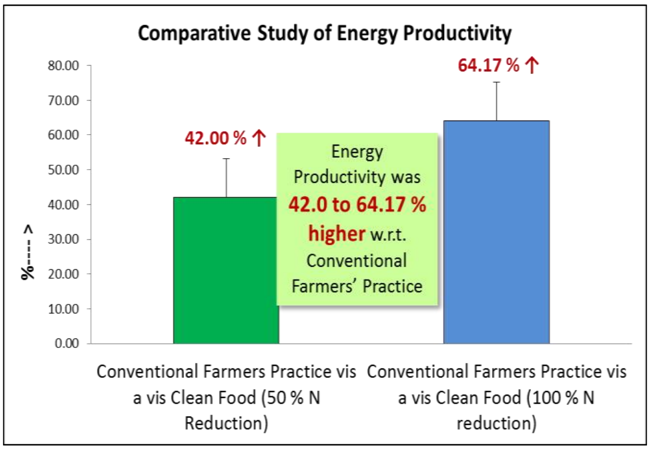


Figure 10: Comparative Study of percent increase in Energy productivity under the different CF Models

Decrease in the use of agro-chemicals (complete elimination of chemical pesticides as well as 50% and 100% elimination of N- fertilizers) under the different CF Models along with higher crop productivity led to higher gain in net energy as well as increase in energy productivity (Fig. 9).Comparative Study of nutrient energy ratio (Fig. 10) under conventional farmers' practice and the different CF Models indicated highest value (7.36) in the case of CF Model-3, which was 183.2 percent higher than that recorded under conventional farmers' practice. The result indicated that adoption of soil and plant health management under IRF Technology helped to minimize the requirement of unsustainable inputs (Fig. 11) on one side and increased the crop productivity on the other. The cumulative impact of these two factors jacked up nutrient energy ratio under the different CF Models.

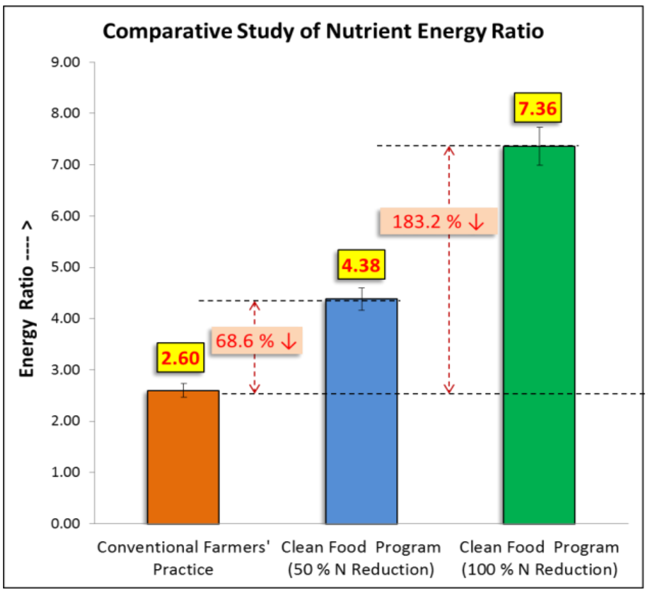


Figure 11: Comparative Study of Nutrient Energy ratio under Conventional Farmers' Practice and different CF Models

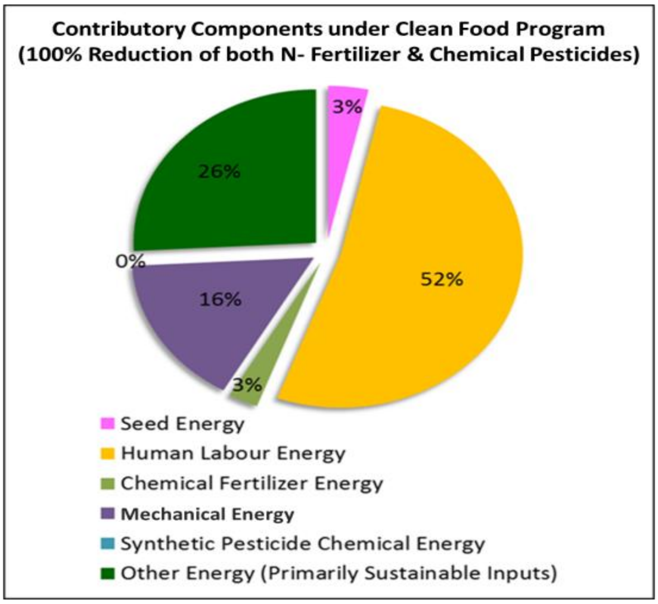


Figure 12: Percent Energy use for different Agro-inputs under CF Model with 100% Reduction of both N- fertilizer and Chemical Pesticides

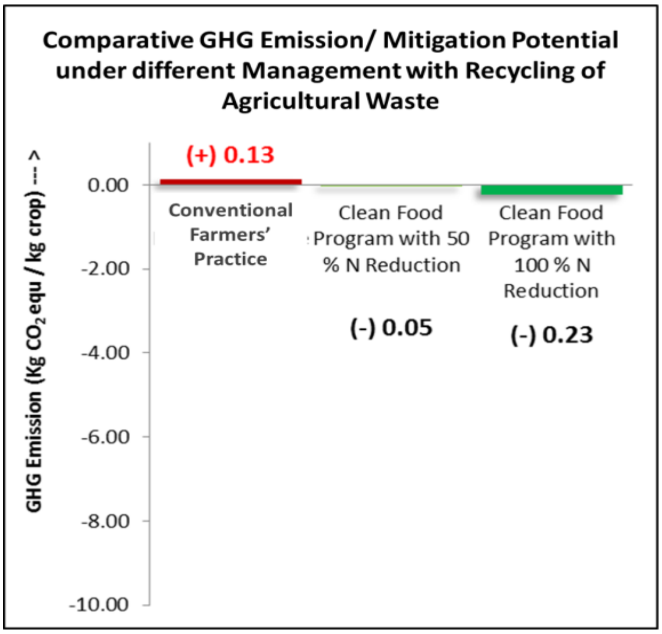
The higher nutrient energy ratio as well as higher energy productivity under CF Model indicated towards its high sustainability quotient.

3.8 GHG Mitigation Potential under CF Model.

Though, increased use of chemical inputs has made Indian agriculture greenhouse gas (GHG)-intensive, agriculture is also the only sector that can enable both GHG mitigation and adaptation.

Average GHG emission of **(+)**0.13 kg CO_2-eq/ kg produce was recorded under the conventionally managed crop sequence. The positive GHG value under conventional farmers' practice was primarily due to the use of N- fertilizers. In contrast, (-)0.05kg CO_2-eq/ kg produce and (-)0.23 CO_2-eq/ kg produce was documented under CF Model- 2 and CF Model-3 respectively, which was primarily influenced by the reduction of N- fertilizer by 50 % and 100 % respectively; utilizing Novcom compost that was obtained from recycling of agricultural waste. The study substantiated up to 276% higher GHG mitigation potential under CF Model, as opposed to the GHG emitting conventional farming; even when the credit for GHG mitigation during waste recycling is not considered (*as per IPCC guideline credit for GHG mitigation during waste recycling is only applicable to landfill waste*).

Moreover, the carbon saving/ GHG mitigation potential of CF Model soared phenomenally (upto 11.71 kg CO_2-eq/ kg crop produced), when Novcom compost obtained through recycling of MSW/ landfill waste was used for reducing/ eliminating N- fertilizer. Recycling of MSW / landfill waste under Novcom composting Technology helped to offset about 6000 kg Methane (in CO_2-eq) per ton waste (IPCC, 2021) from source point; which in turn enabled a GHG mitigation varying from approximately (-)3.19 to (-)5.85 and (-)6.37 to (-)11.71 kg CO_2-eq per kg of CF produced with 50 % and 100 % elimination of N- fertilizer respectively (Fig. 12 and 13).



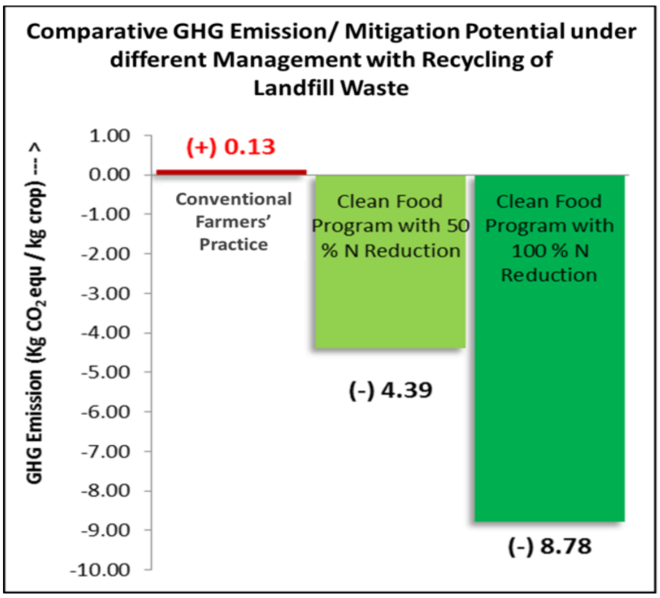
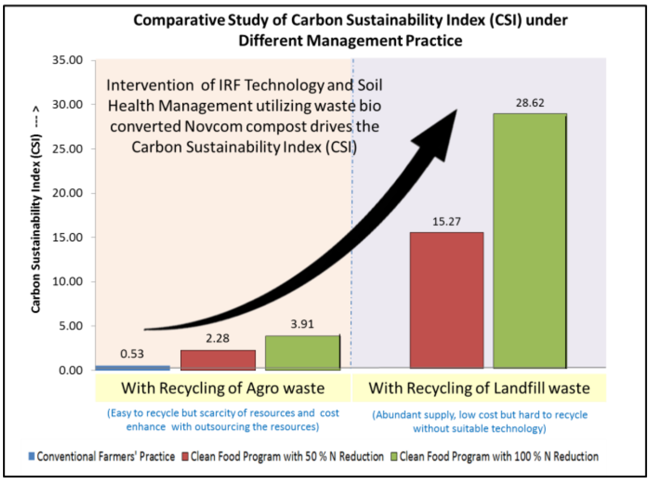


Figure 13 & 14: Comparative GHG emission / mitigation under CF Model utilizing agricultural waste *vis-à-vis* landfill waste

Sustainability of an agricultural system can be measured through carbon input and carbon output under the crop production system which can be measured through Carbon Sustainability Index (CSI) (Lal, 2004). The CSI increased significantly under CF Model. However, the CSI made a quantum jump with recycling of landfill waste under Novcom Composting Technology, indicating an intervention of critical relevance, considering that MSW/ landfill waste are abundant and economic source for compost production; that are mostly unutilized due to lack of suitable technology for effective and safe bioconversion of these toxic-complex-very hard to biodegrade material.

Carbon Efficiency Ratio (CER) indicates the efficiency in carbon usage in terms of carbon input and output in any agricultural system. CER value followed a trend similar to CSI, which indicates a paradigm shift of the CF Model into a more stable and sustainable system with inclusion of MSW/landfill waste (Fig. 14 and 15).



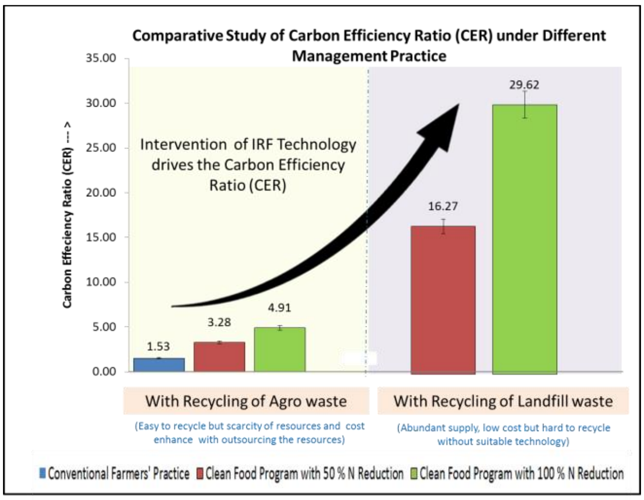
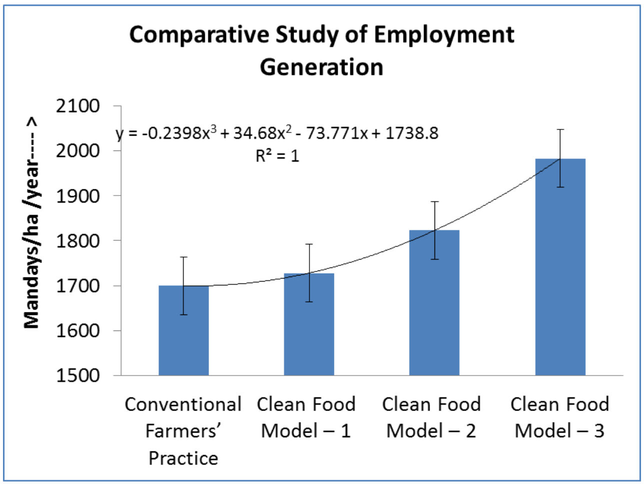


Figure 15 & 16: Comparative Study of Carbon Sustainability Index (SCI) and Carbon efficiency Ratio (CER) under CF Model utilizing agricultural waste *vis-a-vis* landfill waste

3.9 Impact of CF Model in respect of employment generation and livelihood support

Comparative study of employment generation potential (Fig. 16 & 17) showed that the scope can be enhanced up to 16.7 percent under CF Model. Assessment of gross income under the major cropping sequences (calculated using six months average i.e., Dec. 2022 to May, 2023; of farmers' procurement price, Source: Sufal Bangla) indicated that up to 19.7 percent increment can be achieved even in the conventional market; i.e., without undertaking any value added marketing. Hence, if a specific market chain is established for these value-added pesticide free end products, the income potential can be enhanced to a great extent.



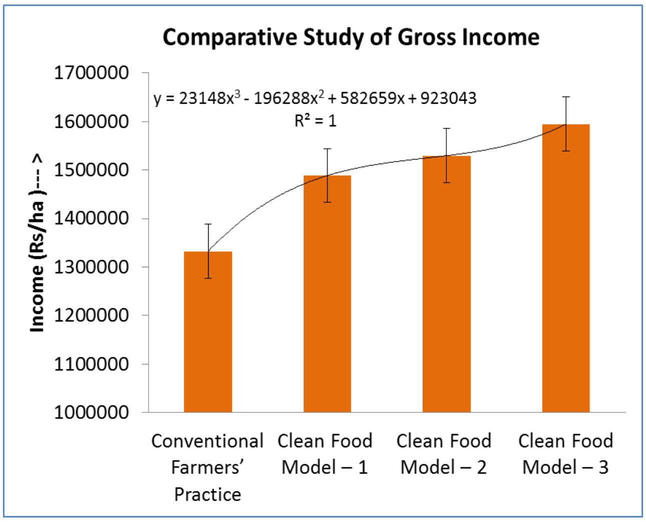


Figure 17 & 18: Comparative Study of Employment generation and gross income under Clean Food program

3.10 Attainment of circular economy with CF Model

In a circular economy, value chains are closed loops, whereby materials originally intended for disposal are reused, recycled, or reprocessed through the economy (EMF, 2017).

Under CF Model different types of waste was recycled utilizing Novcom Composting Technology to generate safe and quality compost in the most economic manner. Along with Novcom compost, adoption of IRF Plant Health Management attained the two major objectives of crop yield sustenance and providence of safe food for human health; and in doing so this approach attained the multiple aspects of circular economy in agriculture (Fig. 18). The CF Model helped in GHG abatement (especially methane mitigation) from source point through waste bio-conversion utilizing Novcom Composting Technology. The model initiated an approach towards development of the soil carbon sink, through the application of waste-bio converted Novcom compost and also enhanced the carbon utilization efficiency of plants through activation of plant physiology, which is reflected by the improvement in crop yield or higher biomass production.

Hence, the CF model helped to enhance resource usability, minimize unsustainable inputs, rejuvenate soil biological productivity and sustain crop yields that empowered the resource poor, economically vulnerable marginal and small farmers while improving the access of safe food for all.

Hence, the CF Model complies all the basic principles of circular agriculture like regeneration of natural system, combat climate change, improve access to safe and nutritious food, support local communities (farmers), render economic sustainability and enable resource generation.

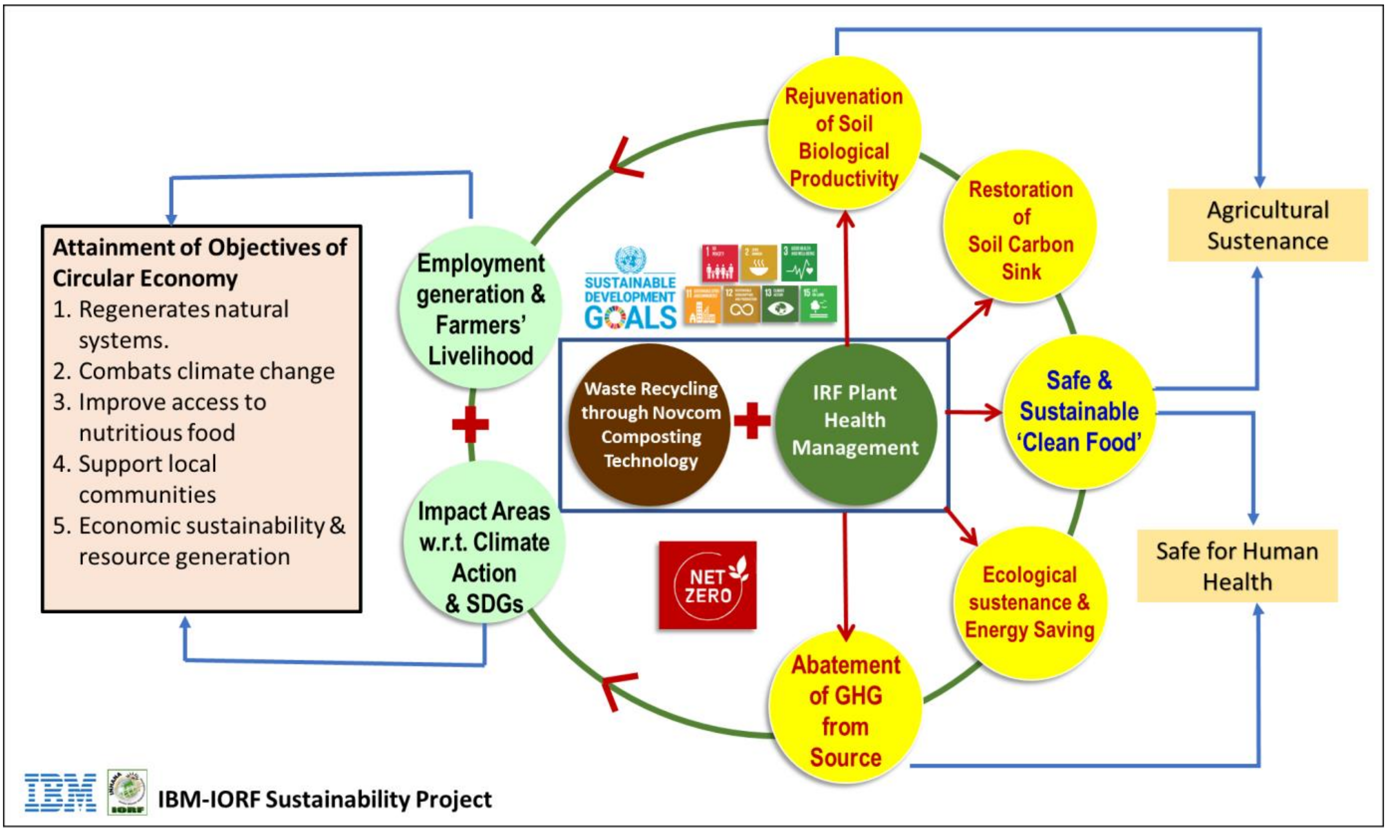


Figure 19: 'Clean Food' can serve as the best fit Agricultural Model for Circular Economy

4.0 Conclusion

'Clean Food' is perhaps the first comprehensive safe and sustainable agricultural model for circular economy that generates pesticide- free, safe 'Clean Food', at the conventional cost of crop production, ensuring affordable safe food for all.

Moreover, the option to recycle any form of waste into safe and quality compost that can be utilized for crop production serves the triad objectives of crop sustainability, soil rejuvenation and GHG abatement; especially methane mitigation from source point, which has presently acquired the center stage of discussion.
This model not only brings forth an adoptable pathway for sustainable agricultural progression aligning with the economically vulnerable marginal and small land holders, it also demonstrates a practical solution for the corporate and the Govt. bodies to meet the Net Zero goal, through adoption of CF Model that recycles landfill materials for 100 percent removal of N- fertilizers. This is because bioconversion and utilization of MSW- bio converted Novcom compost for elimination of N- fertilizers, jacks up the GHG mitigation potential of this Model from 230 kg CO_2-eq to 8780 kg CO_2-eq; per ton 'Clean Food' production.

Moreover, this farmers- participatory model is based on a scientific- nature friendly, safe and sustainable crop technology and a transparent/ analytically backed food safety evaluation system to facilitate the development of a self-sustainable consumer connect agriculture model; that can fuel livelihood upliftment of the farming community.

Thus, CF Model can serve as a practical model for circular agriculture central to the growth of circular economy through creation of new resources from the materials previously considered as waste, reduction/ elimination of the requirement of unsustainable inputs (*chemical fertilizers and pesticides*), reduction of environmental pollution and GHG emissions and facilitation of sustained livelihoods especially in respect of the economically vulnerable marginal and small land holders.

5.0 Acknowledgement

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Research Article

Impact of Clean Food Program on Reduction of Pesticide Residue in Vegetables grown under Irrigated Ecosystem

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Abstract

The use and abuse of pesticides in agriculture has been increasing the risk of food chain contamination. Sustainable agriculture that serves to reduce/ eliminate the use of pesticides and thereby the threat of pesticide residue in the end product; has become crucial to address the issue. In this background, 'Clean Food Program' was taken up under the IBM-IORF Sustainability Project in the Nadia District of West Bengal (India) in 2021, towards the objective of reducing/ eliminating pesticides from crop production without incurring crop loss and without increasing the cost of production. The objective was driven by Inhana Rational Farming (IRF) Technology, through its unique approach of plant health management. Analysis of more than 200 samples of conventionally grown vegetables using Colorimetric Assay Test revealed pesticide residues of >0.01ppm in 34.93% samples. Moreover, multiple pesticide groups were detected in 51% of the pesticides contaminated vegetables. 'Clean Food' Program was found to reduce the risk of pesticide contamination by more than 80%, even for high risk vegetables like pointed gourd, brinjal, chilli and okra; and residue, in terms of single pesticide group was detected in a mere 3.8% samples. The study exposed the hidden risk of food chain toxicity under conventional farmers' practice and highlighted the need of more safe and sustainable agricultural initiatives.

Keywords: Colorimetric assay test, Inhana Rational Farming (IRF) Technology, food safety, maximum residue limit

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Introduction

The growing demand for food commodities and the ensuing climate change impact has led to a significant increase in pesticide usage under the conventional crop production system [1]. Globally the pesticide usage has increased from 1.2 to 1.8 kg/ha when compared with usage in the 1990s [2]. Pesticide residue levels in food commodities are thus a major concern owing to their inherent toxicity and bioaccumulation potential striking a direct implication on human health [3], ecological imbalance and loss of biodiversity. A recent study done by the Ministry of Agriculture, Govt. of India showed that more than 18.7 % food items have pesticide residues [4]. West Bengal being an agricultural intensive state, pesticide usage in 2021-22 at 0.69 kg/ha was about 52.6% higher than the average use in India (0.45 kg/ha) [5,6]. Sustainable Pest Management has been indicated by the FAO as a solution to minimize the pesticide risks to human health and the environment. However, references are lacking regarding the impact of sustainable cultivation practice in respect of reducing the pesticide residues in crop.

In this background, the 'Clean Food' Program was initiated towards development of pesticide free food product, for preservation of soil and ecology and to empower the small and marginal farmers through better livelihood support [7]. The approach was driven by Inhana Rational Farming (IRF) Technology, which served to reduce/ eliminate pesticide use without incurring crop loss and without increasing the cost of production. In the present study, comparative pesticide residue analysis was done for the vegetables grown under 'Clean Food' Program vs. vegetables available in the conventional market; in order to evaluate the impact of safe and sustainable agriculture in respect of food safety and elimination of the risk of pesticide contamination in vegetables.

Materials and Methods

Development of 'Clean Food' (CF) was initiated under IBM Sustainability Project entitled 'Adoption of a Cluster of Villages for Agricultural Sustainability and Food Security through Clean Food Program'. It was conducted during the period 2021-23 by Inhana Organic Research Foundation (IORF); in scientific collaboration with Krishi Vigyan

Kendra (Nadia, BCKV, ICAR). The project comprised five villages namely Satyapole, Bhabanipur, Panchkahaniya, Dhopagachi and Bansbona in the Haringhata block of Nadia district of West Bengal, India. A model farm was also set up in the project area to serve as a Sustainable Agriculture training and demonstration center for the local farmers.

Clean Food Program

Clean Food is developed following a resource independent agricultural model under IRF Technology, executed through the adoption of Inhana Plant Health Management (IPHM).

The concept of 'Clean Food' is based on a scientific hypothesis that the relationship between a plant and pest is purely nutritional. The life time research of plant scientist F. Chaboussou showed that application of chemical fertilizers, specially N-fertilizers along with depressed plant metabolism enhance the free amino acids and free sugar pools in the plant cell sap which serve as the ready food for the pest (**Figure 1**) [8].

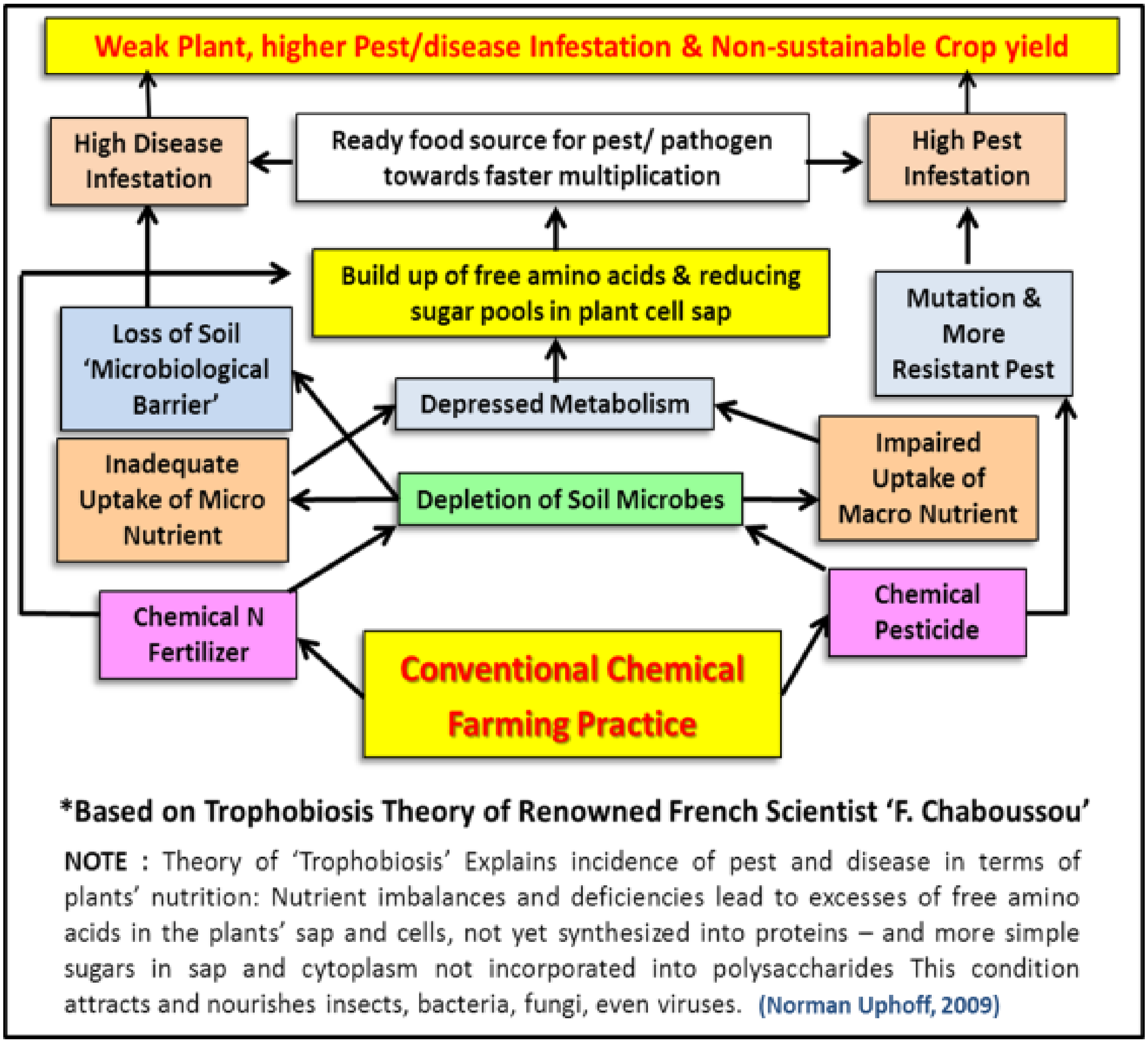

Figure 1 Weak plant system is the root cause for higher pest / disease infestation

Hence, if pesticide use is to be reduced/ eliminated from the crop production system, then first pest need to be reduced and for that the ready food source need to be cut off. This can be only ensured through development of 'Healthy Plants'. Driven by Inhana 'Energy Solutions' IPHM is a 1st ever approach in Indian Agriculture towards development of 'Healthy Plants' through activation of plant physiology for enhanced plant metabolism and biochemical secretions [9]. This approach on one hand enhances the agronomic efficiency of the plants and cuts down the formation and accumulation of free amino acids and free sugar pools in the plant cell sap on the other, thereby reducing the ready food source for the pest (**Figure 2**). Hence, activation of plant physiology ensures the dual premise of crop sustainability and higher plant immunity towards pest and disease leading to elimination of chemical pesticides.

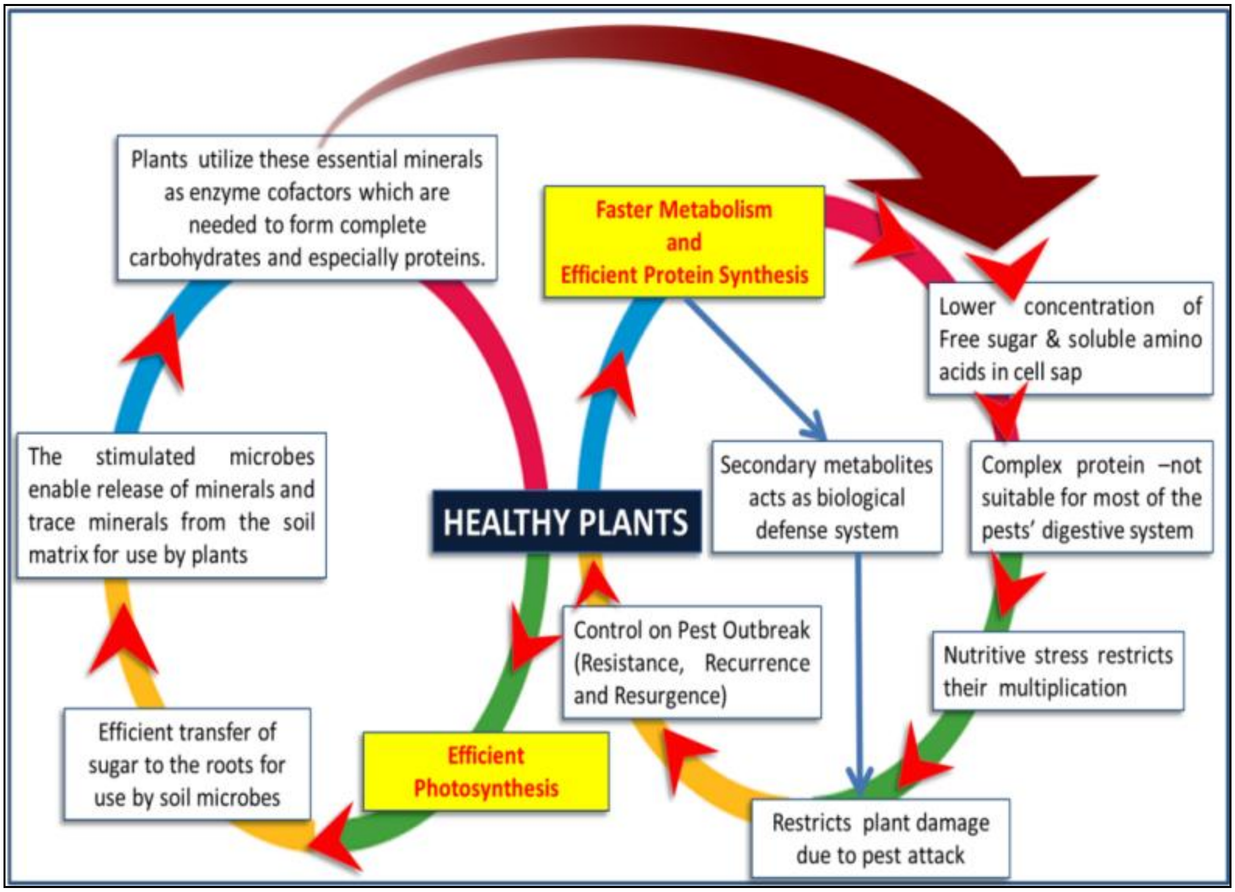

Figure 2 Pest Management through Plant Health Management: How the concept works under IRF Technology

Analysis of Pesticide Residue

Vegetable samples were collected from project villages and from different vegetable markets in Kolkata in 2023. Samples were tested for six major pesticide groups *viz*. Organochlorine, Organophosphate, Carbamate, Synthetic Pyrethroids and Nicotinoids which represent more than more than 650 pesticides formulations covering more than 90 % major insecticides, fungicides and herbicides use in India [8]. QuECHERs method was adopted for processing of the vegetable samples for pesticide residue analysis [10]. Pesticide residue was analyzed as per Colorimetric Assay Test which was jointly developed by IORF, Kolkata and KVK (Nadia, BCKV, ICAR) [11].

Result and Discussion

Pesticide residue analysis was taken up in respect of 18 major vegetables sourced from the project area and from the conventional vegetable markets in Kolkata. Total 584 vegetable samples were taken for Colorimetric Pesticide Assay Test, among which 218 sample were sourced from vegetable markets, 204 samples were collected from 'Clean Food' Project area, 108 samples from Clean Food Model Farm within 'Clean Food' Project area and another 54 samples were sourced from certified organic selling points.

Safety aspect of 'Clean Food' was evaluated following the regulation of Codex Alimentarius Commission (CAC) [12] and the Food Safety and Standards (Contaminants, Toxins And Residues) Regulations (2011)[13]; developed by Food Safety and Standards Authority of India (FSSAI); according to which the maximum residue limit (MRL) for vegetables is 0.1 ppm (for individual pesticides). However, for 'Clean Food' 0.1 ppm was considered as the MRL for the total pesticide residues in a particular pesticide group (irrespective of the number of pesticides in that group), to enable more stringent evaluation of its safety aspect.

Out of the total 584 vegetable samples analyzed for pesticide residues (**Table 1**), 83 samples (14.21 %) showed the presence of at least one group of pesticides with an MRL >0.1 ppm. In respect of the vegetable samples collected from the conventional markets, pesticide residue was detected in 34.93 % samples. Based on the risk of pesticide contamination these vegetables could be categorized under three groups (i) Low to no risk zone (presence of at least one group of pesticides with MRL >0.1 ppm in <20 % samples) : peas, cabbage, cauliflower, potato, onion, yam, spinach and coriander; (ii) Moderate risk zone (presence of at least one group of pesticides with MRL >0.1 ppm in 20

- 50 % samples) : French bean, cucumber, carrot, tomato, potato, pumpkin and ridge gourd and (iii) High risk zone (presence of at least one group of pesticides with MRL >0.1 ppm in >50 % samples) : pointed gourd, brinjal, chilli and okra.

Table 1 Segment wise vegetable samples taken for pesticide residue analysis and samples having the presence of atleast one group of pesticides with an MRL > 0.1 ppm

Type of Vegetables	Source of Vegetables				
	Market Source	Clean Food Project	Model Farm	Certified Organic	Total Samples
Brinjal (*Solanum melongena L.*)	17 (11)	17 (2)	6 (0)	3(0)	43 (13)
Tomato (*Solanum lycopersicum*)	11 (3)	11 (1)	6 (0)	3(0)	31 (4)
Potato (*Solanum tuberosum*)	15 (2)	15 (1)	6 (0)	3(0)	39 (4)
Green Chilli (*Capsicum annuum*)	14 (9)	9 (1)	6 (0)	3(0)	32 (10)
Cucumber (*Cucumis sativus*)	12 (5)	7 (1)	6 (0)	3(0)	28 (6)
Pumpkin (*Cucurbita pepo L.*)	9 (3)	9 (0)	6 (0)	3(0)	27 (3)
Pointed gourd (*Trichosanthes dioica Roxb.*)	15 (10)	15 (2)	6 (0)	3(0)	39 (12)
Ridge Gourd *(Luffa acutangula (L.) Roxb.*)	9 (3)	9 (0)	6 (0)	3(0)	27 (3)
Peas (*Pisum sativum*)	9 (1)	9 (0)	6 (0)	3(0)	27 (1)
French beans (*Phaseolus vulgaris*)	9 (4)	9 (1)	6 (0)	3(0)	27 (5)
Cabbage (Brassica oleracea var. capitata)	17 (2)	16 (0)	6 (0)	3(0)	42 (2)
Cauliflower (*Brassica oleracea var. botrytis*)	17 (2)	16 (0)	6 (0)	3(0)	42 (2)
Okra (*Abelmoschus esculentus*)	14 (8)	14 (2)	6 (0)	3(0)	37 (10)
Onion (*Allium cepa*)	12 (2)	12 (0)	6 (0)	3(0)	33 (2)
Carrot (*Daucus carota subsp. Sativus*)	13 (4)	13 (1)	6 (0)	3(0)	35 (5)
Spinach (*Spinacia oleracea*)	9 (0)	9 (0)	6 (0)	3(0)	27 (0)
Yam (*Dioscorea*)	7 (0)	7 (0)	6 (0)	3(0)	23 (0)
Coriander (*Coriandrum sativum*)	9 (1)	7 (0)	6 (0)	3(0)	25 (1)
Total	218 (71)	204 (12)	108 (0)	54(0)	584 (83)

Note : Figures in parenthesis represents the no. of samples that have atleast one group of pesticides with MRL > 0.1 ppm

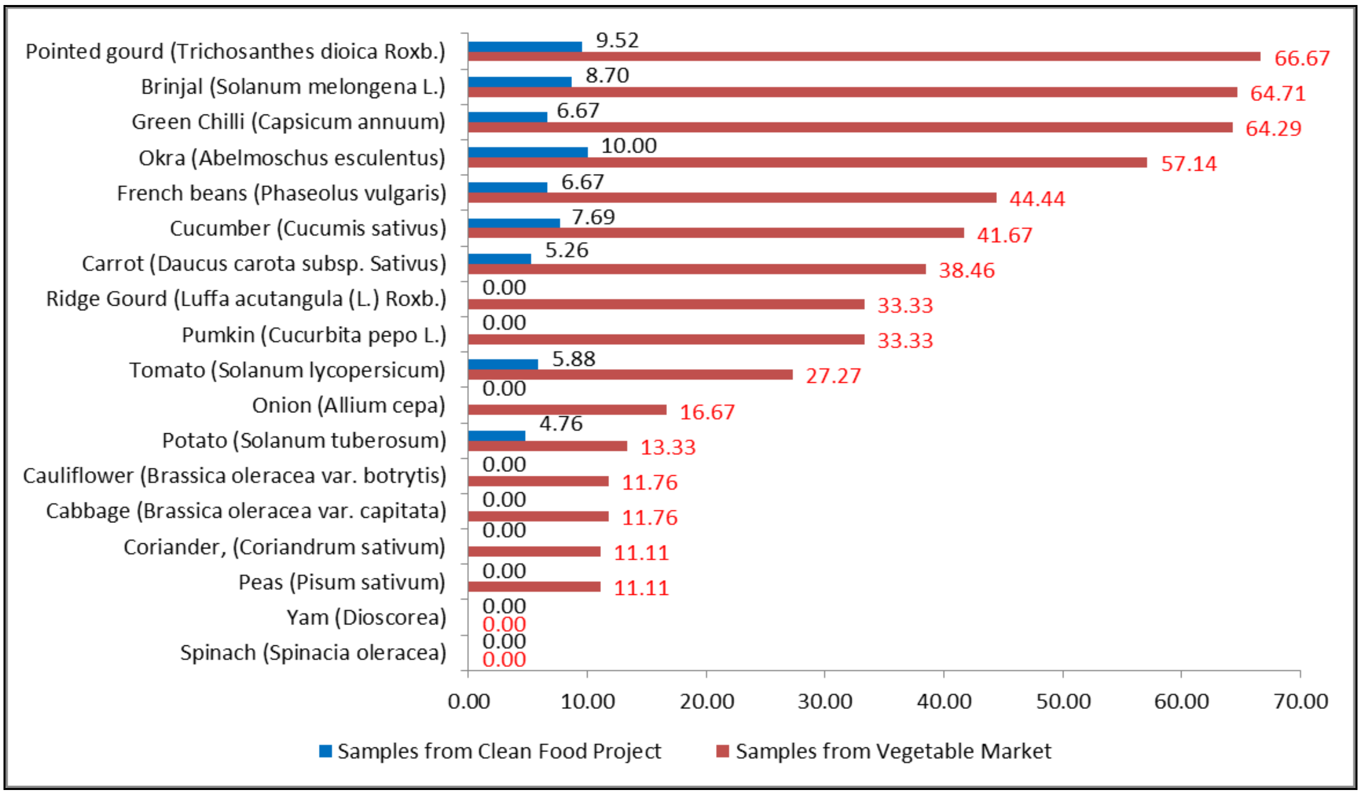

Figure 3 Categorization of the different vegetables in respect of the presence of pesticide residue, as per Standards of Codex Alimentarius FAO-WHO & FSSAI (> 0.10 ppm)

Evaluation detected the presence of pesticide residue (one pesticide group with MRL >0.1 ppm) in only 3.85% samples; out of the total 312 vegetable samples collected from the 'Clean Food' project area (including the model farm). Most significantly, out of the 18 different types of vegetables, 9 types of vegetables (i.e., about 50%) were found to be completely clean (No pesticide residue) (**Figure 3**).

Also, for the categories of vegetable that came under the high risk zone, those collected from the conventional markets showed risk of contamination in 63.3% samples while the same was observed for only about 12.7% samples collected from the 'Clean Food' Project Area. The finding indicated that adoption of this safe and sustainable initiative led to a significant (80 %) reduction in the risk for pesticide contamination even for vegetables under high risk category.

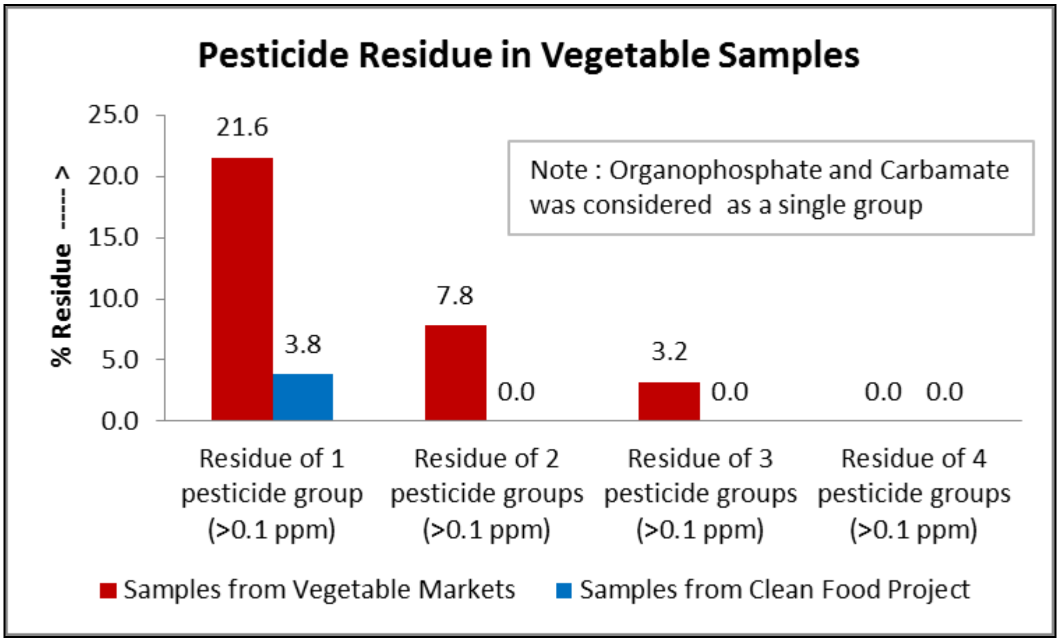

Figure 4 Comparative study of presence of pesticide residue in conventional vegetables *vis-a-vis* those grown in the project area.

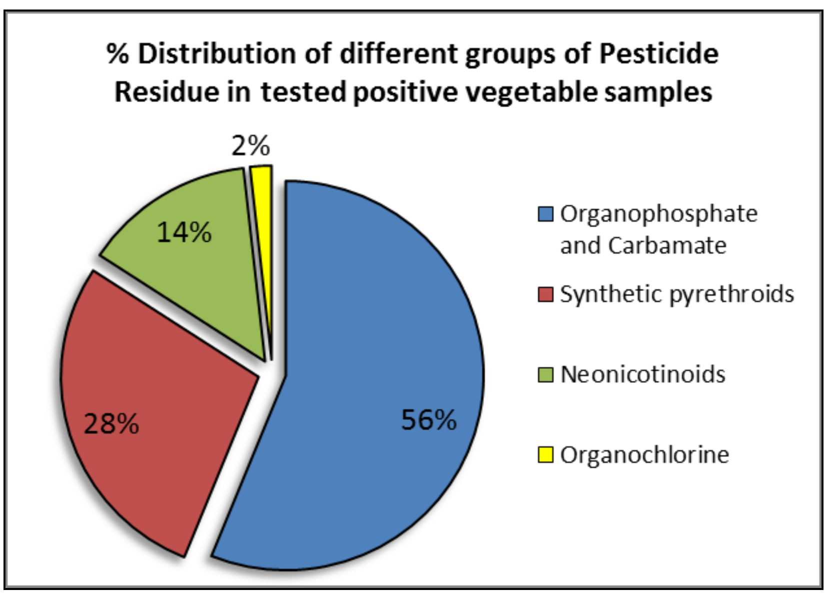

Figure 5 Comparative presence of different pesticides groups in the vegetables tested positive for pesticide residues.

Comparative study w.r.t. the number of pesticide groups present, interestingly revealed single pesticide group in about 21.6 % samples and two to three groups (**Figure 4**) in 7.8 and 3.2% samples (respectively); collected from the conventional vegetable markets. In contrast, presence of pesticide residue, that too single pesticide group was detected in only about 3.8% vegetable samples; collected from the 'Clean Food' project area

Percent distribution of different groups of pesticides in positive tested vegetable samples indicated residues of Organophosphate and Carbamate groups in 56%, Synthetic pyrethroids in 28%, Neonicotinoids in 14% and Organochlorine in 2% cases (**Figure 5**).

Conclusion

The study is perhaps a pioneering initiative which indicated that adoption of Sustainable Agriculture in terms of 'Clean Food' program had a significant impact on the overall pesticide usage in the project area, leading to development of Safe Food. This could be primarily due to focus on Plant Health Management under IRF Technology, that led to an improvement in plant immunity leading to a considerable reduction in pest pressure during crop production, which naturally lowered the requirement for pesticide application; even in the case of high pest prone crops like brinjal, okra, chilli, etc. Thus the study on one hand could serve as an eye opener in respect of the underlying threat to human health due to the increasing risk of pesticide contamination in food chain, while also demonstrating the relevance of undertaking more and more safe and sustainable initiatives in agriculture for food safety, ecological sustenance and to sustain farmers' livelihood.

At the same time the above can serve as a benchmark study to attend the objectives of Sustainable Developmental Goals 2 (SDG2) where safe and sustainable food production is the prime focus. Moreover, the highest investment gap in respect of SDG 2 itself indicates the lack of technical intervention and the need for more scientific efforts towards fighting hunger, food and nutritional in-security. The present study can guide sustainable agriculture programs in respect of reducing the dependency on chemical pesticides while also ensuring crop sustainability. Moreover the technique adopted for pesticide residue analysis in this study can revolutionize the Food Safety Authentication aspect in the entire Indian Agricultural scenario in respect of practical feasibility and economic viability and thereby empower the future sustainable agriculture initiatives.

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