PROJECT REPORT

(Phase II : 2022-23)

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

Phase – II

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

Project Period : 2022 – 2023

Submitted By
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IBM - IORF SUSTAINABILITY PROJECT

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

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

Project Duration : 2022 – 2023

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Foreword

It gives me immense pleasure to note that in Phase –II of the IBM-IORF Sustainability Project, IORF has opened up a new vista in the Climate Action Arena through the demonstration of **Clan Food 'Net Zero' Model- with the Clear Impact Area with respect to SDG-13, that simultaneously attends the most critical Area of Sustainability i.e. SDG – 2.**

I would like to thank IBM Sustainability Platform for providing the sustainability impetus that provided the opportunity towards stepping up the momentum of the initiative.

Climate change is real and has already increased the food security challenges. Most importantly **Methane has acquired the Centre Stage of Discussion**, and Scientists have recognized that acting now to reduce methane emissions will have immediate benefits to the climate. The Phase –II Project at Mandya gains special significance considering that it has demonstrated the First of a **Kind Model for Source Point Methane Mitigation through bio-conversion of waste (Coirpith) especially landfill materials under Novcom Composting Technology.** Moreover, a Model for **Degraded Soil Reclamation has been delivered through the application of this bio-converted waste which has demonstrated successful vegetable cultivation in soils, which were practically unfit for agricultural production.**

Phase –II project has some very significant and relevant areas which need specific intervention like **Reclamation of Agricultural Degraded Land, Biodegradation of Coconut Waste (coirpith), Integrated Model for Coconut Plantation** ect. have been attained in the 25 Hec. Area. **More than 6000 MT CO_2e has come out as the Negative GHG Emission in just 25 hec. Area.**

Foreword

This project has successfully shown that the Clean Food 'Net Zero' Model can successfully attend Seven Critical SDGs i.e. SDG – 1, 2, 3, 11, 12, 13 & 15 and also developed first Agricultural Net Zero Model. Last but not the least I am extremely glad to share that the **Project exhibited an Energy Transition of more than fifty percent in the Clean Food 'Net-Zero' Model,** when Agriculture has not been included in the Energy Transition Commission (ETC) for extreme difficulties for Energy Transition.

All these findings have a huge scope for further exploration in the large area in the next year Project.

This project has also highlighted the need for quality- climate resilient seeds towards Sustainable Agriculture. Seed Development Program even under conventional crop management is a complicated exercise especially due to the challenges posed by any sudden climatic disruptions and chances of higher pest and disease, both of which can cause extensive crop loss. Hence, development of Climate Resilient 'Net Zero' Seeds under Complete Organic Management, that too without any crop loss, has delivered a benchmark initiative in this Project.

I am sure the Phase-II Project Report will serve as a ready reckoner in respect of Climate Action through Safe and Sustainable Agriculture. And I wish to place on record my sincere appreciations to IORF for bringing out this Report.

Dr. P. Das Biswas
Founder Director

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

Phase - II

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

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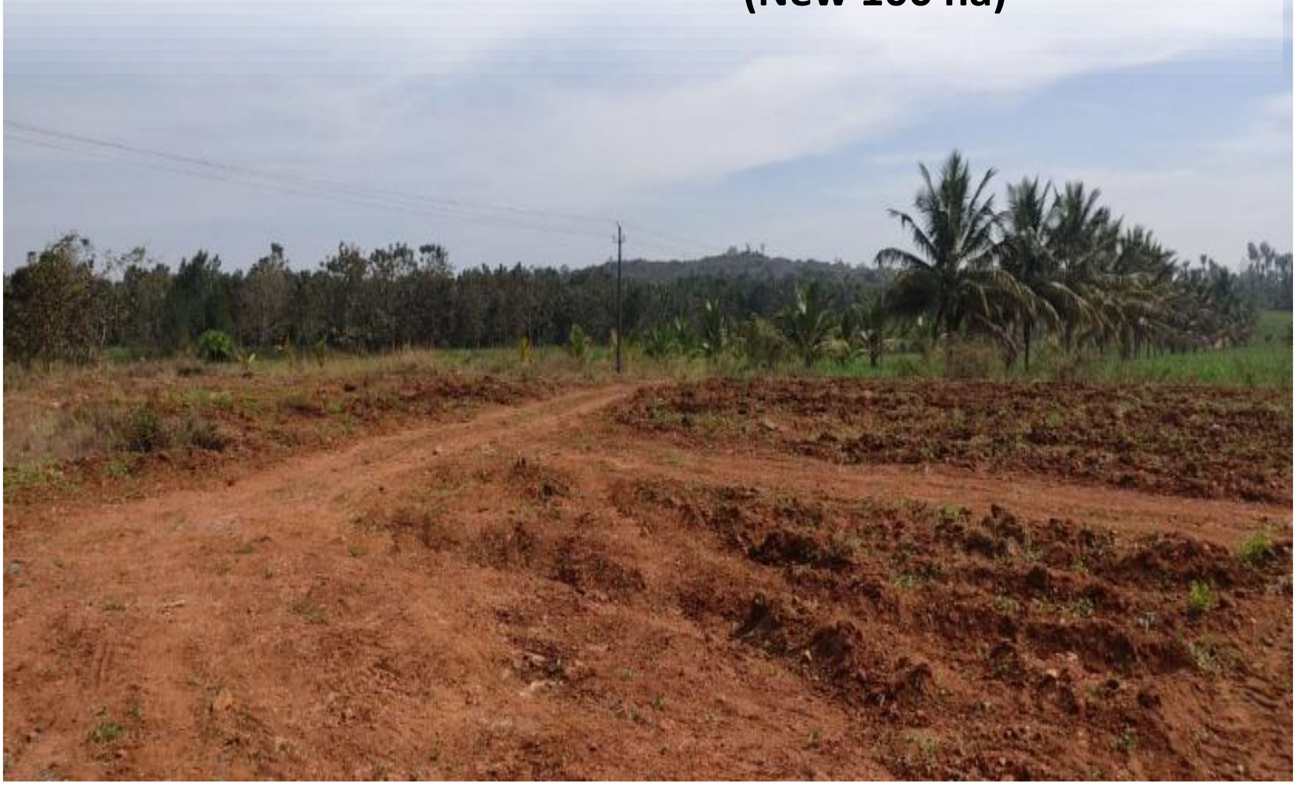
SUMMARY

Clean Food 'Net Zero' Program
Mandya, Karnataka

(New 100 ha)



Clean Food 'Net Zero' Program : Mandya, Karnataka

Summary

Climate change affects the social and environmental determinants of health – clean air, safe drinking water, sufficient food and secure shelter. The average temperature over land for the period 2006–2015 was 1.53°C higher than for the period 1850–1900, and 0.66°C more than the equivalent global mean temperature change. These warmer temperatures with changing precipitation patterns have altered the start and end of growing seasons, contributed to regional crop yield reductions, reduced freshwater availability, and put biodiversity under further stress. As a result the climate crisis threatens to undo the last fifty years of progress in development, global health, and poverty reduction, and further widen the existing health inequalities between and within populations.

The challenge is intensified by agriculture's extreme vulnerability to climate change. The effects of climate change on agriculture can result in lower crop yields and nutritional quality due to drought, heat waves and flooding as well as increases in pests and plant diseases. This entails higher use of synthetic fertilizers and pesticides to sustain crop. This puts food safety in question, while also increasing economic vulnerability of the marginal and small farmers who comprise more than 90 % of the Indian farming community

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.

Agriculture in India faces the major challenge of climate change. Higher temperatures tend to reduce crop yields and favour weed and pest proliferation. Climate change has negative effects on irrigated crop yields across agro-ecological regions both due to temperature rise and changes in water availability. Rainfed agriculture is being impacted due to rainfall variability and reduction in number of rainy days. At the same time land degradation due to climate change impact is a major issue. With close to 30 per cent of its geographical area already affected, land degradation is definitely among India's most pressing environmental problems.

Some 97.85 million hectares (29.7%) of India's total geographical area (TGA) of 328.72 mha underwent land degradation till 2018-19.

To make matters worse, almost **all Indian states have recorded an increase in degraded land in the past 15 years**, with the most rapid increase being noted in the biodiversity-rich northeastern states. Land degradation threatens agricultural productivity by reducing soil health, thus in turn impacting the livelihood of rural people.

With close to 6.96 million hectares of land undergoing degradation and desertification, Karnataka is the fifth biggest contributor to the total geographical area under degradation in India. Land degradation though is not limited to any one part of the state. From Bellari to outskirts of Bengaluru, degradation has been reported everywhere, as data from the Indian Remote Sensing Satellites (IRS) have revealed over the years. Water Erosion, i.e., loss of soil cover mainly due to rainfall and surface runoff water is observed in both hot and cold desert areas, across various land covers and with varying severity levels.

Out of the 1,91,79,100 hectares of total geographic area (TGA), 69,51,000 hectares or **36.24% of land in Karnataka is under Degradation**

Mandya was considered one of the most agriculturally prosperous districts in Karnataka but with climate change impact, lowering of crop productivity, top soil erosion and lower economic return has led to unsustainable agriculture

The total geographical area of the Mandya district of Karnataka is 4,98,244 Hectares. The soils are inherently thin gravelly and underlain with a murrum zone containing weathered rock. They are highly leached and poor in bases and the water holding capacity is low. The high gravel content of the soil (sometimes upto 50%) coupled with Very Low Soil Organic Carbon means the soil are HIGHLY PRONE TO EROSION. The fact is vividly demonstrated by MODERATELY ERODED SOILS that measure 249,166 ha and account for about 50.28% of the district's TGA.

More than half of the total land area in the district is put to agricultural use, where about **67,000 ha is under Coconut Plantation. However, coconut productivity in Mandya is about 30% lower than the national average.**

Along with extensive coconut plantations, Mandya is also one of the biggest sugarcane producing regions (30,630 ha.), in Karnataka,. However, these profitable crops are facing **yield decline and lower sugar content since the past few years majorly due to the Climate Change Impact, majorly temperature rise and drought like conditions**.

The other crops of the district are ragi (85,467 ha.), rice (79,892 ha.), pulses (*predominantly horse gram and to some extent tur, cowpea, green gram, black gram, avare*) and oilseeds (mainly groundnut and sesame). But increasing soil erosion (annual soil loss is 27 tons/ha/year) due to lack of sustainable practice, is a widespread threat towards crop sustainability.

This is due to **continuous application of synthetic inputs** like chemical fertilizers and pesticide **in these limiting soils** (having <0.5 % organic carbon and mere 5 – 10 % clay content), which is speeding up the cycle of degradation **and is continuously reducing soils' carrying capacity.**

Restoration of Soil Biological Productivity, forms the only Solution to mitigate the Rising Challenges towards Crop sustenance and Farmers' Livelihood security. And application of Safe and Quality Compost in Soil forms the Only Solution towards the Objective.

Raw Material Source for Compost production is pre- requisite, but for program at SCALE, the raw material SOURCE has to be ABUNDANT and ECONOMIC.

WASTE of any type especially landfill/ legacy waste/ MSW or waste from Agro-industry perfectly fit the bill. But apparently there is **dearth of Environmentally Safe and Economically Viable Composting Technology/ ies that can transform these Toxic, especially METHANE EMIITING pollutants** into a Safe, Stable and Mature Compost, suitable for agricultural use.

The Mandya District of Karnataka has an abundant source of Coir pith – a toxic, hard to biodegrade, and a very high Methane emitting waste from coir industry. But, considering that so far there is no effective and economically viable composting technology which can effectively biodegrade coir pith, hence; it continues to be dumped in open lands and during the rainy season, the tannins and phenols of the coir pith leach out into the soil and the irrigation canals, thereby making agricultural lands unproductive.

In Karnataka alone about 5.0-6.0 lakh MT coir pith is generated every year, and forms a major source of environmental pollution due to lack of effective, economically viable and socially acceptable technology/ies for its bioconversion

Moreover, Coir pith forms a VERY HIGH GHG EMITTER (6.0 mt CO_2-eq per ton of coir pith approx.) – primarily METHANE, which has 75 times Higher Global Warming Potential ($GWP_{24\ years}$) as compared to CO_2, and is also the Precursor to O_3, which itself is a GHG.

These WASTE material however, can serve as excellent Soil Rejuvenators when recycled following a Technology Driven Process.

The insight gave the Impetus to IORF to initiate the Clean Food 'NET ZERO' Program at Mandya, in order to demonstrate a **CLIMATE ACTION MODEL** that will actually deliver **SAFEST FOOD –** Safe for Human Health, Soil & Environment.

Hence, the 'Clean Food' 'NET ZERO' program was initiated in Mandya with an aim to demonstrate :

1. **SAFEST FOOD – SAFE for Human health, Soil & Environment**
2. **Coir pith Waste based GHG (METHANE) Mitigation MODEL**
3. **Utilization of Coconut Waste (coir pith) to improve Coconut Productivity**
4. **Coconut Plantation based 'Net Zero' Intercropping MODEL in Marginal Soils, to improve Farm Productivity and Farm Economics**
5. **MODEL for Reclamation of Agriculturally Degraded Lands**

Inhana Rational Farming (IRF) Technology –A comprehensive Organic Package of Practice for Ecologically & Economically Sustainable agriculture was the Prime Technological intervention behind successful Clean Food 'Net Zero' Program

Agriculture in Mandya - The Challenges

Among the challenges faced by the District Farmers Four, are Critical and Need Immediate Attention to Ensure both Present and the Future Crop Sustainability :

- Soil Degradation
- Increasing Pest & Disease
- Rising Cost of Cultivation

While some efforts are being made through programs such as the Integrated Watershed Management, **Effective Models are Still lacking that can Singlehandedly Mitigate all the three Constraints.**

Clean Food 'Net Zero' is 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**

Development of Clean Food 'NET ZERO' (CFNZ) can deliver SAFEST FOOD – SAFE for Human health, Soil and Environment. Clean Food 'NET ZERO' Model is the only Model that delivers CLIMATE NEUTRAL 'Clean Food' i.e., LOWEST GHG FOOTPRINT WHICH INDICATES HIGHEST LEVEL OF SUSTAINABILITY. A switch over from Conventional Farmers' Practice to Clean Food 'NET ZERO' Model, can totally transform the present GHG Emitting agriculture to a GHG Sink Agriculture;

This approach was driven by INHANA RATIONAL FARMING (IRF) TECHNOLOGY – a comprehensive organic crop technology developed by Dr. P. Das Biswas; the pioneer of Sustainable Organic Tea Cultivation in India. **IRF Technology** is so far the only available Crop Technology that undertakes the approach of 'PLANT HEALTH MANAGEMENT**'** **towards CROP SUSTENANCE and development of PLANT IMMUNITY against all biotic and abiotic stress factors, which enables natural elimination in the requirement for chemical pesticides** (*a major unsustainable component of conventional food production*), **leading to 'Clean Food' production.**

Clean Food 'Net Zero' Model attends the Most Critical Area of Sustainability- **SDG 2**, but is also the **Numero Uno Model in Agriculture for Climate Action SDG-13** (*Both Climate Change Mitigation & Adaptation*) where the Total Investment GAP is 460-780 Billion USD. **The CFNZ Model is also a model for Degraded Soil Reclamation** with clear impact area w.r.t. **SDG-15** - End desertification & restore degraded land.

And finally this Model impacts **four other Crucial SDGs** i.e., **SDG-1** (Inclusive Agriculture & Food Production can Create Jobs and Eliminate Hunger in Rural Areas, giving people a chance to feed their families and live a decent life). **SDG-3** (Ensure Healthy Lives through Nutritional Security), **SDG-11** (Ensure Sustainable Farming Communities) and **SDG-12** (Achieve the Sustainable Management and Efficient use of Natural Resources and Achieve the Environmentally Sound Management of chemical and all wastes).

Clean Food 'Net Zero' Program can successfully attend Seven Crucial Sustainable Developmental Goals (SDG)

Novcom composting Technology developed by IORF, has enabled bioconversion of **1000 ton of Coir pith to Safe–Stable-Mature Compost rich in self generated microflora** (one trillion billion Microflora per ton compost) **within 30 days -** Bioconversion of Toxic Methane Emitter to an Excellent Resource for Soil- C Sequestration .

Periodical study of Novcom coir pith compost samples on 0, 10, 20 and 30 days of composting demonstrated a rapid degradation of organic matter as indicated by the rapid decline of C:N ratio from 1:100 to < 1:25, appreciation of total nitrogen by 98 percent and 60% degradation of lignin within a 30 days time period. And the values are corroborated by the respective very high population of bacteria, fungi and actinomycetes (*in the order of 10^{16} c.f.u. per gm or One Trillion Billion per ton compost)*. Phytotoxicity Bioassay test values confirmed not only absence of phytotoxic elements in compost, but also indicated that it can actually accelerates seed germination and root growth.

About 1000 ton of coir pith was bio converted to produce Novcom coir pith compost and utilized for Elimination of Chemical Fertilizer especially N- Fertilizer through sustainable soil health management towards development of SAFEST - Clean Food 'Net Zero'.

The initiative is note worthy because it was driven successfully in soils that are practically unfit for agricultural crop production due to the very high gravel content sometimes upto 50%.

In this project on one hand coir pith, i.e., the waste from coir industry was recycled into the coconut plantation for improvement of productivity, at the same was also utilized for safe and sustainable cultivation of ginger, maize and different vegetables, which were grown as intercrop in the planation in the project area.

Most importantly this Project has demonstrated **an adoptable pathway for IMPROVING COCONUT PRODUCTIVITY**, which is about 30% lower than the national average; **as well as improving COCONUT FARM PRODUCTIVITY**, through adoption of Coconut based 'Net Zero' Intercropping Model.

How Clean Food 'NET ZERO' was developed ?

This Program focused on demonstrating the Pathway for Net Zero GHG Emission in Agriculture through GHG Omission from Source, GHG Abatement and GHG Adaptation through High Atmospheric-C capture. The Dual approach of Soil Health Management & Plant Health Management was aimed at attaining these very objectives.

Bioconversion of raw coir pith – a landfill waste, especially a High METHANE Emitter under Novcom Composting Technology demonstrated GHG OMISSION FROM SOURCE while converting this Waste into a Stable, Mature and Non-phytotoxic compost within a shortest period of 30 days.

On- farm produced **Novcom Coir pith Compost** at 40-50 ton/ ha as well as various organic concoctions were used for **SOIL HEALTH MANAGEMENT** towards **ELIMINATION OF N- FERTILIZERS**.

Elimination of N- fertilizers means **stoppage of N_2O Emission- another critical GHG**, while Restoration of Soil Biological productivity, through Novcom Compost application can initiate the regeneration process of **Soil-C Sequestration Potential**.

Adaptation to Climate Change was exhibited through the adoption of **INHANA PLANT HEALTH MANAGEMENT (IPHM),** driven by **Inhana** '**ENERGY SOLUTIONS**'. **IPHM was adopted towards reactivation of Plant Physiology.**

Moreover, IPHM works towards **Curtailing the Accumulation of Ready Food Source** for Pests, in Plants' Cell Sap & **Enhancement of Host- Defense** of Plants **to Discourage Disease and Pest Incidence leading to the ELIMINATION OF PESTICIDES**

The approach ensures **higher agronomic efficiency towards SUSTAINED/ HIGHER Crop Yields**, meaning **Higher atmospheric-C capture- a critical measure for Adaptation to Climate Change**

Production of SAFEST Vegetable Crops in soils that are practically unfit for agricultural crop production, that too in the very 1st year, and with comparable yield (if not more); is a major highlight of Clean Food 'NET ZERO' program' because it also demonstrates an adoptable Model for Degraded Soil Reclamation

Evaluation of GHG Emission under Novcom Composting Technology was undertaken to assess its potential w.r.t. Source Point GHG Mitigation.

Agriculture Carbon Footprint Assessment Tool (ACFA – Version 1.0) developed by IORF, is probably the 1st Carbon Assessment Tool for Agricultural GHG Estimation in India

The assessment was done using the Carbon Assessment Tool -ACFA- Version 1.0. The basis for estimation of GHG emission from waste was taken from the Report on *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,* which was accepted by the IPCC Plenary at its 16th session held in Montreal, 1-8 May, 2000. We followed the default IPCC methodology that is based on the theoretical gas yield (a mass balance equation) to calculate total methane emission (at a time), assuming that all potential methane is released in the same year when the solid waste is disposed.

The evaluation indicated that coir pith when dumped untreated (as often witnessed around the vicinity of coir factories) can potentially emit methane in the range of 5897 – 6025 kg CO_2 equivalent (taking $GWP_{24\ years}$ of methane: 75).

Moreover, GHG emission during coir pith biodegradation under Novcom Composting Technology, was found to be about 31 times lower (6.47 kg CO_2 equivalent/ ton treated waste) than the reference values recorded in respect of any other standard biodegradation process (200 kg CO_2 equivalent/ ton treated waste).

Especially in terms of methane the negligible emission under this composting technology is the highlight, as corroborated by the documented value of 0.61 kg CO_2 equivalent/ ton treated waste. The primary reason behind negligible methane emission is the aerobic process of composting that minimize the anaerobic pockets, controls the O_2 solubility and balances the redox potential.

Moreover the enhanced microbiological activity in the composting also means higher storage of the carbon from the decomposed organic matter into the microbial biomass, which lowers the escape potential of C as a potent GHG from the composting heap. Low GHG emission in terms of N_2O under Novcom Composting Technology might be due to speedy biodegradation process driven by very high microbial population that leaves little scope for generation and escape of this gas from the composting heap, due to effective nitrification of the NH_4 ions formed during organic matter breakdown.

The study indicated that bioconversion of coir pith utilizing Novcom Composting Technology can enable Methane mitigation of about 6000 ton CO_2 equivalent per 1000 ton waste, directly from the source point. This finding not only has critical relevance in respect of climate action considering that methane mitigation has been indicated by scientists worldwide as the fastest and the cheapest way to cool planet earth; but also forms an effective pathway towards the Net Zero Goal.

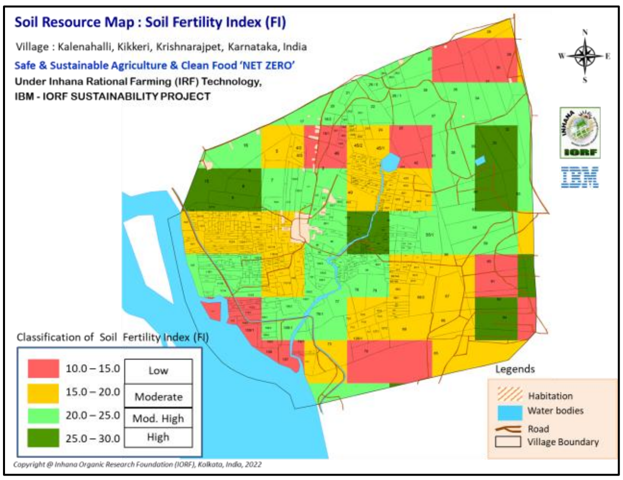
The Study indicated that bioconversion of coir pith under Novcom Composting Technology, can enable a **Methane mitigation of about 6000 ton CO_2 eq.** per 1000 ton waste

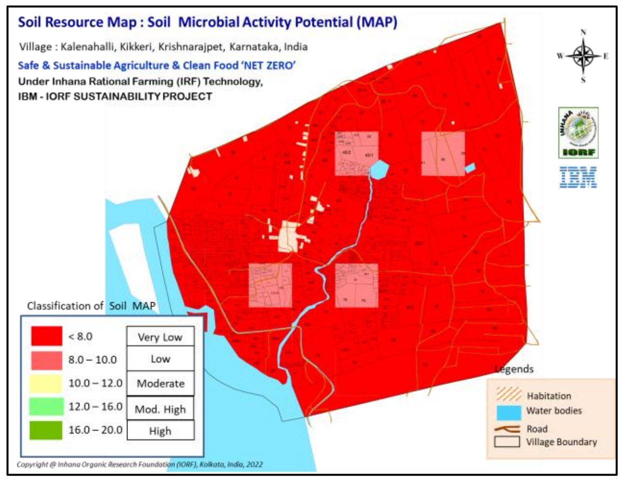
SOIL RESOURCE maps are the most useful tool for identification of potential and problematic areas of any area in order to enable the formulation of an effective and customized soil management program. It is one of the most important step with respect to Sustainable Soil Management, where judicious application of organic soil inputs has a direct bearing on the practical feasibility and the related economics; especially considering the existential scarcity of resources for on-farm compost production of quality compost in the required quantity. This is specially relevant for the Mandya district where the soils are inherently thin gravelly, underlain with a murrum zone containing weathered rock, highly leached, poor in bases with low water holding capacity. The high gravel content of the soil (sometimes upto 50%) coupled with Very Low Soil Organic Carbon means the soil are HIGHLY PRONE TO EROSION.

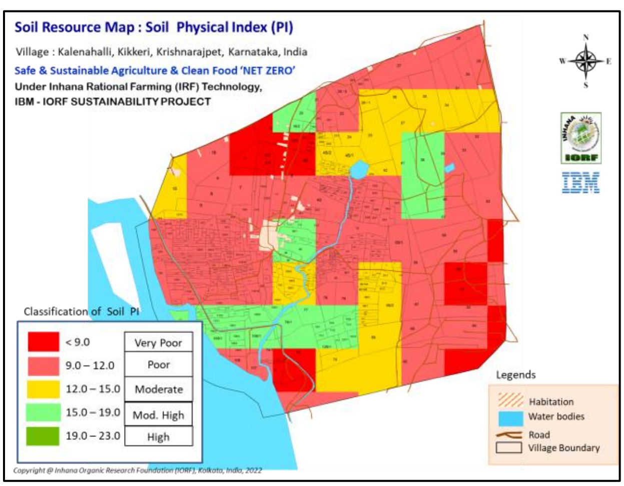
Hence, an initiative was taken up to analyze the soil health and develop Soil Resource Maps for the project area

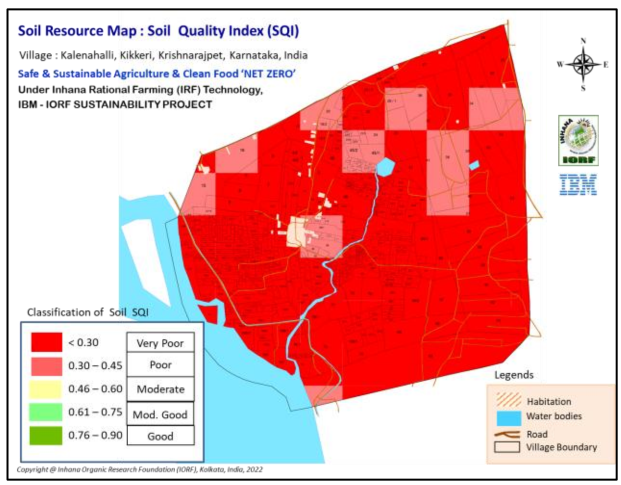
Due to higher sand percent, gravel content and lack of organic matter in soil, soil aggregates in majority area is very low to low and prone to soil erosion specially in the undulating plains.

Soils were analyzed for physical, physicochemical, fertility and microbial properties as per standard guidelines. The area is a combination of plain and undulating plains with mostly reddish colour soil with 40 to 60 % gravel content. As per textural class , the soils varied from sandy loam to sandy clay loam, sand percentage varying from 59 to 86 percent. Though the soils are light texture but due to presence of small to medium gravels proper root penetration was hindered. Soil organic carbon is one of the most limiting factor in the project area as soils were poor to very poor and mean value under different land use varied from 0.42 to 0.57 %.









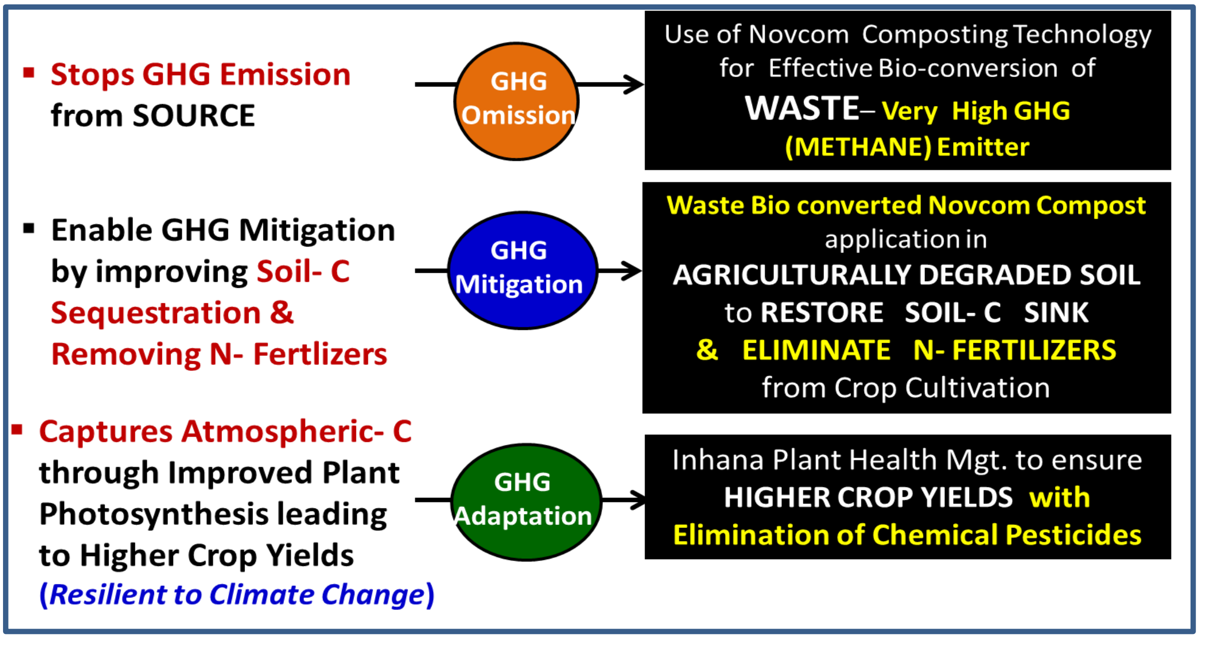
Soil Quality Index (SQI) value in the project area was found to be very low in most of the soil, primarily due to poor to very poor microbial activity and limitation w.r.t. soil physical characteristics.

The world is committed to achieve **carbon neutrality by 2050**. And **ENERGY TRANSITION** (*i.e., the shift to renewable energy sources that produces very limited, if not zero, carbon emissions*) **forms the TOOL for this Target Achievement**.

Evaluation of ENERGY FOOTRPINT under Clean Food 'Net Zero' program revealed **432% Higher Energy Efficiency** i.e. Crop productivity per Unit Energy Investment (*for Nutritional Management*) w.r.t. the major crops grown in the Mandya District of Karnataka.

The Carbon Footprint of Vegetable production under Clean Food 'Net Zero' program was evaluated through **ACFA (Version 1.0).** It was found that the Clean Food 'NET ZERO' Program can POTENTIALLY MITIGATE about 13.78 kg CO_2 equivalent per kg vegetable produced.

High GHG Mitigation Potential is contributed by THREE WAY APPROACH under this Model.



Production of Vegetables under Clean Food 'NET ZERO' program at Mandya, potentially OFFSETS 13.78 kg CO_2 equivalent/kg production. Hence, a **100 ha Clean Food 'NET ZERO' Program can OFFSET about 24,833 MT CO_2 eq. per year. Moreover, if Coconut based 'NET ZERO' Intercropping Model is adopted the same 100 ha can OFFSET more than 50,000 MT CO_2 eq. per year.**

Development of India's 1st Agriculture Carbon Foot Print Assessor (ACFA Version 1.0)

SUMMARY

Clean Food Program
Nadia, West Bengal

(2nd Year Continuation)

Clean Food Program : Nadia, West Bengal

Summary

The Continuation Project in the Nadia district of West Bengal, is a practical demonstration of Safe and Sustainable Agriculture that delivers Safe and Sustainable 'Clean Food' through elimination of chemical pesticides – SAFE for Human health. Moreover as this Safe Food is produced with No Crop Loss and No hike in the Cost of Production, hence it is SUSTAINABLE FOR ALL.

The relevance of this Project is clearly indicated in the Statement of the UN, "It is currently not clear or well defined what constitutes productive and sustainable agricultural practice".

'Clean Food' provides much needed Safety To Human Health as these are devoid of synthetic crop protectants, hormones and heavy metals.

The relevance of Sustainable Agriculture increases multifold in the Indian context where **more than 90% farmers are marginal and small land holders**

Now looking at the small and marginal farmers of India with average land holding less than 0.38 hec and high dependence on land, are therefore highly vulnerable to climate change, compelled to use a large quantity of synthetic agrochemicals but often receive inconsistent revenue. **The situation is more challenging in case of West Bengal which shares 2.4% of the country's geographical area but provide food for 8% of the country's population;**

96% of the state's food producers are small and marginal farmers belonging to the backward and minority class with a land holding even less than 0.26 hec. (almost 1/10th area as per the land classification range). Due to economic insecurity, minimum livestock support, highest exploitation from middleman and input dealers and least access to newer agro-technology and knowhow, these farmers are most vulnerable in respect of the increasing climatic adversities.

Hence, any further disruption in their livelihood can destabilize the very fundamental base of our food production system, considering that small and marginal farmers make up the bulk of the Indian agricultural economy by contributing 51 per cent of total agricultural output and 70 per cent of high value crops (TOI, 2nd Sept. 2022).

The situation demands a format for Sustainable Agriculture, which can sustain/ improve crop yields through efficient use of on- farm resources, while reducing the dependency on off-farm unsustainable inputs, maintaining ecological integrity and enable sustainable production of Safe Food that can secure farmers' livelihood while opening the access of Pure Food for All.

'Clean Food' not only provides Safety to Human Health as these are grown without synthetic crop protectants, hormones and heavy metals through induction of nature friendly IRF Technology, but also because of their enhanced (*as indicated in primary investigation*) qualitative components like antioxidants, vitamin C, etc. contribute towards health nourishment.

Apart from Chemical Pesticides, CHEMICAL FERTILIZERS especially **N- Fertilizers** form the **other major UNSUSTAINABLE Component** of Conventional Food Production

Reduction/ elimination of N- Fertilizer Without Crop Loss is practically possible only through application of Quality Compost in soil. Reduction of the Nitrate Fertilizers was also done in this program through utilization of the locally available organic bio-resources using Novcom Composting Technology of IORF. But Soil Health Management, that is crucial towards reduction/ elimination of N- Fertilizer, was a formidable task to carry out in the entire 100 ha, considering the **acute resource scarcity for compost production.**

Hence, IORF selected **MODEL FARM for demonstration of Inhana Soil Health Management (ISHM) towards Reduction/ Elimination of N- fertilizer** under five major cropping sequences followed in the area, with an objective to **estimate the GHG Mitigation Potential under Two different 'Clean Food' Models i.e., i) Clean Food with 50% Reduction of N- Fertilizer and ii) Clean Food with 100% Reduction of N- Fertilizer.**

The 'Model Farm' initiative was primarily taken up to exhibit that Sustainable Crop Production is possible even under Reduction/ Elimination of Chemical Fertilizers.

The Phase- I Project has delivered the following Outcomes :

- Development of **'Clean Food' Model** – perhaps the First Model for Safe and Sustainable Agriculture – No Crop Loss and No Hike in Cost of Production.
- **Clean Food means SAFETY @ SAME COST- hence, it is SUSTAINABLE for All**
- **About 400 Marginal and Small Farmers now have the Access to Crop Technology** (*IRF Technology- Perhaps the Only Negative GHG Emission Technology*) **for Safe & Sustainable Crop Production**, through elimination of synthetic pesticides.
- **The Farmers now have the Access to an Adoptable and Sustainable Pathway for Elimination of Chemical fertilizers,** utilizing WASTE bio-converted, on- farm produced Safe, Non- phytotoxic, Microbial Rich (**One Trillion Billion self- generated Microflora per ton**) Novcom Compost.

. . . OUTCOMES

- **COMPREHENSIVE** (25 Quality Parameters especially Microbiological, five Soil Quality Indices, and Colour Coding for easy understanding of the farmers) **'SOIL HEALTH CARD' for each and every farm land – FIRST OF A KIND INITIATIVE**
- **Development of 96 SOIL RESOURCE MAPS & 10 SWOT MAPS to benefit more than 1000 farmers.**
- **Development of SOIL HEALTH PROXIMITY MODEL- to provide Soil Health Card for 'Every land' at 1/10th of Conventional Cost - FIRST OF A KIND INITIATIVE.**
- **Standardization of Pesticide Footprint Assessment Tool – A FIRST OF A KIND TOOL** (*so far unavailable in Indian Agriculture*) **to assess potential risk associated with pesticide use**
- **Development of 'COLORIMETRIC PESTICIDE ASSAY TEST' – A Speedy Technique for Residue Analysis @ 1/10th of Conventional Cost,** especially relevant for safety authentication of multiple harvest crops that forms an adoptable solution especially for the marginal and small farmers.
- **Development of Clean Food 'NET ZERO' (CFNZ) Model – SAFEST FOOD, Safe for Human health, Soil & Environment - SINGLE MODEL MULTIPLE IMPACTS**
  - **A First Ever Model with Impact Areas w.r.t Multiple SDGs :**
  - **A First Ever Model for Climate Resilient Agriculture**
  - **A First Ever Model for Energy Transition in Agriculture :**

In the second year, the Project was continued with the crucial objective of Climate Smart- 'NET ZERO' Clean Seed Development under Complete Organic Management to showcase an adoptable Pathway especially for the marginal and small farmers towards achieving self-sustenance for sustainable agriculture progression.

Out of the total seeds used by the Indian farmers only 30% are certified/quality seeds. And the present production meets only 20% of the total demand. **Apart from climatic adversity, poor quality seed is a prominent cause of crop failure and low productivity in India**. At the same time our own seed bank and seed diversity has been greatly affected under chemical agriculture. Climate smart agriculture as a part of climate change mitigation strategy starts with quality- resilient seeds.

The seeds developed under conventional farming are generally high fertilizer responsive hence; they lack the quality traits *viz*. higher nutrient use efficiency, disease resistance and resilience against biotic and abiotic stress, **that are required for sustaining crop yields irrespective of the changing climatic patterns**.

In this context seed produced under organic environment could help out in infusing such quality traits that can enable Better Adaptability against Climate Change and Support Sustainable Agriculture.

It is estimated that the direct contribution of quality seed alone to the total production is about 15–20% depending upon the crop, and it can be further raised up to 45% with efficient management of other inputs. Hence, quality organic seeds can yield plants that are more adaptive of the changing climate and thrive well under organic conditions or in other words ensure sustained crop production irrespective.

A range of breeding goal desired for the climate resilient agriculture such as reduce reliance on inorganic N-inputs, higher nutrient use efficiency, greater resistance against diseases as well as other biotic and abiotic stress; are severely compromised under the conventional high input dependent seed development program (Lueck, 2006).

But the availability of Organic Seed is practically NIL, considering the fact that the farmers usually incur from 30 to 70% Crop Loss during Organic Seed Production.

Especially the vegetable crops are highly sensitive to climatic vagaries, where sudden rise in temperature or irregular precipitation at any phase of crop cycle can affect growth, flowering, pollination and fruit development, which may subsequently lower the crop yield (Afroza *et al*., 2010). To mitigate the adverse impact of climate change on the productivity and quality of vegetable crops there is need to develop sound adaptation strategies (Spaldon, 2015).

Although vegetable production in India has increased (187.47 mt) with time but shrinking land resources (10.43 mha) and increasing environmental challenges have made the development and use of quality seeds more important to meet the increasing demand of vegetables by Indian populace (NHB 2018-19, 1st advance estimate).

RICE production system is one of the most climate change sensitive agro-ecosystems, which faces huge threat of crop loss under any drastic fluctuation in the weather pattern. In West Bengal almost half of the arable land is under rice cultivation. Moreover, the major rice is grown during the Kharif (rainy) season and is majorly affected by weather fluctuations.

The most important reason why this crop was selected for 'NET ZERO' Clean Seed production is because it is also **one of the most CHALLENGING crops w.r.t. climate change mitigation considering the HIGH WATER and NITROGEN USAGE and HIGH GHG EMISSION POTENTIAL.**

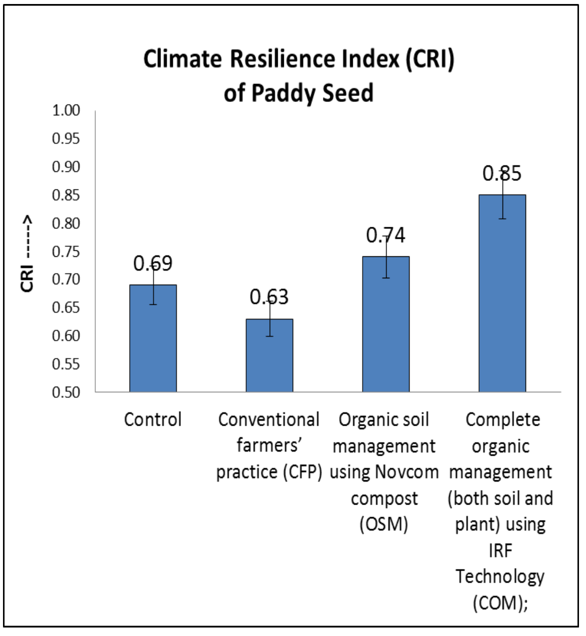
'NET ZERO' CLEAN PADDY SEED grown under **COMPLETE ORGANIC MANAGEMENT** utilizing Inhana Rational Farming (IRF) Technology

The average yield of 4021 kg/ ha obtained under **'NZ' Clean Paddy Seed program** exclusively demonstrated the relevance of **Inhana Plant Health Management** towards not only yield sustenance, rather yield improvement, especially significant, because this was obtained overcoming the extreme climatic events that occurred during the tillering and seed setting phase.

Evaluation of seed quality as per the Indian Seed Certification Standards indicated a Germination Rate of 92% on an average, indicating a high seed viability. Study related to Germination under water stress and salt stress also pointed out the higher resilience of NZ Clean Paddy Seeds towards abiotic stress factor; in comparison to conventional seeds.

QUALITY (RESILIENT) SEEDS are the primary requirement for **SAFE & SUSTAINABLE AGRICULTURE**. In this respect the Seed Vigour Test that defines seed ability to germinate and establish seedlings rapidly, uniformly, and robustly across diverse environmental conditions; forms a crucial indicator. The test results conclusively indicate **'NZ' Clean Paddy Seeds** (*developed under IRF technology*), **as 'High Vigour' seeds, which indicates their potential to enhance the critical and yield-defining stage of crop establishment** - the primary objective of Safe & Sustainable Agriculture.

"CLIMATE RESILIENCE INDEX (CRI)"



"Climate Resilience Index (CRI)" which was developed majorly as a function of seed germination under abiotic stress, showed 35.5 % and 14.6 % higher value in case of the 'Net Zero' Clean Paddy seeds (COM) as compared to CFP and OSM respectively. The overall better performance of 'Net Zero' Clean Paddy seeds critically indicates that **the concept of "feed the soil" for sustainable organic farming does not hold true till focus is generated towards "PLANT HEALTH MANAGEMENT".**

ATTRIBUTES OF 'NET ZERO' CLEAN PADDY SEEDS

- ✓ **Climate Resilient Seed**
- ✓ **ZERO CO_2 Footprint Seed**
- ✓ **Zero Pesticide Foot print Seed**
- ✓ **Seed with Zero Seed borne Diseases**
- ✓ **Seed with Higher Germination Potential**
- ✓ **Biotic & Abiotic Stress Resistant Seed**
- ✓ **Seed with Higher Nutrient Utilization Potential**
- ✓ **Seed with 25% Lower Requirement than conventional seeds**

The **'NET ZERO' Clean Paddy Seeds developed under West Bengal Project** was provided to the **Project Farmers of Phase-II, IBM-IORF Sustainability Project at Mandya (Karnataka)** and it is for the **First Time in the Indian Agricultural Scenario that Safe & Sustainable 'Climate Resilient' Seeds has been used for Safe and Sustainable 'NET ZERO' Clean Paddy production through the utilization of Novcom Coir-pith Compost.**

The initiative is also significant considering that a **MAJOR OBJECTIVE** is to test the **CLIMATE RESILIENCE OF THESE SEEDS** in a completely different agro-ecological setting; and to **TRANSFORM** the production scenario from **COARSE GRAIN TO FINE GRAIN VARIETY**.

Seed production initiative in respect of VEGETABLES, indicated higher productivity of almost all the vegetables under Clean Food 'Net Zero' program as compared to the average productivity of the same under conventional farmers' practice. **The yield increase under Clean Food 'Net Zero' varied from 10 - 15% on an average. But the result is stupendous considering the fact these crops were grown under COMPLETE ORGANIC MANAGEMENT** utilizing **IRF TECHNOLOGY**. **The results are also exemplary considering that these were short duration vegetable crops, where balanced nutrition is a primary requirement under specific growth phases; and any mismatch at any stage can lead to severe yield reduction.**

The findings completely nullifies the general myth of crop loss under sustainable/ organic crop production systems especially in the initial years and critically **indicates the relevance of an effective and sustainable crop technology in this respect.**

This initiative could be a benchmark for sustainable/ organic management of the vegetables and the technological advancement under this project gains special relevance especially for the vegetable growing zones of our country, which are usually one of the high agrochemical using zones, that face enhanced risk of soil deterioration and ecological disruptions.

But Seed Development Program is a complicated exercise considering the longer residence time of the crop in the field, which increases the challenges in respect of any sudden climatic disruptions as well as chances of pest and disease infestation, **both of which can cause extensive crop loss**. **This is primarily the reason why only a small percentage of the vegetable growers actually undertake seed production.**

The fact that the 'Net Zero' Clean Seeds were developed under Complete Organic Management i.e., without using any Chemical Fertilizer and Chemical Pesticides; and in the farmers' field, without any specific seclusion from the surrounding fields, with sustained yield; clearly points out the relevance of '**PLANT HEALTH MANAGEMENT**'.

The program conclusively highlights the relevance of a Science based, Effective and Sustainable Crop Technology, and Effective Organic Soil Management towards mitigation of all the challenges and etches out a Pathway for production of Climate Resilient, Safe and Quality VEGETABLE Seeds that are prerequisite for scaling up Safe and Sustainable/ Organic Vegetable Crop Production.

Potato is one of the most important food crop in West Bengal, ranked 2nd position after U.P. The state contributes About 28 % of the national production. **But there has been an increasing susceptibility of this crop towards climate change even leading to crop failure.**

Potato suffers from many fungal diseases, among them early blight, is a major problem in India especially in West Bengal. As a result, the full potential of this crop is far from being exploited due to several biotic and abiotic stresses. **Hence, there is a huge scope of improving the productivity and utilization of non – productive area. Moreover qualitative enhancement can significantly increase the cost benefit ratio.**

But to ensure the desired objectives a Safe and Sustainable pathway for potato production will be crucial and in this respect quality- climate resilient and disease free **POTATO SEEDS** are the prime requirement.

Highlights of Potato Seed Production from the Project Area

- Under Conventional Farmers' Practice, potato yield was about 24.38 ton/ ha, which includes potatoes that were rejected during selection for seeds.
- Under Conventional Farmers' Practice, during selection for seeds, about 14% potato got rejected.
- The farmers were expecting a higher potato seed production this year considering that there was insignificant incidence of pest and disease.
- But in actuals, the farmers experienced a higher percent of wastage as compared to last year.
- **About 46% Higher Yield was obtained under 'Net Zero' Clean Potato Seed Program, as compared to Conventional Farmers' Practice.**
- In case of the Net Zero Clean Potato Seeds grown under Complete Organic Management following IRF Technology; a very high standard was maintained for seed selection, so much so that the potatoes rejected during the process still complied the general set seed standards and could be sold as seed, with a 50% return value.

Soil- Site Suitability evaluation of Major Crops was undertaken in the IBM-IORF Sustainability Project (Phase– II), to assess whether the presently grown crops are appropriate for the area, and to ensure that the land use plan adopted by the farmers provides better economic returns and livelihood sustenance, under the existential climate change impact.

Evaluation revealed that Soil Fertility formed the major bottleneck towards crop cultivation especially due to the poor microbial dynamics in soil, leading to improper nutrient mineralization and availability in the soil solution. Hence, improvement of this aspect can actually promote the suitability aspect of these soils with respect to the presently cultivated crops.

Evaluation of Energy Investment was also carried out w.r.t. ELEVEN different cropping sequences in the Model Farm under different 'Clean Food' Models which are as given below :

i) 'Clean Food' Program with 100% Reduction of Chemical Pesticides (CF).

ii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **50% Reduction of N- fertilizer** (CF_{50}).

iii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **100% Reduction of N- fertilizer** (CF_{100}).

The data obtained was compared with energy use under Conventional Farming Practice (CFP).

27 to 57% higher Energy Output was recorded under the different levels of 'Clean Food' Program, which **indicates higher resilience of this Crop Production Model in terms of ensuring Crop and Economic Security** both in the present and future. Especially the **highest Energy Output (57%)** under 'Clean Food' program with 100% Reduction of both Chemical Pesticides and N- fertilizers, indicates that these are the primary hands of unsustainability, and when eliminated can reduce not only agriculture's vulnerability towards climate change, but also the economic vulnerability of resource poor marginal and small farmers. Also, a **137 percent increase in Nutrient Energy Ratio recorded under the different cropping sequences under 'Clean Food' Model with 100% N- fertilizer Reduction + 100 % Reduction of Chemical Pesticides, highlighted better nutrient utilization efficiency and higher crop response per unit nutrient application, under IRF technology.**

The **ENERGY INVESTMENT lowered by a remarkable 94%** when both chemical pesticides and N- fertilizers were completely eliminated. These 'Clean food' Models demonstrated significant ENERGY TRANSTITION, most importantly WHILE SUSTAINING CROP YIELDS; enabled by the interventional IRF Technology as well as IMPROVEMENT OF ENERGY PRODUCTIVITY, a benchmark criteria for SUSTAINABLE AGRICULTURE.

GHG EVALUATION under the different Clean Food Models w.r.t. Eleven different Cropping Sequences was also done in comparison to the Conventional Farmers' Practice.

The Average GHG emission was (+) 0.12 kg CO_2-eq/kg produce under conventionally managed crop sequence, where as (-)0.05 kg CO_2-eq/kg produce and (-)0.19 CO_2-eq/kg produce or a **NET MITIGATION of (-)0.17 to (-)0.31 kg CO_2-eq/kg produce**, under Clean Food Models with 50 % Chemical N Reduction+ 100 % reduction of chemical pesticides; and 100 % Reduction of both N-fertilizer and Chemical Pesticide; respectively**.**

Comparative study of GHG Emission under Conventional Farmers' Practice *vs*. the GHG mitigation potential under the different 'Clean Food' Models under the Phase-II Project once again substantiated that, **a progression towards Safe and Sustainable Agriculture especially complete elimination of both the hands of unsustainability i.e. the N-fertilizers and Chemical Pesticides** can totally transform agriculture from a GHG Emitting Source to a CARBON Guzzling Sink.

Development of India's 1st Agriculture Carbon Foot Print Assessor (ACFA Version 1.0)

BACKGROUND

Establishment of 'Clean Food' Model and the Transformational Journey towards Clean Food 'NET ZERO' Model Development

PROJECT BACKGROUND

Establishment of 'Clean Food' Model and the Transformational Journey towards Clean Food 'NET ZERO' Model Development

The FAO estimates that by 2050 we will **need to produce 60% More Food** to feed a world population of 9.3 billion (*UN Chronicle, 2012*). But up to **25% REDUCED CROP YIELDS** is predicted due to climate change impact (*www.agrivi.com/blog/sustainable-agriculture*). The world has **lost a third of its arable land** with potentially disastrous consequences as global demand for food soars (The Guardian, 2023). 97.85 million hectares (mha) of India's total geographical area (TGA) of 328.72 mha (29.7 %) underwent land degradation during 2018-19, according to the Desertification and Land Degradation Atlas of India. The UN warns **"Only 60 Years of Farming Left If Soil Degradation Continues".** Generating three centimeters of top soil takes 1,000 years, and if current rates of degradation continue all of the world's top soil could be gone within 60 years (United Nation, 2014).

Food safety is also a serious concern, considering that with time the ill-effects of pesticides on natural resources, food chain toxicity, human health, and agricultural sustainability has become widely apparent. As the second largest agrarian country of the world, India has also become one of the largest users of pesticides. The World Health Organization (WHO) states that "If it is not safe, it is not food", as it does not serve its purpose to provide proper and safe nutrition. The **FAO reiterates that Sustainable Agriculture that seeks to increase yields while limiting the need for application of pesticides or synthetic fertilizers; only can relate Food Security with Food Safety.** Food can Boost Up Immunity only when it is naturally rich in anti-oxidants, minerals, vitamins and other qualities, but food grown under conventional chemical farming i.e., using synthetic fertilizers and pesticides cannot serve the objective. 'Only Healthy Plants can Produce Healthy Food'.

That means in the existing situation we need HIGHER FOOD PRODUCTION FROM LESSER LAND AREA WHILE REDUCING/ ELIMINATING THE USE OF UNSUSTAINABLE/ NON RENEWABLE INPUTS. Hence, the situation demands a **TRANSFORMATIVE CHANGE** in Agricultural Practices to ensure **SUSTAINED production and availability of Safe Food for the rising global population while Mitigating Climate Change Impact** (*The Future of Food and Agriculture- Trends and Challenges, FAO-2017*). Sustainable agriculture that integrates three main goals i.e., environmental health, economic profitability, and social equity is the only solution especially in for a country like India with 224.3 million undernourished people. But the **CHALLENGE** is exhibited by UN's own Statement "**It is currently not clear or well defined what constitutes productive and Sustainable Agricultural Practice**".

The relevance of Sustainable Agriculture increases multifold in the **Indian context** where **more than 90% farmers are marginal and resource poor, with a land holding less than 0.38 hec.**, are therefore highly vulnerable to climate change, compelled to use a large quantity of synthetic agrochemicals but often receive inconsistent revenue.

The situation is more challenging in case of West Bengal which shares 2.4% of the country's geographical area but provide food for 8% of the country's population; 96% of the state's food producers are small and marginal farmers belonging to the backward and minority class with a land holding even less than 0.26 hec. (almost 1/10th area as per the land classification range). Due to economic insecurity, minimum livestock support, highest exploitation from middleman and least access to newer agro-technology and knowhow, these farmers are most vulnerable in respect of the increasing climatic adversities.

Hence, any further disruption in their livelihood can destabilize the very fundamental base of our food production system, considering that small and marginal farmers make up the bulk of the Indian agricultural economy by contributing **51 per cent of total agricultural output and 70 per cent of high value crops** (TOI, 2nd Sept. 2022). The situation demands a format for Sustainable Agriculture, which can sustain/ improve crop yields through efficient use of on- farm resources, while reducing the dependency on off- farm unsustainable inputs, maintaining ecological integrity and enable sustainable production of Safe Food that can secure farmers' livelihood while opening the access of Pure Food for All.

This was the background behind 'Clean Food' initiative of IORF, to enable Farmers' Access to an Effective, Economically Viable and a Conveniently Adoptable Sustainable Crop Technology that can ensure Elimination of Chemical Pesticides from the crop production system with No Crop Loss and No Hike in the Cost of Production, leading to Safe and Sustainable 'Clean Food' production - SAFE for Human Health, SAFETY @ SAME COST – hence, SUSTAINABLE FOR ALL.

This IBM-IORF 'Clean Food' Project in the **Nadia District of West Bengal** is a **First of a Kind and the Largest Program for Pesticide Free - Pure Food Production in India** encompassing 100 ha area, about 400 marginal and small farmers and has already enabled the development of about 2000 ton '**Clean Vegetables'- SAFE FOR HUMAN HEALTH** in **Phase-1 Project (2021-22).**

The farmers for the first time received COMPREHENSIVE 'SOIL HEALTH CARD' (25 Quality Parameter especially Microbiological) **for each piece of their farm land- another First approach in the Indian Perspective. About 96 SOIL RESOURCE MAPS & 10 SWOT MAPS** were developed to benefit more than 1000 farmers .

The IBM-IORF Sustainability Project in Phase-I (2021-22) also enabled the development of Five Stupendous SUSTAINABILITY TOOLS; that on hand serve as solutions for safe and sustainable agriculture at scale, while on the other enable impact Study for any sustainable agriculture initiative; which is again crucial for progression of such initiatives at scale. These Models are as follows :

i) **SOIL HEALTH PROXIMITY MODEL-** Comprehensive Soil Health Card with soil physical, fertility and biological parameters for '**Every Land**' in economically viable (**$1/10^{th}$ of Conventional Cost.)** in time bound manner**,**

ii) **'COLORIMETRIC PESTICIDE ASSAY TEST' –** Make the Pesticide Residue Analysis practically feasible and economically viable (@ $1/10^{th}$ of Conventional Cost),

iii) **METHANE MITIGATION MODEL –** through WASTE bioconversion, especially hard to biodegrade, toxic and high GHG emitting Landfill material,

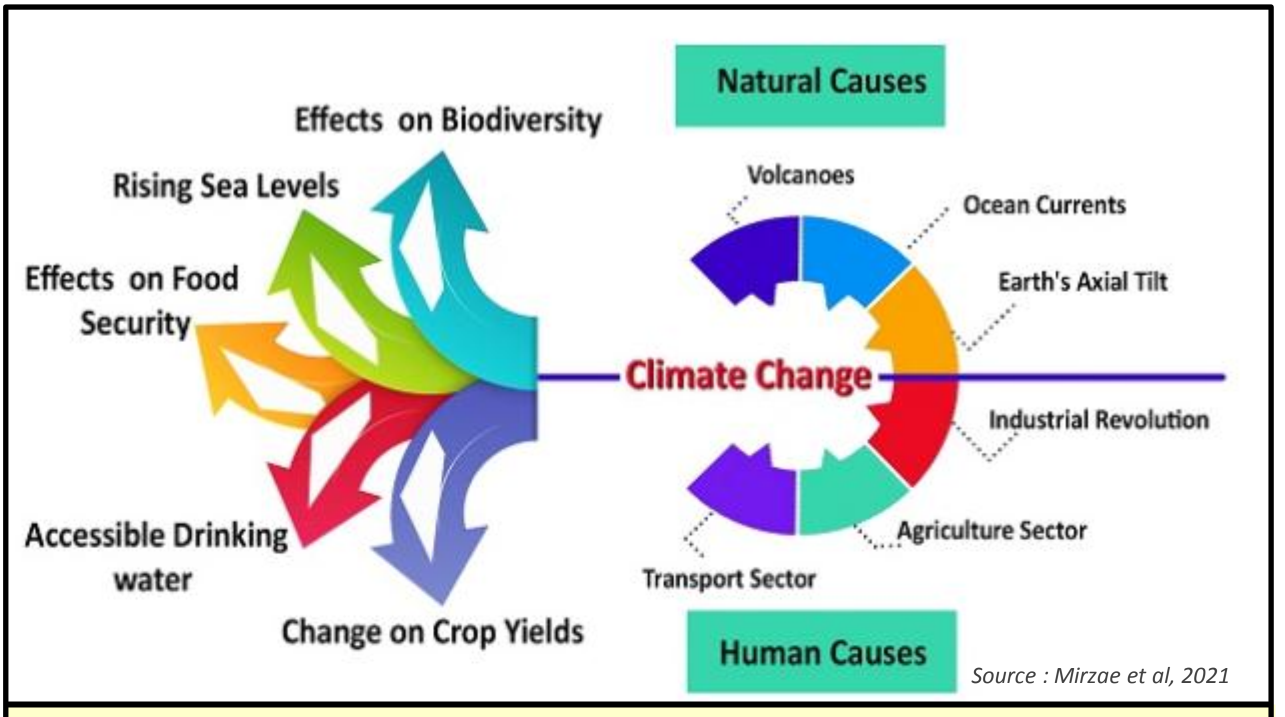
iv) **AGRICULTURE CARBON FOOTPRINT ASSESSOR (ACFA version 1.0) -** a First of a Kind Solution to evaluate the Carbon Sustainability Potential of any Agricultural Initiative.

v) **Clean Food 'NET ZERO' Model –** a First of a Kind Model in Agriculture for GHG Mitigation especially Methane Abatement and Degraded Soil Reclamation that delivers SAFEST FOOD – Safe for HUMANS, SOIL & ENVIRONMENT.

Landscape view of IBM-IORF Sustainable Project Area at Nadia, West Bengal, India

The Climate Change is existential and already affecting food security through increasing temperatures, changing precipitation patterns, and greater frequency of some extreme events. There has been a worldwide focus on curtailing carbon dioxide emission resultant from burning of fossil fuels, but it is also critical to cut methane emissions that has a more powerful near-term warming effect than CO_2. A recent assessment from the United Nations Environment Program and the Climate and Clean Air Coalition found that cutting farming- related methane emissions would be the key in the battle against climate change (UNEP, 2021).

Agriculture is the most vulnerable to climate change, at the same time it is the only sector that can make a significant contribution towards both GHG mitigation and adaptation. **Omitting source point METHANE emissions e.g. from any form of agri- waste especially landfill materials, lowering/ eliminating fertilizer use, especially nitrate fertilizers in crop production and higher application of microflora (*self- generated*) rich organic amendments for improving the Soil- C sequestration can serve towards GHG mitigation. At the same time improving the crop yields *vis-à-vis* eliminating chemicals pesticides and fertilizers can serve the adaptation strategies.**



Climate change impacts on agriculture and food security : Farmers need to be equipped with Sustainable Agro Technologies to counter the Climate Change Impact towards Crop Sustainability

Besides climate change, land degradation and loss of biodiversity, threatens the delivery of ecosystem services, especially food production. Soil degradation, which contributes to 36–75 billion tons of land depletion every year, threatens the global food supply; which implies that now; More Crop has to be Produced from Less Land. Hence, together with a Safe Approach towards Human Health, a Safe Approach to the Soil and the environment will be crucial to Restore Ecosystem Function Abilities and Deliveries. Two initiatives, i.e., increasing the productivity of Marginal Soils and Reclamation of Degraded Soils for restoring its suitability for agriculture; though herculean tasks can provide significant impact in this arena.

According to an estimate by Dr. Lal, the renowned Soil Scientist and the 2020 World Food Prize Winner, the carbon sink capacity of the world's agricultural and degraded soils is 50 to 66% of what it has been historically. This means our soil can hold 42 to 78 billion metric tons more carbon (Lal, 2001). Increasing the amount of carbon in soil also makes it more productive for farmers which can only be through sustainable farming approaches. Moreover, for sustainable farming, amelioration of soil is the most important criteria (AGRIVI, 2023) and quality manure/ compost, rich in self-generated microflora is prerequisite for ensuring time bound effectiveness irrespective of agro-ecological settings. But to attend the objective at SCALE the raw material source for compost production has to be abundantly available as well as an economic option.

WASTE of any type especially landfill/ legacy waste/ MSW, etc., perfectly fits the bill, because they are abundantly available as well as low cost options. But apparently there is **dearth of Environmentally Safe and Economically Viable Composting Technology/ ies that can transform these Toxic, especially METHANE EMIITING pollutants.**

During the Phase-I Project IORF, had already taken an initiative of WASTE bio-conversion under Novcom Composting Technology and demonstrated its transformation into a Safe, microflora rich and Non- phytotoxic Compost, that can be used for sustainable soil health management and reduction/ elimination of N- fertilizers, finally leading to SAFEST Food production.

This approach had actually led to the development of Clean Food 'NET ZERO' Model. The quest for raw material source brought forth the aspect of **Coir pith - a toxic, hard to biodegrade, and a very high Methane emitting waste from coir industry.** Considering that so far there is no composting technology which can effectively biodegrade coir pith, hence; it continues to be dumped in open lands. And During the rainy season, the tannins and phenols of the coir pith leach out into the soil and the irrigation canals, thereby making agricultural lands unproductive.

But at the same time, COIR PITH can serve as an excellent resource for soil management if bio-converted into a safe and mature compost. **The Mandya District of Karnataka was found to have an abundant source of coir pith.**

Hence, the Phase-II IBM-IORF Sustainability Project was initiated in the Mandya District of Karnataka to establish a Model for SAFEST FOOD production i.e., Safe for Human Health, Soil and the Environment utilizing the Clean Food 'NET ZERO' Model (*developed under Phase-I project*).

This Program served as a **FIRST OF A KIND** demonstration in Agriculture towards GHG Abatement especially Methane Mitigation from source point, reclamation of degraded land and finally the Net Zero Objective.

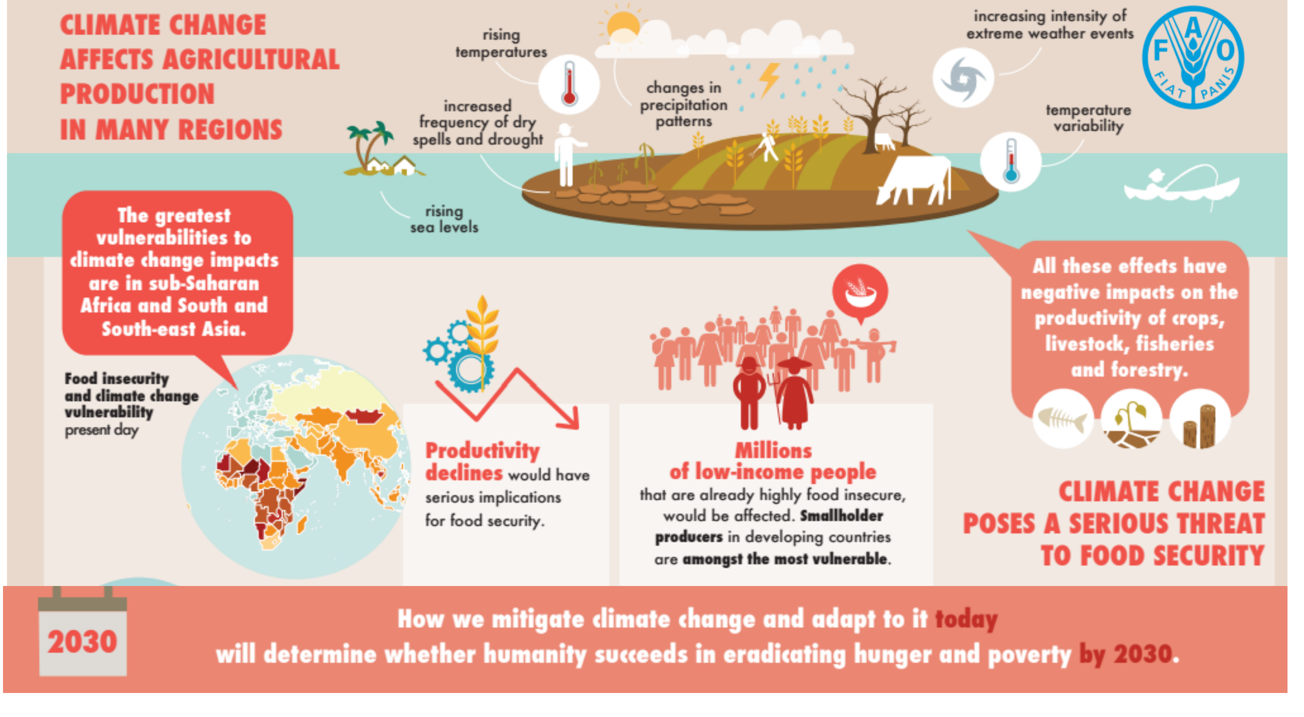
In respect of SAFEST FOOD production FIVE MAJOR AREAS were focused :

1. **Improvement of Coconut Productivity** – Productivity of this crop is about 50% lower as compared to the Largest Coconut Producing State Tamil Nadu and almost 30% Lower than the National Average. Intervention has been taken to recycle the waste of this crop into the plantation towards the objective of yield improvement.
2. **Development of Coconut based "Net Zero' Intercropping Model** - Intervention has been taken to utilize the plantation area through cultivation of intercrops that can ultimately help in improving the overall farm economics.
3. **Development of Clean Vegetables 'Net Zero**' in soil which are practical unfit for field crop production. Mandya is an agricultural district of Karnataka but only about 2-3% area is under Vegetable Production. The objective of this initiative was to demonstrate a Model that can successfully increase the vegetable cultivation area.
4. **Utilization of 'Net Zero' Clean Paddy Seeds** developed under Phase-I in West Bengal towards Paddy cultivation in Mandya, towards transformation of the coarse grain to fine grain rice variety as well as to test the Climate Resilience of the 'Net Zero' seeds in a completely different agro-climatic setting.
5. **Intervention in Sugarcane Production** – with third largest sown area in the district but while Karnataka has witnessed positive growth, in Mandya productivity has actually reduced by 18%. Moreover, while sugar content has increased in Karnataka by about 16%, in respect of Mandya it has actually depleted by about 4%. Scarcity of quality planting material also forms a major challenge for these sugarcane farmers . These very limitations formed the objectives for this intervention.

In 2022-23, a major focus was also imparted in the WEST BENGAL PROJECT AREA towards ORGANIC SEED DEVELOPMENT of Paddy, Vegetables, Potato (*a major cash crop with existential challenges*) **and Oilseeds.**

Out of the total seeds used by the Indian farmers only 30% are certified/quality seeds. And the present production meets only 20% of the total demand. Apart from climatic adversity, poor quality seed is a prominent cause of crop failure and low productivity in India. Moreover, Climate smart agriculture as a part of climate change mitigation strategy starts with quality- resilient seeds. However, the **seeds developed under conventional farming are generally high fertilizer responsive hence; they lack the quality traits** *viz*. higher nutrient use efficiency, disease resistance and resilience against biotic and abiotic stress, **that are required for sustaining crop yields irrespective of the changing climatic patterns.** Quality organic seeds have been indicated to yield plants that are more adaptive of the changing climate and thrive well under organic/ low input conditions, **but their availability is practically NIL, considering the fact that the farmers usually incur from 30 to 70% Crop Loss during Organic Seed Production.**

The objective was to demonstrate before the farmers especially the marginal and small land holders an adoptable and economically viable pathway towards self-sufficiency w.r.t. **CLIMATE RESILIENT SEED** - the basic foundation for Safe and Sustainable Agriculture.



Sustainable Agricultural Initiatives in Two distinctly different Agro-ecosystem was attended under IBM-IORF Sustainability Project

Nadia District, West Bengal, India : Hot, Moist sub humid agro-ecological sub region 15.1 with deep loamy to clayey alluvium derived soil, medium to high AWC and Length of Growing Period 210 – 240 days

Mandya District, Karnataka, India: Hot, Moist semi arid agro-ecological sub region 8.2 with medium to deep red loamy soils, Low AWC and Length of Growing Period 120 – 150 days

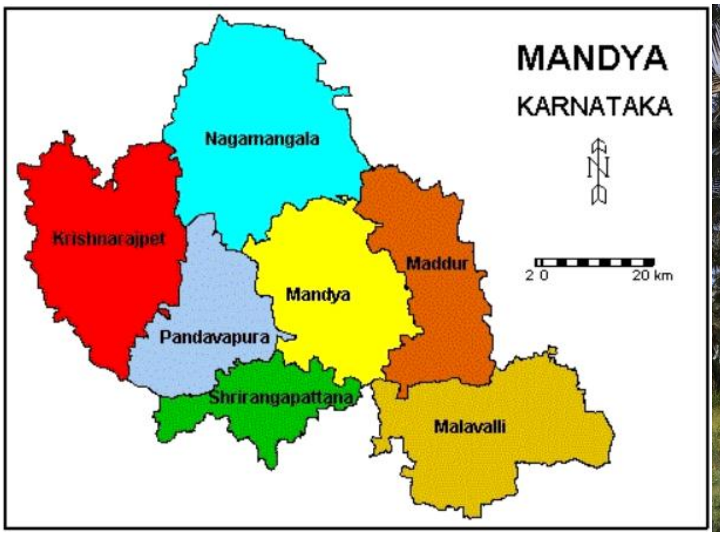
Detailed Project Report

Clean Food ‘Net Zero’ Program
Mandya, Karnataka

Introduction

Mandya district is located in southern part of the state with a total area of 4,961 sq. km. having 7 talukas, 31 hoblies, 1,369 inhabited villages and seven towns with a total population of 18.05 lakh. Agriculture is the mainstay of the economy with around 69.5% of the workers either directly dependent on agriculture as cultivators (44.7%) or indirectly as agriculture labourers (24.8%). Majority of Geographical area of Mandya district is covered by Cauvery basin and agriculture in the district is classified under agro-climatic zone 6 (Southern dry Zone).

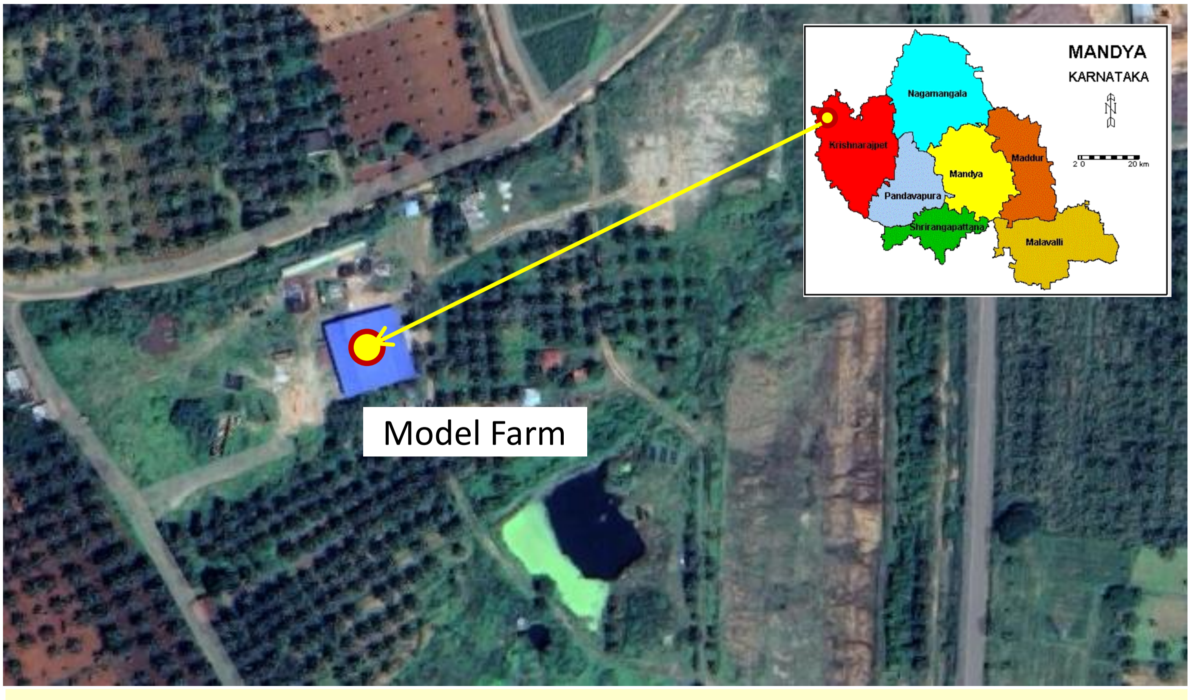
Soils of the district can be classified into two main types viz., Red sandy and Red loamy soils. Red sandy soils are basically neutral to slightly acidic in nature and formed by gneiss and granite. These soils are majorly divided in 3 catgories viz. upland soil, midland soil and low land soil. Upland soils colors ranges from medium reddish brown to deep red and to brown, where as that of mid land and low land soils were deep reddish brown to blackish brown and brown, black to blackish brown in its appearance respectively. The top portion of this soil has gravels, gravely sand where as the bottom comprises of gravely sandy loam. Where as read loam soil are seen in undulating granite rocky areas. Colour of this soil ranges from deep brown to deep red and the top layers contains sandy loam to clay loam whereas the bottom layers have loam, clay loam and sand mixed with gravels in some places.



Agriculture is the main activity in the district. The crop sowing periods are early kharif, late kharif and summer. The average annual rainfall is 700m.m.The district gets bimodal distribution of rainfall. Generally the first peak is during April, May and the second during September, October. The month of June is known for dry spell. The major crops of the district are ragi (85,467 ha.), rice (79,892 ha.), sugarcane (30,630 ha.) , pulses (predominantly horse gram and to some extent tur, cowpea, green gram, black gram, avare) and oilseeds (mainly groundnut and sesame). Other major agricultural crops are Jowar, Maize and Horse gram.

Study Area : Village: Kalenahalli, Hobli: Kikkeri, Taluk: Krishnarajpet, District: Mandya, Karnataka, India

The study was initiated under IBM-IORF Sustainability Project during 2022-23 for establishment of the Clean Food 'Net Zero' Model. The quest for quality compost for sustainable soil health management led to coir-pith; a waste of coir industry, which has abundant supply of 5.0 – 6.0 lakh metric ton yearly in Karnataka alone, and is a cost free source.



Pic. : Model farm in the study area under IBM-IORF Sustainability Project .

Pic. : Toxic leachate containing high salt and phenolic content from coir pith dumps in and around coir factories.

CHAPTER 1 : Bio-conversion of Coir Pith

Summary

Coir pith, a byproduct of coir industry can take decades to decompose when left untreated. Due to absence of effective and viable composting technology/ies for its effective bioconversion, dumping of coir pith in open lands leads to environmental pollution specially METHANE emission. Under IBM-IORF Sustainability project at Mandya, Karnataka, Novcom Composting Technology was utilized towards effective bioconversion of coir pith into safe and mature compost for sustainable soil management. Periodical study confirmed effective degradation of organic matter as demonstrated by the rapid decline of C:N ratio from 1:100 to < 1:25, appreciation of total nitrogen by 98 percent and 60 % degradation of lignin within a 30 days' time period.

And the values are corroborated by the respective very high (*in the order of 10^{16} c.f.u. per gm or One Trillion Billion Microflora per ton compost*) population of bacteria, fungi and actinomycetes. Phytotoxicity Bioassay test values, confirmed not only the absence of phytotoxic elements in compost, but also indicated that this compost can actually accelerate the seed germination and root growth process. Thus adoption of Novcom Composting Technology can transform not only a potential pollutant to a safe and effective organic soil amendment, the process attends the objective of SDG 13, especially in terms of Source Point Methane Abatement; SDG 15, SDG-3 and most importantly SDG-2. Thus Novcom Composting Technology can facilitate to develop an effective model towards attainment of Net Zero commitment with significant social and environmental impacts.

Introduction

Coir pith is a biomass residue generated during the extraction of coir fiber from coconut husk and is a byproduct of the coir manufacturing industry. It is a ligno-cellulosic material forming about 70% of the coconut husk . When husk of 10,000 coconuts are utilized for coir extraction, 1.6 ton of coir pith is obtained as a byproduct. If all the coconut husks available in India are processed, it is estimated that about 2.25 million tons of coir pith could be obtained annually. Usually, coir pith is dumped as agricultural waste and accumulate as a waste product in the form of heaps of coarse and fine dust. Accumulation of this rejected coir pith around coir fibre processing centers year by year is creating disposal problems. This coir pith poses fire hazard, space problem, health hazard and disposal problem if an appropriate solution is not found. **Traditionally, these agricultural wastes are disposed off by burning, which results in various environmental problems, including carbon deposits as well as the warming of the**

atmosphere. During the rainy season, the tannins and phenols of the coir pith leach out into the soil and the irrigation canals, thereby making agricultural lands unproductive. Moreover, the water pollution caused by such leaching is harmful to the aquatic and soil biological life. Present forms of management or utilization are not sufficient enough to totally consume the waste generated and it continues to be a perennial problem to the nearby aquatic and terrestrial environments. But **most importantly as a result of dumping, methane, a potent greenhouse gas is generated which contributes to climate change.**

Pic. : Piling up of coconut husk in coir factory for extracting coir fibre

High salt content and high lignin in coir pith content cause very slow degradability which offers little scope for its direct application in agricultural soil. Moreover people continue **to face tough challenges in respect of effective bioconversion of coir pith into quality manure for soil application; under the available composting technologies.**

Looking at the importance of quality organic manure for any sustainable agriculture initiative, for reclamation of degraded soil as well as for sustained crop productivity, coir pith in the presence of an effective technology, can serve as an excellent resource for compost generation considering its high water holding capacity, nutrient retention capacity as well as large scale availability.

In this background, Novcom Composting Technology was adopted for bio conversion of coir pith. This technology was developed by Dr. P Das Biswas, an Indian scientist and pioneer of Ecologically and Economically Sustainable Organic Tea Cultivation in India; has shown its potential as a speedy, effective and economic pathway for quality compost generation (Barik *et al.* 2014). Under IBM-IORF sustainability project at Mandya, Karnataka; total 1000 ton Novcom coir pith compost was developed under Novcom Composting Technology which was utilized for sustainable soil management and at the same time played a significant role in climate change mitigation through Source Point Methane Abatement.

GHG offsetting potential under this composting method was evaluated through ACFA (Version 1.0). This Agriculture Carbon Footprint Assessment Tool was developed by IORF and in this tool the basis for estimation of GHG emission from waste bioconversion was taken from the guidelines prepared for the IPCC National Greenhouse Gas Inventories Program to support the development of *Good Practice Guidelines* for estimation of greenhouse gas emissions from the Waste sector and to manage the associated uncertainties. We followed the default IPCC methodology that is based on the theoretical gas yield (a mass balance equation) to calculate total methane emission (at a time), assuming that all potential methane is released in the same year when the solid waste is disposed.

Pic. : Coir factory for extracting coir fibre and coir husk.

Raw materials used : Raw Coir pith sourced from coir factory and cow dung in 80 : 20 ratio was used for making compost.

Novcom solution : It is the biologically activated and potentized extract of Doob grass (Cynodon dactylon), Bel (Sida cordifolia L) and common Basil (Ocimum bascilicum). Details of the solution is given by Seal *et al.* (2012) who worked on the biodegradation pathway of Novcom Composting Method.

Working Mechanism of Novcom Solution under Element Energy Activation (E.E.A.) Principle.

Novcom Composting Technology is a unique biodegradation system, that can convert any type of biodegradable material including toxic and hard to biodegrade materials into quality compost. Through the erection of Novcom composting heap, we tried to create an environment for self-generation of diversified microflora, **while the application of Novcom solution served to provide the desired energy sources in the most pure and subtle form for their speedy multiplication and higher activity efficiency.** This energy management is based on the 'Element Energy Activation' (E.E.A.) Principle, inspired by the Vedic philosophy.

An effective biodegradation process is usually guided by the mesophillic- thermiophillic – mesophillic stages, where one stage comes only when the previous one completes. **Novcom solution along with heap construction just speeds up this orchestra in a very organized and synchronized manner.** This method provides just the necessary environment for completion of each step so that the next step can take over ultimately culminating into a stable, mature and non-phytotoxic compost within the shortest time period. Here no specific input or agent that is known to have influence in the breaking down of the organic material, is added because these have their own limitations either singly or in combination.

Process of Novcom Solution Development

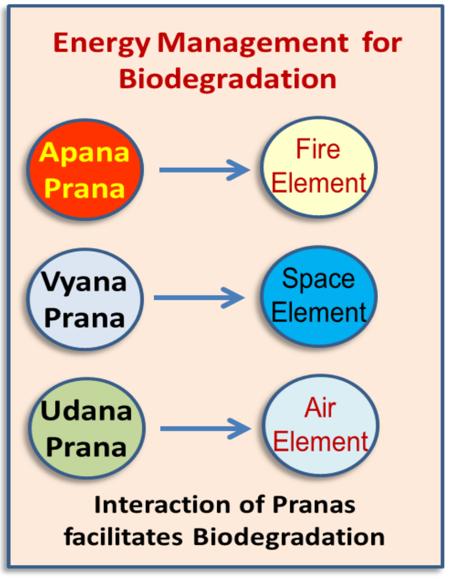
Selection of specific plants (specific day & time)
▼
Alcoholic Extraction (Specific Plants parts in specific time and procedure)
▼
Energization (Isolation of energy components)
▼
Potentization (Release of bound energy in order of 10^3 to 10^4 times)
▼
Combination of the Potentized & Energized Extracts

If the mechanism of Novcom Composting Technology is interpreted under the Element Energy Activation Principle, it manifests as a unique, novel but the most convenient system for generation of quality compost. It is known that all objects of Earth are composed of five elements. Hence, in the first stage of degradation under Novcom Composting Technology, the elements are broken into their individual identity. Then, the temperature rises 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 thermophilic bacteria start growing up. After a span of time the actinomycete group of micro-organisms come and break the degraded material into 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 so rapid, intense and programmed that it finishes within the shortest period of three weeks.

Working Mechanism of Novcom Solution under Element Energy Activation (E.E.A.) Principle.

The technology promises to provide solution irrespective of the type or nature of raw material or the agro climatic situations. The process does not require any microbial inoculation because the necessary microbes are generated naturally due to set up of an ideal environment. Moreover, microbial inoculation is 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 behavior that can never match when applied in combination with other microbes. Hence, 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 pre-poning any stage will always make the process a complex one.

The compost developed with Novcom Technology provides the energized environment for regeneration of soil fauna. Hence, application of even a small quantity of the compost brings about a noticeable change in the soil in the shortest possible time. Finally, one thing is to be remembered that microbes also need an adequate environment to grow and function. Hence, to provide the environment is more necessary than to inoculate them directly into the soil. The effectiveness of Novcom Composting Technology is defined by its mechanism to create the required environment.



Pic. : Support structure for erecting Novcom coir pith compost heap.

Pic. : Transport of coir pith for making Novcom coir compost at model farm, Mandya, Karnataka.

Preparation of Novcom Coir pith compost

At a selected upland and flat area, a 10 ft. x 8ft. x 6ft. support structure was made with bamboo strips and coconut leaves for erecting the coir pith compost heap (approx. weight 8-9 ton). A layer of cow dung slurry was put as the bottom layer and the same was sprayed on the inside walls of the support structure. Coir pith was mixed with cow dung slurry at 80:20 ratio (coir pith and cowdung on weight basis) and spread layer wise (each layer being approximately 0.5 ft. thick.) till it reached to the top of the structure. About 60 ml Novcom solution (diluted 25 ml in 5 liter water) was sprayed on each layer. Total 16 layers were required to reach a height of 6ft., because the heap height gradually reduced with compression and hence, total 2000 ml of Novcom solution was required for this heap.

The heap was covered with coconut leaves and left in this manner for 9 days. On 10th day, one side of the heap structure was opened and the material was altered and mixed properly with JCB. The material was again put in the heap, repeating the previous process. Once again 2000 ml of Novcom solution was used. The process was again repeated on 20th day and the compost was ready on 30th day.

Pic. : Preparation of cow dung slurry and mixing of cowdung slurry with raw coir pith in 80 : 20 ratio (coir pith and cow dung on weight basis) at Model farm, Mandya, Karnataka under IBM-IORF Sustainability Project.

Analysis of compost quality :

To evaluate the composting process and end product quality under Novcom Composting Technology, raw coir pith, samples from 1st turning (10th day), 2nd turning (20th Day) and final Novcom coir pith compost (30th day) were evaluated for 19 different quality parameters as per National and International standards. The samples were analyzed for physicochemical properties, microbial population, maturity and phytotoxicity parameters (Table 1 and 2).

Changes of organic carbon, nitrogen and C:N ratio with transformation of coir pith to mature compost

Changes of organic carbon and C:N ratio is most important indicator of compost maturity and stability. Microorganisms break down the chemical bonds of organic materials in the presence of oxygen and moisture and the rate of decrease in carbon content of waste over time indicates the speed of biodegradation during composting. In case of Novcom Coir pith compost, organic carbon decrease from 52.10 % in raw material to 31.28 % in the final compost (i.e. on day 30 of composting) indicated faster biodegradation and simultaneously pointed to compost maturity (as organic carbon varied within 16 to 38 % in mature compost) within a short time frame.

The change in C:N ratio of the composting material was also considered in terms of stability, because as the readily available- C in the organic matter is oxidized and released as carbon dioxide, there is a general reduction in carbon content over time . **The C:N ratio of 30 day compost sample was 24.9:1 indicating maturity as a ratio of 20–30 results in an equilibrium state between mineralization and immobilization and is considered good for soil application**. This is because, soil microorganisms have a C:N ratio of around 8.0 and they must acquire enough carbon and some nitrogen from the soil to maintain that ratio in their cells and have been found to do best on a “diet” having a C:N ratio of 24.0. According to USDA Natural Resources Conservation Services (NRCS) soil microorganisms use 16 units of carbon for energy and the other eight parts for maintenance. Under these optimum conditions, soil microbes can spur release of nutrients and this ratio influences the amount of soil-protecting residue cover that remains on the soil. Novcom coir pith compost also met the additional criteria for compost stability, i.e. $C:N_{final}/C:N_{initial}$ ratio <0.75, confirming that it attained maturity within 30 days. So this compost might be proven as an ideal soil energy enhancer for soil microbial rejuvenation resulting in sustenance of soil productivity.

Pic. : Mixing of raw coir pith with cowdung slurry at Mandya, Karnataka

Pic. : Transfer of cow dung slurry mixed Coir pith for erection of Novcom compost at model farm

The total nitrogen content in the compost sample increased from 0.59 to 0.76 % during the first phase of composting (days 0 to 20) which might be due to a concentration effect following a decrease in substrate carbon during the degradation of non-nitrogenous organic matter. Evaluation of the graph showing the decrease in organic carbon and increase in total N value revealed that the trend lines (Figure 6) of organic carbon degradation and lowering of C:N ratio gradually separated from each other over time (as the shaded area widen). This indicated that there was a relatively greater increase in total N compared with the decrease in the organic carbon content. The finding might provide an indirect indication of the fixation of atmospheric- N within the compost heap by the autotrophic microorganisms generated during the composting process. According to de Bertoldi *et al.*, an increase in the population of N-fixing bacteria in the later phase of composting, can be attributed to the increase in the value of total- N in compost, despite volatilization (primarily) losses from compost heap during biodegradation.

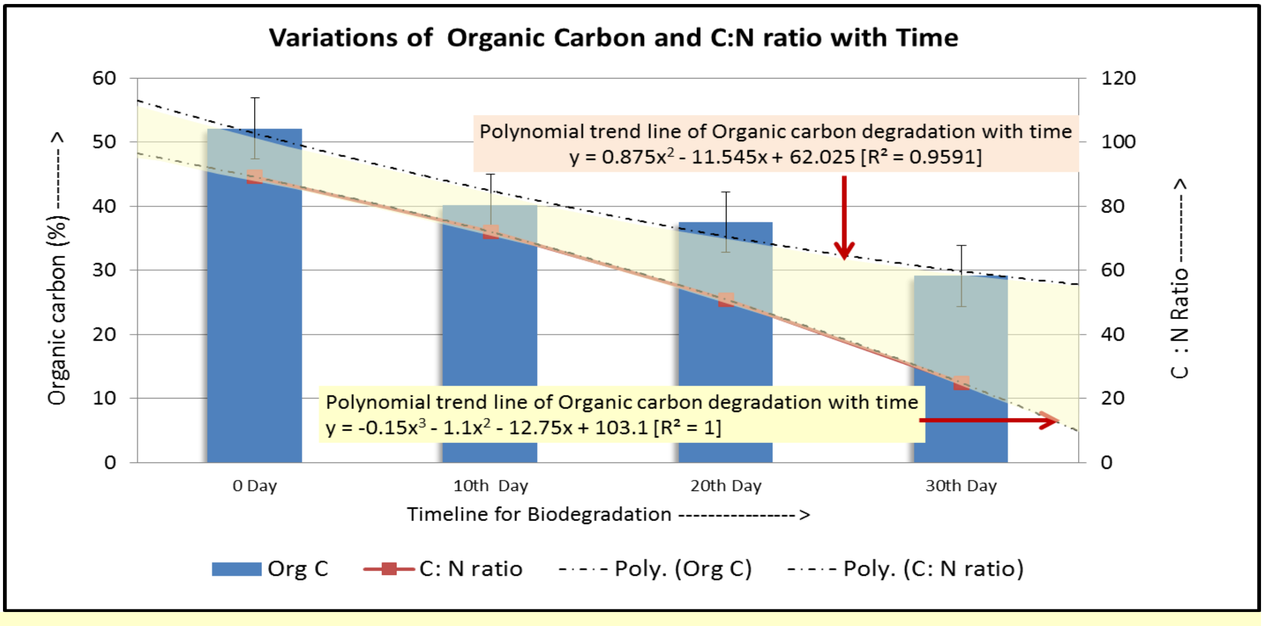


Fig. 1 : Variations in the organic carbon content and C:N ratio of coir pith during Novcom biodegradation process.

Pic. : Addition of Novcom solution in water and spraying of Novcom solution on coirpith at model farm, Mandya, Karnataka.

Degradation of Lignin under Novcom Composting Technology

In composting, the degradation of lignin in coir pith is problematic due to its complex structures. According to studies in natural condition, when dumped in open environment, lignin content in coir pith takes decades to decompose. It only begins to break down when it is 10 years old as the pentosan/lignin ratio of pith is 1:0.30 while the minimum value required for moderately fast decomposition in the soil is 1:0.50 (Narendar and Dasan, 2014). In the case of Novcom Composting Technology, >60% of lignin is degraded within 30 days of composting. This was primarily influenced through energy infusion, brought about by the application of Novcom solution that enabled self- generation of a huge population of microflora within Novcom heap during the process of composting (Fig. 3).

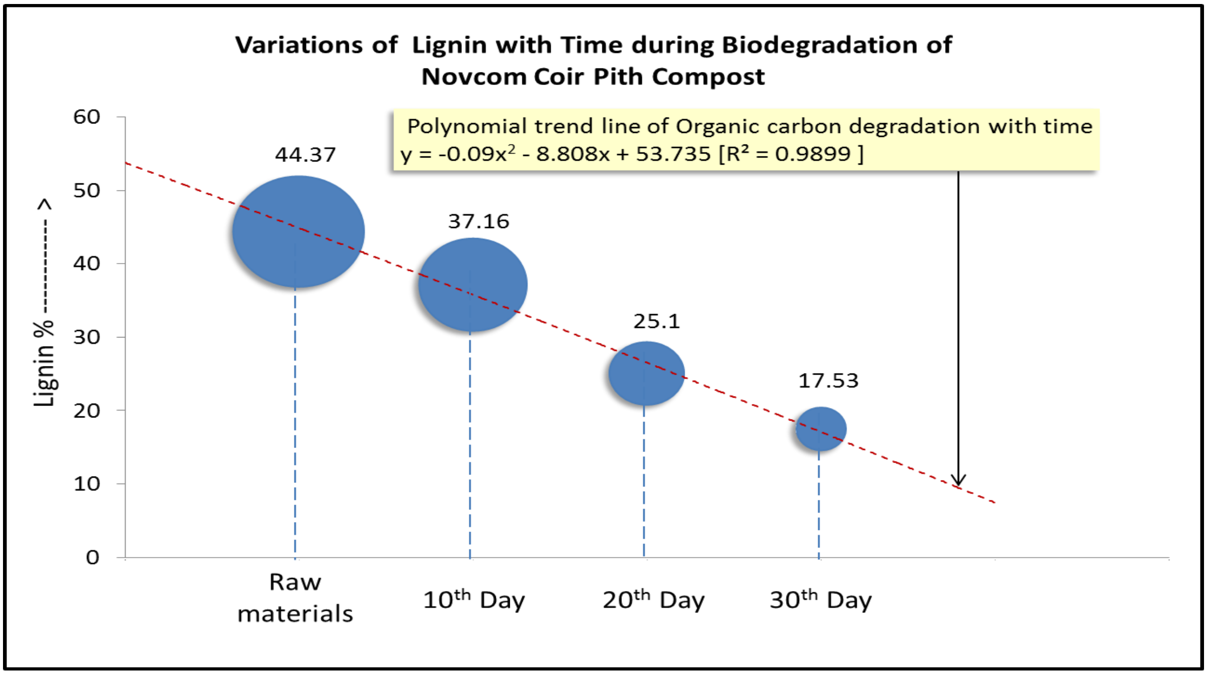


Fig. 2 : Degradation of lignin content in coir pith under Novcom Composting Technology, at Mandya, Karnataka under IBM-IORF Sustainability Project.

Pic. : Inspection of the on-going large scale Novcom Composting program utilizing Coir pith by Dr. P Das Biswas, Developer of this Method; at Model farm, Mandya, Karnataka under IBM-IORF Sustainability Project.

Quality of Novcom Coir- pith Compost

Qualitative evaluation of Novcom coir pith compost (as per 19 different analytical parameters) was carried out to assess the potential of the composting method towards production of high-quality mature compost. In this study, samples collected on the 10th, 20th and 30th day of composting were analyzed for physicochemical, microbial, stability and maturity/phytotoxicity parameters (Table 1 and 2).

Physicochemical parameters of Novcom coir pith compost

The predominant use of compost is to mix it with soil to form a good growing medium for plants, for which pH forms an important criteria of consideration. The pH value of the compost samples ranged between 6.29 and 7.35, with a mean of 7.32, which was well within the stipulated range for good quality and mature compost. Electrical conductivity of the compost samples ranged between 1.83 and 1.96 with a mean of 1.89 dSm^{-1}, indicating the absence of any saline toxicity effect.


Pic. : Preparation of Novcom coir pith compost at Model farm, Mandya, Karnataka under IBM-IORF Sustainability Project.

Composting transforms raw organic residues into humus-like material through the activity of soil microorganisms. The organic matter content of compost is a necessity for determining the compost application rate to obtain sustainable agricultural production. By increasing soil organic matter content, which fuels microbial activity and nutrient cycling, compost applications can increase the overall soil fertility. Organic carbon content in the compost samples ranged between 26.8 and 32.1%, with a mean value of 29.1%, which met the standard value of >19.4% suggested by Australian Standard 4454 for nursery application.

Fertility and microbial parameters of Novcom coir pith compost

Although 36 different nutrients are required for plant growth, the macronutrient (N, P, and K) contribution of compost is usually of major interest (Tisdale *et al*. 1985). The total nitrogen content in the compost samples ranged between 1.12 and 1.20 %, which was well above the Indian standard of 0.5% and the range of 1–2% total N content suggested by Alexander and Watson.

Table 1 : Variation of physicochemical properties, fertility parameters and lignin content during bioconversion of coir pith into quality compost utilizing Novcom Composting Technology.

Sl No	Quality Parameters	Raw Coir pith		10^{th} day Sample		20^{th} day Sample		30^{th} day Sample	
		Range Value	Mean Value	Range Value	Mean Value	Range Value	Mean Value	Range Value	Mean Value
1	Moisture (%)	47.00 – 55.4	50.76 ± 0.71	68.50 - 75.0	72.50 ± 0.69	64.96 - 72.50	69.2 ± 0.66	66.0 - 72.0	69.6 ± 0.45
2	pH	5.90 - 6.73	6.15 ± 0.07	6.53 - 6.86	6.70 ± 0.03	6.13 - 6.85	6.60 ± 0.07	7.29 - 7.35	7.32 ± 0.01
3	EC (dSm^{-1})	2.69 - 3.24	3.11 ± 0.05	1.95 - 2.65	2.43 ± 0.08	1.96 - 2.30	2.14 ± 0.04	1.83 - 1.96	1.89 ± 0.01
4	Ash Content (%)	3.00 - 11.11	4.83 ± 0.73	21.09 - 41.09	27.65 ± 2.17	19.2 - 39.7	32.4 ± 2.17	42.11 – 51.75	47.6 ± 0.81
5	Total Vol. Solids (%)	88.89 - 97.00	95.17 ± 0.73	58.91 - 78.96	72.35 ± 2.17	60.3 - 80.8	67.6 ± 2.17	50.4 – 57.89	52.4 ± 0.81
6	Org. Carbon (%)	49.38 - 53.89	52.87 ± 0.41	32.73 - 43.87	40.20 ± 1.20	33.5 - 44.9	37.5 ± 1.21	26.81 – 32.16	29.11 ±0.45
7	Total N (%)	0.53 - 0.67	0.59 ± 0.01	0.47 - 0.62	0.56 ± 0.01	0.58 - 1.18	0.76 ± 0.06	1.12 - 1.20	1.17 ± 0.01
8	Total P_2O_5 (%)	0.08 - 0.21	0.16 ± 0.01	0.12 - 0.26	0.17 ± 0.01	0.12 – 0.24	0.17 ± 0.01	0.18 - 0.22	0.20 ± 0.01
9	Total K_2O (%)	1.38 - 1.61	1.48 ± 0.02	1.60 - 1.81	1.72 ± 0.02	2.10 - 2.74	2.48 ± 0.06	2.67 - 2.87	2.80 ± 0.02
10	C:N ratio	89:1 - 99:1	89.9 :1	69 : 1 – 81 : 1	72 : 1	38:1 - 62:1	50.9 : 1	23 : 1 - 27 : 1	24.9 : 1
11	CMI	–	–	0.48 – 1.26	0.71 ± 0.08	0.43 - 1.19	0.89 ± 0.08	1.31 - 1.93	1.64 ± 0.05
12	Total lignin %	40.2 – 47.4	44.37± 0.79	33.6 - 41.9	37.16 ± 0.81	18.7 - 30.5	25.1 ± 1.11	15.40 - 20.5	17.53 ± 0.54

Total phosphorus (0.18–0.20%) was around the minimum suggested standard of 0.22%, whereas the values obtained for total potassium (2.67–2.87%) were much higher than the range (0.2–0.5%) suggested by Alexander and Watson, on dry matter basis.

Microbial Status of compost is one of the most important parameter for judging compost quality because microbes are the driving force behind soil rejuvenation and maintenance of soil – plant – nutrient dynamics that is crucial for crop sustenance. The huge population of microflora (in the order of 10^{16} cfu/gram moist compost for total bacteria, fungi and actinomycetes) in Novcom compost, corroborated the uniqueness of this composting technology in respect of fast conversion and high nutrient content, as also found by other research workers in the case of Novcom Composting Technology.

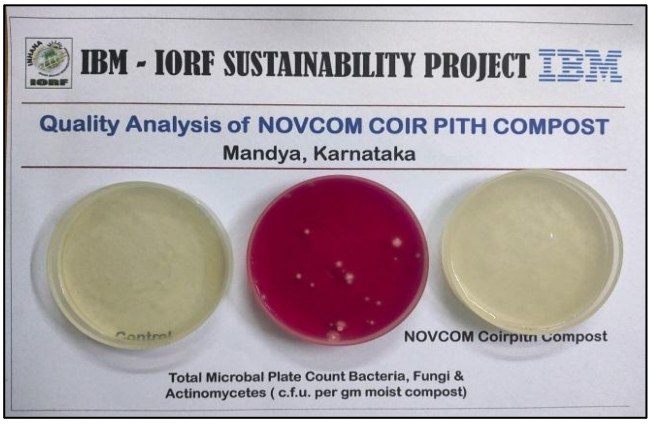
Pic. : Novcom Coir pith compost ready in 30 days, confirmed by Stability, Maturity and Phytotoxicity Test.

Evaluation of stability, maturity and phytotoxicity of Novcom coir pith compost

Compost stability, maturity and phytotoxicity rating are the most important criteria because immature compost may contain high level of free ammonia, organic acids or other water-soluble compounds, which can limit seed germination and root development. The stability of a given compost is important in determining the potential impact of the material on nitrogen availability in soil or growth media, and maintaining consistent volume and porosity in container growth media. Most uses of compost require a stable to very stable product that will prevent nutrient tie up and maintain or enhance oxygen availability in soil or growth media. Hence, microbial respiration formed an important parameter for determination of compost stability. Mean respiration or CO_2 evolution rate of all compost samples (1.74 to 1.89 mgCO_2–C/g OM/day) was more or less within the stipulated range (2.0 - 5.0 mgCO_2–C/g OM/day) for stable compost.

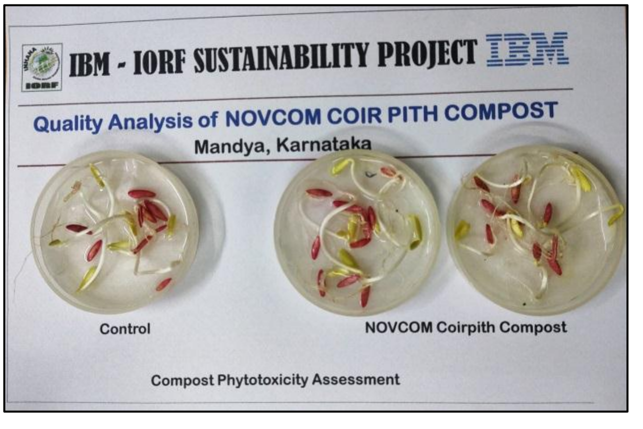
Table 2: Variation of microbial, stability, maturity and phytotoxicity parameters during during bioconversion of coir pith into quality compost utilizing Novcom Composting Technology.

Sl No	Quality Parameters	Raw Coir pith		10^{th} day Sample		20^{th} day Sample		30^{th} day Sample	
		Range Value	Mean Value	Range Value	Mean Value	Range Value	Mean Value	Range Value	Mean Value
13	Bacteria (c.f.u. per gm moist compost)	–	–	(22-51) x 10^{14}	38 x 10^{14}	(67-176) x 10^{16}	115 x 10^{16}	(127-168) x 10^{16}	142 x 10^{16}
14	Fungi (c.f.u. per gm moist compost)	–	–	(2-7) x 10^{12}	5 x 10^{12}	(4-11) x 10^{14}	6x 10^{14}	(12-22) x 10^{16}	17 x 10^{16}
15	Actinomycetes (c.f.u. per gm moist compost)	–	–	(9-15) x 10^{10}	11 x 10^{10}	(1-5) x 10^{14}	3x10^{14}	(9-18) x 10^{16}	12 x 10^{16}
16	CO_2 evolution rate (mg CO2-C/g/OM/day)	–	–	2.68 - 3.70	3.1 ± 0.13	1.96 - 3.60	2.63 ±0.14	1.74 -1.89	1.82 ±
17	Seedling emergence (% over control)	–	–	79.1 - 87.1	81.2 ± 0.95	78.6 - 102.7	92.85 ± 2.09	92.4 -102.0	98.3 ±0.8
18	Root elongation (% over control)	–	–	73.1 - 85.8	82.6 ± 1.21	82.5 -102.8	94.32 ± 1.85	119.5 - 138.5	130.5 ±1.84
19	Germination Index	–	–	0.58 - 0.75	0.67 ± 0.02	0.68 – 0.96	0.88 ± 0.03	1.18 - 1.37	1.28 ±0.02



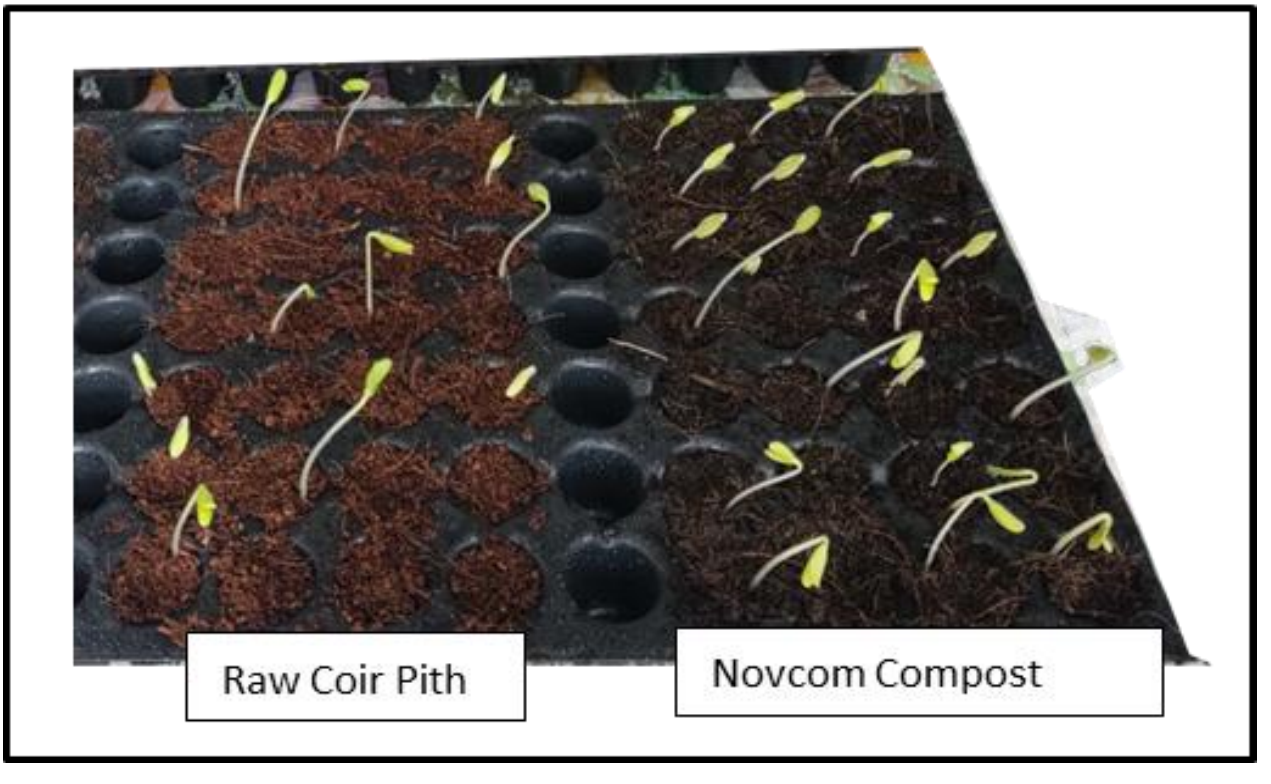
Pic. : Analysis of compost fertility parameters and microbial properties in IORF laboratory, Kolkata; under IBM-IORF Sustainability Project.

The phytotoxicity bioassay test, as represented by the germination index, provided a means of measuring the combined toxicity of whatever contaminants may be present. Phytotoxicity is also a significant indicator of final compost product maturity and is assessed through germination bioassays using a variety of crop seeds. It is known that immature compost introduce phytotoxic compounds such as heavy metals, phenolic compounds, ethylene and ammonia, excess accumulation of salts and organic acids which could retard seed germination and plant growth. The mean germination index value (1.23) of Novcom compost was well above the highest order of rating (1.0). The value indicated the absence of phytotoxicity in the compost and also confirmed that the compost enhanced rather than impaired germination and radicle growth.



Pic. : Phytotoxicity bioassay test of mature Novcom coir pith samples in IORF laboratory, Kolkata under IBM-IORF Sustainability Project.

Pic. : Transformation of raw coir pith to mature compost in 30 days under Novcom Composting Technology.



Pic. : Comparative evaluation of seed germination under raw coir pith (thoroughly washed) and Novcom Compost with that materials

CHAPTER 2 : Methane abatement under waste recycling through utilization of Novcom Composting Technology.

Summary

Study of the GHG mitigation potential of coir pith under Novcom Composting Technology as per IPCC guideline , indicated that, this Composting Technology can be the most effective and economic option towards GHG abatement. Considering the reference value of 200 kg GHG emission per tonne, treated wet waste, during composting, Novcom coir pith composting was about 31 times MORE EFFICIENT in terms of GHG mitigation, especially w.r.t. SOURCE POINT METHANE MITIGATION. This might be due to the prolific (*in the order of 10^{16} c.f.u. per gm or One Trillion Billion Microflora per ton compost*) self- generated population of native microflora within the compost heap, that speeds up the biodegradation process and alternately shortens the biodegradation period to 30 days.

Under IBM-IORF sustainability, 1000 ton of Novcom coir pith compost was made which potentially mitigated about 6000 ton GHG in terms of CO_2 equivalent. At the same time Pearson correlation coefficient (r) value (r = 0.9863) indicated that there was high degree of POSITIVE CORRELATION between measured and calculated GHG values and thus AFCA (version 1.0) can be utilized for GHG evaluation specially where Novcom Composting Technology is adopted.

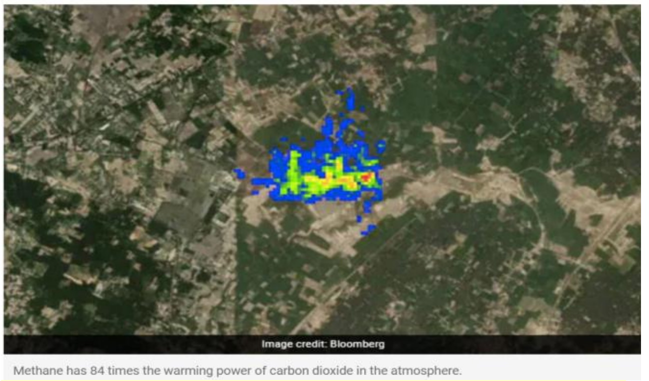
Thus Novcom coir pith composting could be an important component towards attending the Net Zero Goal, enable successful reclamation of degraded lands and improve crop productivity; while also generating additional mandays and options for income generation; that can empower farmers' livelihood.

Why Methane abatement is necessary ?

There has been a worldwide focus on curtailing carbon dioxide emission resultant from burning of fossil fuels, but it is also critical to cut methane emissions—not least because methane has a more powerful near-term warming effect than CO_2, but also because cutting methane emissions would have a more immediate impact on the climate. **A recent assessment from the United Nations Environment Programme (UNEP) and the Climate and Clean Air Coalition found that cutting farming-related methane emissions would be the key in the battle against climate change.** Methane mitigation is most important as it is the primary contributor to the formation of ground-level ozone, a hazardous air pollutant and greenhouse gas, exposure to which causes 1 million premature deaths every year. Methane is also a powerful greenhouse gas. Over a 20-year period, it is 80 times more potent at warming than carbon dioxide. At the same time, methane has accounted for roughly 30 per cent of global warming since pre-industrial times and is proliferating faster than at any other time since record keeping began in the 1980s.

According to data from the United States National Oceanic and Atmospheric Administration, even as carbon dioxide emissions decelerated during the pandemic-related lockdowns of 2020, atmospheric methane shot up.

Methane mitigation is more important because carbon dioxide remains in the atmosphere for hundreds to thousands of years. This means that even if emissions were immediately and dramatically reduced it would not have an effect on the climate until later in the century. But it takes only about a decade for methane to break down. So, reducing methane emissions now would have an impact in the near term and is critical for helping keep the world on a path to 1.5°C. Thus, methane anthropogenic reduction goals are between 44% and 67% to the 2010 level to achieve the maximum 1.5^{o}C global temperature increase by 2050 whereas anthropogenic CO_2 reduction goals are nearer 100% (IPCC 1.5^{o} target).



Methane has 84 times the warming power of carbon dioxide in the atmosphere.

Pic : Methane Cloud Spotted By Satellite Near India Waste Sites

Pic : COP27: U.N. to hunt sources of climate-warming methane from space

Debate on GWP of methane on 100 years basis or on a shorter scale

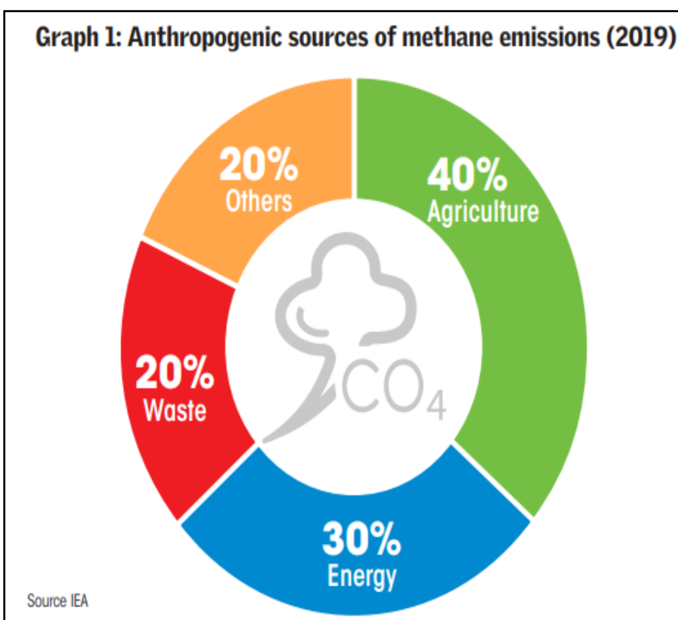
For many years, methane was overlooked in the climate change conversation. But scientists and policymakers are increasingly recognizing that methane reductions are crucial. Atmospheric concentration of methane is increasing faster now than at any time since the 1980s. At the same time though, annual emissions are only 3% w/w of those associated with CO_2 (0.56 $GtCH_4$/year *vs.* 14.5 $GtCO_2$/year for methane and CO_2 respectively) but methane has a radiative forcing approximately 120 times more than CO_2 immediately after it is emitted, which means that now is the methane moment.

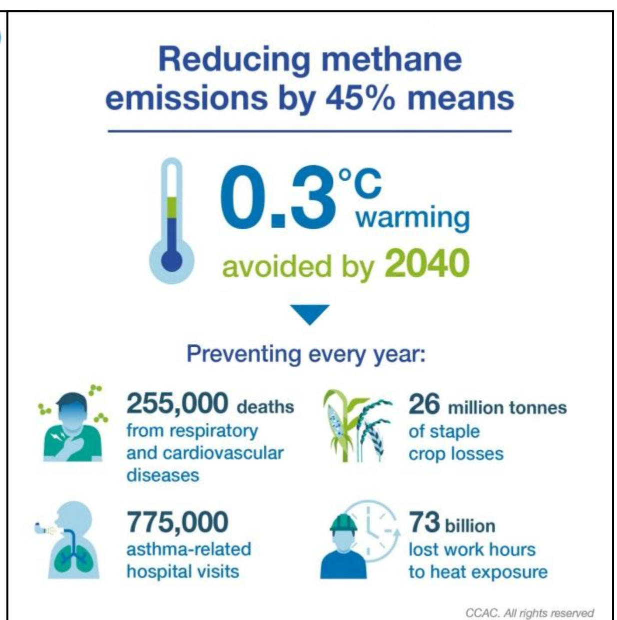
Acting now to reduce methane emissions will have immediate benefits to the climate that reductions in carbon dioxide cannot provide on their own. But there is an emerging debate whether, GWP of methane will be taken on 100 years basis (as IPCC recommended) or on a shorter scale. Because, GWP hides trade-offs between short- and long-term policy objectives inside a single time scale of 100 or 20 years. Increasingly there are calls for the use of different time horizons (*e.g.* 20 years) or even different metrics that better reflect climate change or align with climate targets (*e.g.* the global temperature change potential as described in the IPPC AR5.

The most common form, GWP_{100}, focuses on the climate impact of a pulse emission over 100 years, diluting near-term effects and misleadingly implying that short-lived climate pollutants exert forcing in the long-term, long after they are removed from the atmosphere. Meanwhile, GWP_{20} ignores climate effects after 20 years. Now, the challenge is majorly related to methane, which is a powerful greenhouse gas with a 100-year global warming potential 28-34 times that of CO_2. Measured over a 20-year period, that ratio grows 84-86 times. Despite methane's short residence time, the fact that it has a much higher warming potential than CO_2 and that its atmospheric volumes are continuously replenished make effective methane management a potentially important element in countries' climate change mitigation strategies .

According to J. Trancik, an MIT associate professor at the Institute for Data, Systems, and Society, more scientists are beginning to model the warming effects that today's methane emissions will have over the next 20 or 30 years, in order to predict more accurately whether humanity can avoid overshooting targets such as stopping global warming at 1.5 degrees Celsius.

Scientists also indicated that methane's short atmospheric life has important implications for the design of global climate change mitigation policies in agriculture. Results also showed that the choice of a particular metric for methane's warming potential is the key to determine optimal mitigation options, with metrics based on shorter-term impacts leading to greater overall emission reduction. Most importantly, when the ambition is to reduce warming in the next few decades, a shorter time horizon might be applied in comparing the effects of CO_2 and CH_4. Thus a two-value approach, which indicates the effect over two different time horizons, is suggested by a number of studies.





Methane mitigation from waste management and Agriculture sector can have significant impact on Climate change action.

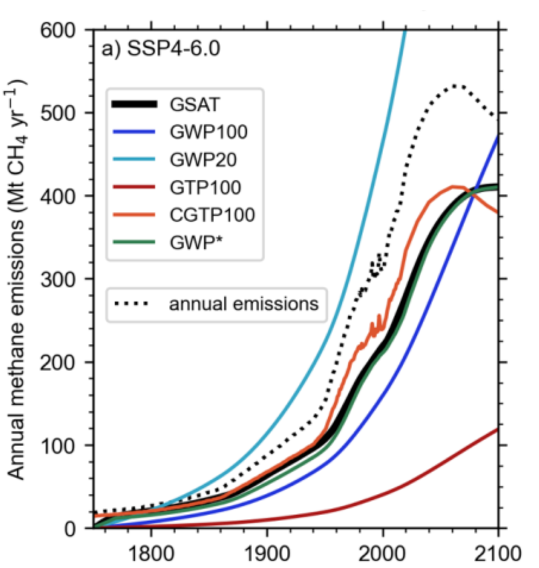
In the latest IPCC report (AR6), it has been clearly maintained that, IPCC does not recommend an emissions metric because the appropriateness of the choice depends on the purposes for which gases or forcing agents are being compared. Emissions metrics can facilitate the comparison of effects of emissions in support of policy goals. They do not define policy goals or targets but can support the evaluation and implementation of choices within multi-component policies (e.g., they can help prioritize which emissions to abate). **The choice of metric will depend on which aspects of climate change are most important to a particular application or stakeholder and over which time horizons.** Different international and National climate policy goals may lead to different conclusions about what is the most suitable emissions metric. **Although there is significant history of using single-basket approaches, supported by emissions metrics such as GWP-100, in climate policies such as the Kyoto Protocol, multi-basket approaches also have many precedents in environmental management, including the Montreal Protocol** (Daniel et al., 2012)

Hence, the moot point is that we do not have another 100 years to achieve our 2050 climate neutrality and net zero targets and whatever we need to change, have to be done now. So though under UNFCCC, GWP_{100} remains the standard: according to the Paris "rulebook," people can use other metrics to provide information; this comes with the requirement to provide supporting documentation.

Now, according to Abernethy and Jackson, Emission metrics, a crucial tool in setting effective exchange rates between greenhouse gases, currently require an arbitrary choice of time horizon. So they propose a novel framework to calculate the time horizon that aligns with scenarios achieving a specific temperature goal and to best align emission metrics with the Paris Agreement 1.5 ◦C goal. They recommend a 24 year time horizon, using 2045 as the endpoint time, with its associated GWP1.50 C = 75.

Assessment Report of IPCC (AR6) : Discussion regarding the use of a range of emission metrics, including GWP20 and GWP100 and how they perform

GSAT changes estimated with cumulative CO_2 equivalent emissions computed with GWP_{20} matches the warming trend for comparatively shorter time scale (a few decades) but quickly overestimates the response, whereas estimating emissions using GWP_{100} underestimate the warming potential (IPCC ARC 6, 2021).



So the moot point is we do not have another 100 years to achieve our 2050 climate neutrality and net zero targets and whatever we need to change, have to be done now.

Calculation of GHG emission potential from biowaste (primarily landfill materials) as per IPCC guideline (utilizing Carbon Assessment Tool : ACFA- Version 1.0)

GHG emission (MT in CO_2 equivalent) =

$[(LM_T \times LF_F \times MC_F \times DOC \times DOC_F \times F \times 16/12 - R) \times (1 - OX)] \times GWP_{CH4}$

LM_T : Total Landfill Material(MT)

LF_F : Fraction of Landfill Material disposed at site (if 100 % landfill material which is generated is deposited at site, then LF_F value will be 1.0, default value)

MC_F : Methane correction factor (fraction) (IPCC default value is 0.6, when there is no specific information)

DOC : Degradable organic carbon (fraction) (kg C/ kg landfill material)

DOC_F : Fraction DOC dissimilated (IPCC default is 0.77)

F : Fraction of CH_4 in landfill gas (IPCC default is 0.5)

16/12 : conversion of C to CH_4

R : Recovered CH_4 (MT) (in general value is 0 if not any specific treatment plants in disposal sites to recover methane

OX : oxidation factor (fraction – IPCC default is 0)

GWP_{CH4} : 75 (based on 24 year time horizon)

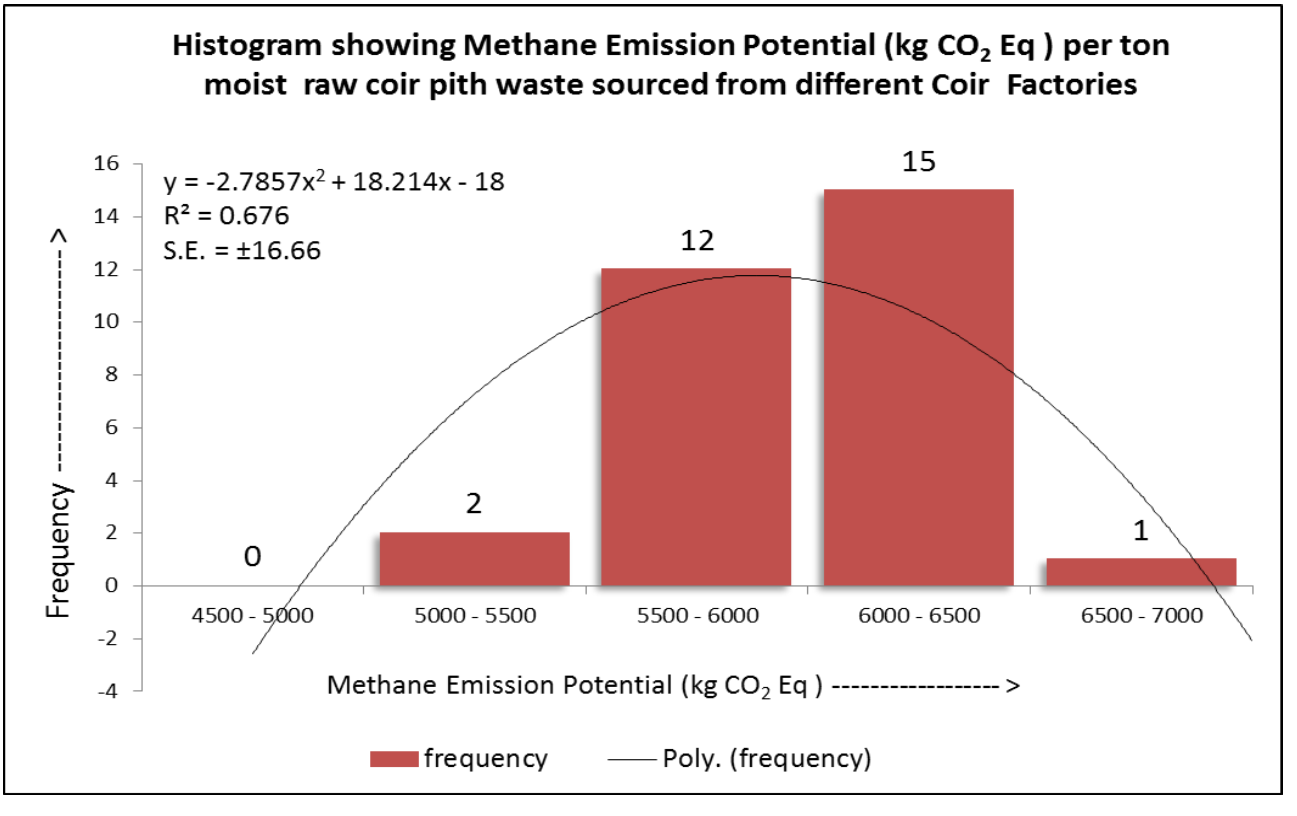


Fig. 3 : Histogram showing Methane Emission Potential (kgCO_2 Eq) per ton moist raw coir pith, as per IPCC guideline.

Thirty samples of raw coir pith were collected from different coir factories at Karnataka and analyzed to generate the required database for calculation of the methane emission potential (kg CO_2-eq) per ton moist raw coir pith waste, as per IPCC guideline**.** The GHG emission (kg CO_2-eq) per ton moist raw coir pith based on 24 years' time horizon varied from 5446 to 6963 kg CO_2-eq with a mean value of 6013.7 kg CO_2-eq. The histogram represents the distribution of numerical data in specific range, which showed that GHG emission potential of raw coir pith is mostly in the range of 6000 – 6500 kg CO_2-eq/ ton wet raw coir pith followed by 5500 – 6000 kg CO_2 eq/ ton wet raw coir pith (Fig. 1).

Study of GHG Emission in Novcom coir pith compost

Ten Novcom coir pith compost heaps were selected to study the emission of CO_2, CH_4, N_2O and NH_3 during biodegradation period under IBM-IORF Sustainability project.

Study of carbon dioxide (CO_2) emission under Novcom coir pith composting process : The CO_2 released during composting is considered biogenic, not anthropogenic, so it is not considered in greenhouse gas calculation. CO_2 emission measured on day basis during the Novcom composting process showed higher values in the 1st week which gradually decreased with progression in the composting period and became minimum after 30 days indicating completion of the biodegradation process. Total CO_2 emission during entire biodegradation period was 1.848 kg CO_2/ ton raw material.

Emission of Methane (CH_4) under Novcom Composting Technology: Methane is one of the contributor to non-biogenic greenhouse gas emissions from composting, and the majority of that CH_4 is emitted early in the composting process. In the case of Novcom coir pith composting process methane emission was found to be negligible (0.61 kg CO_2 equivalent per ton wet coir pith) as compared to that documented by several research workers in respect of other standard biodegradation processes (2.25 – 600 kg CO_2 equivalent per ton wet waste, considering $GWP_{24years}$ of CH_4 : 75). This might be attributed to the intense microbial activity within the Novcom Composting heap accelerated by the creation of favourable environment due to the application of subtle energy forms through Novcom solution.

Emission of Nitrous oxide (N_2O) under Novcom Composting Technology : Nitrous oxide (N_2O) emission during composting is an important issue. It not only leads to nitrogen (N) loss from compost, but also exacerbates the greenhouse effect. In case of Novcom coir pith composting, emission of nitrous oxide (N_2O) was about 5.86 kg CO_2 equivalent/ ton wet coir pith w.r.to reference range of 16.38 – 163.8 kg CO_2 equivalent/ ton wet waste (considering $GWP_{100years}$ of N_2O : 273).

The lower values under Novcom coir pith composting might be due to initial lower value of N in the raw material as well as higher speed of biodegradation under this method that is induced by the self- generated diversified microbial pool (in order of 10^{16} c.f.u. per gm moist compost) and not through any mechanization or artificial induction. The speedy nitrification process as well as faster immobilization of the nitrogen released due to organic matter breakdown by the high microbial pool; reduces the escaping chances of N_2O from Novcom Composting heap during the process of organic matter breakdown .

Emission of Ammonia (NH_3) under Novcom Composting Technology: Ammonia is one of the main compounds responsible for generation of offensive odours and atmospheric pollution due to composting of organic wastes with high nitrogen content. In case of Novcom coir pith composting, NH_3 emission (0.03 g CO_2 equivalent/ ton wet coir pith) decreased with progression of composting indicating intense microbial activity within compost heap that reduced the escaping chances of NH_3 during the biodegradation process. However, due to its very low CO_2 equivalency, NH_3 is generally not considered under the GHG calculation methodology, though it has a negative impact on environment & reduces the nutrient quality of compost.

Pic. Large scale Novcom coir pith composting at Mandya, Karnataka for Clean Food 'Net Zero' program

Total GHG emission during biodegradation of Novcom coir pith compost

To calculate the total GHG emission during biodegradation of Novcom coir pith compost we took the total emission value of methane (CH_4) and nitrous oxide (N_2O) in terms of CO_2 equivalent as per IPCC guideline. It was found that a total 6.47 kg CO_2 eq was emitted per ton of raw coir pith during the entire biodegradation period of 30 days. Now, considering the reference value of 200 kg GHG emission per tonne treated wet waste during composting, Novcom coir pith composting was about 31 times more efficient in terms of GHG mitigation which might be due to the prolific self- generated population of native microflora within the compost heap, that speed up the biodegradation process and alternately shortened the biodegradation period to under 30 days.

Case Study of GHG emission from 1000 ton landfill material (Coir pith) bio- converted utilizing Novcom Composting Technology under IBM–IORF Sustainability project at Mandya, Karnataka; during 2022 – 23.

Clean Food 'Net Zero' program was taken up under the IBM-IORF Sustainability Project, to establish the 'Net Zero' Model in Agriculture towards impactful climate action especially in respect of methane mitigation, towards degraded soil reclamation as well as to showcase the relevance of safe and sustainable agriculture in respect of crop yield improvement *vis-à-vis* farmers' empowerment. About 1000 ton of coir pith was collected from the nearby coir-pith factories and coir pith bioconversion was taken up under Novcom Composting Technology. The total GHG emission/ mitigation was evaluated through ACFA (version 1.0) – An Agriculture Carbon Assessment Tool, developed by IORF as per IPCC guideline, which uses an empirical equation to calculate total GHG emission from raw material under Novcom Composting Technology with inputs of moisture, carbon and nitrogen value from initial and final stages.

As per ACFA (version 1.0) – An Agriculture Carbon Assessment Tool, calculation of GHG emission from composting activity (E_{CA}) is as follows

E_{CA} (Kg CO_2 equivalent/ MT Raw Materials) = $E_T + E_{CM} + E_{CB}$

Where,

E_T : Total GHG Emission from Raw Material Transport (kg CO_2 equivalent/MT Raw materials)

E_{CM} : Total GHG Emission from Composting Activity (kg CO_2 equivalent/MT Raw materials)

E_{CB} : Total GHG Emission during Compost Biodegradation

Total GHG Emission from Raw Material Transport (E_T)

E_T : $[2 \times D_{LS} \times FE_V \times E_F] / V_{CC} + (E_{E1} \times V_w \times T_O) / V_{CC}$

$=[2 \times 10 \times 0.224 \times 2.644]/5 + [0.0975 \times 12 \times 2.5]/5$ kg CO_2 Equivalent / MT Raw material

= 2.954 kg CO_2 Equivalent MT Raw material

So, GHG emission for 1000 MT coir pith transport = 2954 kg CO_2 equivalent

Where,

D_{LS} : Total distance (in km) from composting unit to disposal site from where raw materials are collected (Default value 10 km upto 5,000 ton and 0.003 km / ton when value is > 5000 ton)

FE_V : Fuel Efficiency of the vehicle carrying the landfill material (i.e. litre of diesel / petrol / gasoline used to carry the vehicle 1 km) (Default value 0.224 litre diesel/km)[81]

E_F : Reference GHG emission value of the fuel used by the vehicle (Default value 2.653 kg CO_2equ / litre).

V_{CC} : Carrying Capacity of the vehicle carrying the landfill material (i.e. total amount of landfill material can be carried (in MT) in single trip). (Default value 5 MT).

E_{E1} : Embodied emissions factor for the vehicle per hour (Default value 0.0975 kg CO_2equ / hour/ ton)[5]

V_W : Total weight of the empty vehicle (Default value 12 MT)

T_O : Total Time of Operation (i.e. time (in hour) required to carry single trip landfill material from disposal site to composting unit) (Default value 2.5 hour upto 5000 ton and (1.5 +0.1 x Km) hour for < 5000 ton)

Total GHG Emission from Composting Activity (E_{CM})

=[(T_{CM} x F_M x E_F)+(T_{ECM} x E_M x EC_E)] +[(E_{E2} x M_w x T_{CM}) +(E_{E2} x M_{Ew} x T_{ECM})]

= [(0.2 x 5 x 2.644)+(0x 0.0 x 0.236)] +[(0.0975x 10 x0.2)+(0.0975x 0 x 0)] kg CO_2 equ

=2.839 kg CO_2 equivalent

So, GHG emission for 1000 MT coir pith preparation = 2839 kg CO_2 equivalent

Where,

T_{CM} : Total machine operating time for compost making (in hour) (Default value 0.2 hour / MT raw materials).

T_{ECM} : Total electric machine operating time for compost making (in hour) (Default value 0.0 hour / MT raw materials).

F_M : Total Fuel used per hour (in ltr) for compost making (Default value 5 ltr / hr)

E_F : Emission factor (kg CO_2 equivalent) per liter Fuel used (Default value 2.653 kg CO_2equ / litre)

E_M : Total Electricity used by machinery (in MJ) per hour for compost making (Default value 0 MJ)

EC_E : Emission factor (kg CO_2 equivalent) per MJ electricity used. (Default value 0.236 kg CO_2/ MJ)

E_{E2} : Embodied emissions factor per hour for the machinery used (Default value 0.0975 kg CO_2equ/ hour/ ton). (for both electric and diesel operated machinery)

M_w : Total Weight of the general machines used for compost preparation (Default value 10).

M_{Ew} : Total Weight of the electric machines used for compost preparation (Default value 0).

TL_C : Total Raw material used for compost making

Total GHG Emission during Compost Biodegradation (E_{CB})

To evaluate the total GHG emission during biodegradation of Novcom coirpith composting, we took the help of hypothetical equation developed by Bera *et al* [13] which was used by the carbon assessment toll ACFA (version 1.0).

Now total GHG emission during biodegradation of Novcom coir pith composting

= E_{N2O} (kg CO_2 equivalent / MT waste) + E_{CH4} (kg CO_2 equivalent / MT waste)

Now in case of Novcom compost

E_{N2O} (kg CO_2 Equivalent / MT waste) = [39.31 x $TNL_{20\ Days}$ (kg/ton waste) + 0.6338] x 1/1000 x 273 ----- (i) (Where $TNL_{20\ Days}$: Total Nitrogen Loss in first 20 days)

Calculation of $TNL_{20\ Days}$ from the analytical value

$TNL_{20\ Days}$ (kg/ton waste) = [(100– $M_{0\ Day}$) x ($TN_{0\ Day}$/100)-(100 – $M_{20\ Day}$) x ($TN_{20\ Day}$/100)]x10

=[(100 -50.76) x(0.59/100) –(100-69.20) x (0.76/100)] x 10 kg/ton waste

=0.6 kg/ton waste

So, E_{N2O} = [39.31 x 0.6 + 0.6338] x 1/1000 x 273 kg CO_2 Equivalent / MT waste

=6.44 kg CO_2 Equivalent / MT waste

E_{CH4} (kg CO_2 Equivalent / MT waste) = [0.06399x $TCL_{30\ days}$ (kg/ton waste) - 0.2498] x 1/1000 x 75 (Where $TCL_{30\ days}$: Total Carbon Loss in first 30 days)

Calculation of $TCL_{30\ days}$ from the analytical value

$TCL_{30\ days}$ (kg/ton waste) = $[(100 - M_{0\ Day}) \times (TOC_{0\ Day}/100) - (100 - M_{30\ Day}) \times (TOC_{30\ Day}/100)] \times 10$ $=[(100-50.76) \times (52.87/100) - (100-69.6) \times (37.53/100)] \times 10$ kg/ton waste

=146.2 kg/ton waste

So, E_{CH4} (kg CO_2 Equivalent / MT waste) = [0.06399x 146.2 - 0.2498] x 1/1000 x 75

=[9.355 – 0.2498] x 1/1000 x 75 kg CO_2 Equivalent / MT waste (Considering GWP_{24} of Methane = 75 for which detail discussion was done in earlier part of the paper)

=0.68 kg CO_2 Equivalent / MT waste

So, GHG emission during biodegradation for 1000 MT coir pith was 7120 kg CO_2 equivalent

So total GHG emission from 1000 ton Novcom coir pith composting is as follows

$E_{CA} = E_T + E_{CM} + E_{CB}$ (kg CO_2 equivalent/ 1000 MT raw coir pith)

=2954 +2839 + 7120 kg CO_2 equivalent / 1000 MT raw coir pith

==12.913 ton CO_2 Equivalent /1000 MT coir pith

Total GHG Offsetting with conversion of coir pith materials to Novcom coir pith compost

GHG Offsetting with conversion of coir pith materials to Novcom coir pith compost

GHG Offsetting with conversion of landfill materials to compost = GHG Emission from untreated waste - GHG Emission during composting

=(6013.7 -12.91) MT CO_2 equivalent /1000 MT coir pith

=**6000.79 ton CO_2 equivalent /1000 MT coir pith**

12th IconSWM-CE & IPLA Global Forum 2022
12th International Conference on Sustainable Waste Management & Circular Economy and IPLA Global Forum 2022
International Society of Waste Management, Air and Water (ISWMAW)
Sri Venkateswara University, Tirupati, Andhra Pradesh, India
November 30 - December 03, 2022
IconSWM-CE Excellence Award 2022
for Best Paper Presentation
Title of Paper: Technological breakthrough for large scale Bioconversion of Coir pith, a Highly Soil and Water Polluting Material, huge GHG Emitter with a very high GWP value, towards Development of an effective GHG Offsetting Model
Authors: Bera R., Datta A., Bose S., Barik A.K., Mallick R., Das A., Ganguli M., Narasimhan V.L., Quah E., Seal A.
Prof. Dr. S. Varadarajan
Convener, 12th IconSWM-CE & IPLA Global Forum 2022, SVU, Tirupati, India
Prof. Dr. Sadhan K Ghosh
Founder & Chairman, IconSWM-CE and IPLA-GF, President - ISWMAW
ISWMAW
IPLA
Certificate issued on December 02, 2022 from ISWMAW and SVU at Tirupati, Andhra Pradesh, India

Pic. : Presentation of the Coir pith bioconversion case study under IBM-IORF Sustainability Project by Dr. Antara Seal in 12th International Conference on Sustainable Waste management and Circular Economy and IPLA Global Forum,2022; which received IconSWM-CE Excellence Award 2022 for Best Paper Presentation.

Comparison of GHG emission from actual study and value calculated with utilization of hypothetical equation from AFCA (version 1.0)

In the following study we compared GHG emission from actual study and from empirical equation under AFCA (version 1.0) to evaluate how much this data sets are correlated and whether this tool can be used in any practical projects as actual study for every case is not practically visible and economically viable. **Pearson correlation coefficient (r) value (r = 0.9863) indicated that there was high degree of relationship between measured and calculated GHG values and thus AFCA (version 1.0) can be utilized for GHG evaluation specially where Novcom composting technology is adopted**

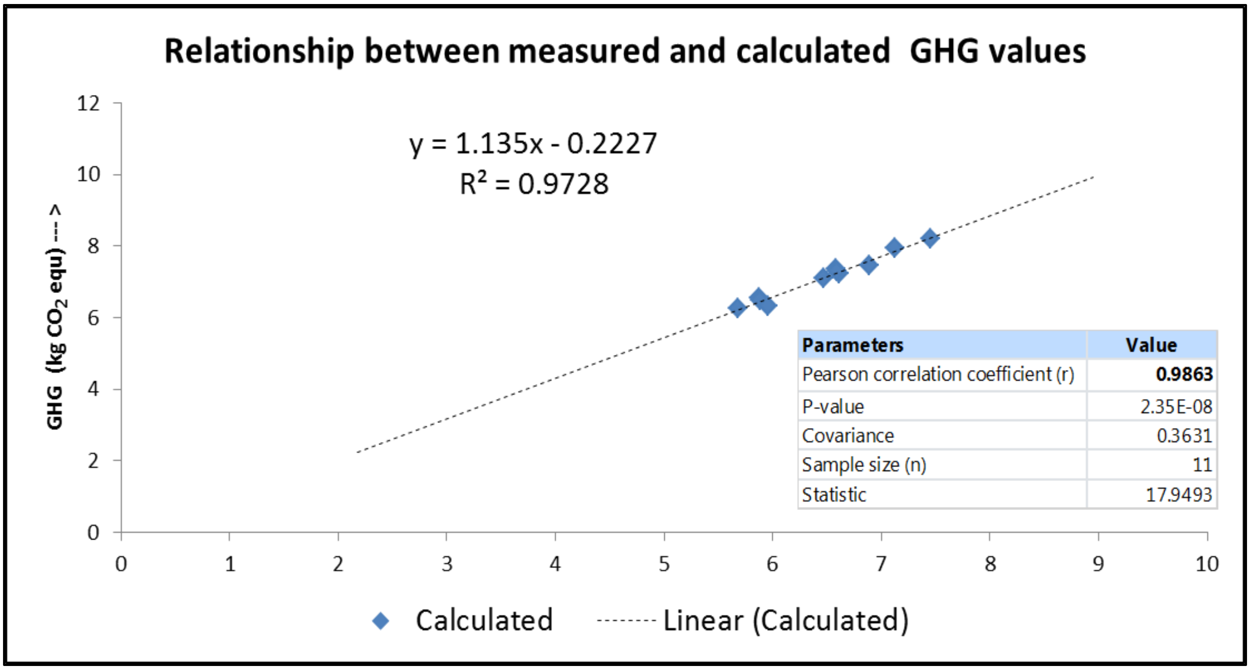


Fig. 4 : Relationship between measured and calculated GHG values (kg CO_2 equivalent / MT wet raw coir pith) under IBM-IORF Sustainability Project at Mandya, Karnataka.

Pic. : Demonstration of Clean Food Net Zero Model - Celebrating World Food Day at Mandya.

CHAPTER 3 : Soil Quality Assessment and Soil Resource Mapping

Summary

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 the context of climate change and sustainable agricultural initiative, importance of soil quality assessment enhances many fold. Under IBM-IORF Sustainability project at Mandya, Karnataka we took soils from the entire project village and analyzed for 25 soil quality parameters encompassing physical, physicochemical, fertility and biological properties to develop resource maps of the village as a benchmark study and a ready reckoner for all the farmers towards soil-test based sustainable soil management.

Soil Quality analysis indicated that the soils are basically red gravelly soils with more than 50 % gravel content in most of the area which imposes a major bottleneck for agriculture. Apart from that the soil is poor in organic carbon, moderate in available N & P but very high available K which might be due to potash rich parent materials. Soil biological properties also depict poor biological activities in the soil which is a major cause of concern both in respect of crop sustainability as well as soil erodibility potential.

IORF also developed COMPREHENSIVE SOIL HEALTH CARD for the farmers which includes **25 quality parameters as well as 5 Soil Quality Indices in colour coding** for easy understanding of the farmers regarding their soil status.

Introduction

The Climate Change is existential and already affecting food security through increasing temperatures, changing precipitation patterns, and greater frequency of some extreme events. Besides climate change, land degradation and loss of biodiversity, threatens the delivery of ecosystem services, especially food production.

Soil degradation, which contributes to 36–75 billion tons of land depletion every year, threatens the global food supply; which implies that now; More Crop has to be Produced from Less Land. **Soil degradation in India is estimated to be occurring on 147 million hectares** (Mha) of land, due to inappropriate agricultural practices including excessive and unbalanced use of inorganic fertilizers, poor irrigation and water management techniques, pesticide overuse, inadequate crop residue and/or organic carbon inputs, and poor land use planning.

Hence, together with a Safe Approach towards Human Health, **a Safe Approach to the Soil and the environment will be crucial to Restore Ecosystem Function Abilities and Deliveries**. Two initiatives, i.e., increasing the productivity of Marginal Soils and Reclamation of Degraded Soils for restoring its suitability for agriculture; though herculean tasks can provide significant impact in this arena.

Importance of Healthy Soil

Soil health is an integrative property that reflects the capacity of soil to respond to agricultural intervention, so that it continues to support agricultural productivity, food quality, environmental resilience, and ecosystem sustainability. 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 people and animals (FAO, 2015).Thus it was said that, **Healthy Soil is A Prerequisite for Achievement of the Sustainable Development Goals (SDG's) (** FAO, World Soil Day, 5th December, 2021).

The Sustainable Development Goal - 2 of the UN depicts . . .

- Higher Production from Lesser Inputs or More Output from Less Input.
- More Production from Less Soil – The Soil Resource is continuously Depleting, Crop productivity is either Stagnant or Declining but the Increasing Population means More and More Mouths to Feed.

But Most Importantly, the knowledge about Soil Health Status is Crucial in order to judge what steps to undertake for Sustainable Soil Management.

Soil Quality and Relevance of Soil Quality Components

Soil quality is defined as the soils capacity to function within natural or managed ecosystem boundaries and to sustain plant productivity while reducing soil degradation. Due to increasing land use pressures, soil quality assessment is in growing demand. But soil quality is a complex functional concept and cannot be measured directly in the field or laboratory but can only be inferred from soil characteristics, a range of soil parameters or indicators has been identified to estimate soil quality. However, to understand soil quality status in a composite manner Soil Quality Index (SQI) can be handy but a standard set of proceedings to assign a Soil Quality Index (SQI) would be beneficial.

Soil Quality Index is an important tool for bringing forth the Status of Soil Health especially in relation to Crop Growth; under existing cultivation practices. It also helps towards formulation of specific protocol for enhancement of soil quality (in case of lower status) through management of specific soil parameter that is found to contribute majorly towards lowering of SQI value.

Quality Index of soil was developed by IORF, Kolkata in collaboration with Krishi Vigyan Kendra, Howrah, BCKV, ICAR and forms a sustainability tool towards formulation of soil health management protocol under any sustainable agriculture initiative.

Development of Soil Quality Index (SQI)

Quality Index of soil was measured as the area of the triangle with Soil Physical Index, Soil Fertility Index and Soil Microbial Activity Potential Index; as three vertices as per the index formulation concept of Kang et al, 2005.

Soil Physical Index : Soil Physical Index was formulated by taking five major soil physical parameters viz. soil depth, Soil Coarse Fragment (%), soil texture, soil bulk density and soil aggregates. A Scoring system was developed to score the individual quality parameter as against their analytical value and the index was formulated as per the following index

$$\text{Soil Physical Index (PI)} \quad = \quad a/n \sum_{I=1}^{n}(I1 + I2 + I3 + \ldots\ldots\ldots\ldots. + In) \qquad \ldots\ldots\ldots\ldots. \text{(i)}$$

Where, 'n' is the number of soil physical parameters undertaken for calculation of Soil Physical Index and 'a' is the number of soil physical parameters above critical limits. In the present formulation the critical limits are considered to be the lowest scoring value.

Soil Fertility Index : Soil Fertility Index was formulated by taking seven major soil parameters viz. pH, ECe, organic carbon, available N, available P2O5, available K2O and available SO4. A Scoring system was developed to score the individual quality parameter as against their analytical value and the index was formulated as per the following index

$$\text{Soil Fertility Index (FI)} \quad = \quad a/n \sum_{I=1}^{n}(I1 + I2 + I3 + \ldots\ldots\ldots\ldots. + In) \qquad \ldots\ldots\ldots\ldots. \text{(ii)}$$

Where, 'n' is the number of soil parameters undertaken for calculation of Soil Physical Index and 'a' is the number of soil physical parameters above critical limits. In the present formulation the critical limits are considered to be the lowest scoring value.

Soil Microbial Activity Potential : Soil Microbial Activity Potential (MAP) was formulated by taking six major soil biological parameters viz. soil microbial biomass, soil enzyme activities: FDAH (fluorescein diacetate), microbial quotient (qMBC), microbial metabolic quotient (qCO2), microbial respiration quotient (QR) and specific hydrolytic activity (qFDA) . A scoring system was developed to rate the individual quality parameter as against their analytical value and the index was formulated as per the following equation:

$$\text{Soil Microbial Activity Potential (MAP)} \quad = \quad a/n \sum_{I=1}^{n}(I1 + I2 + I3 + \ldots\ldots\ldots\ldots. + In) \qquad \ldots \text{(iii)}$$

Where, 'n' is the number of soil physical parameter undertake for calculation of Soil Physical Index and 'a' is the number of soil physical parameters above critical limits. In the present formulation the critical limits are considered to be the lowest scoring value.

Soil Quality Index (SQI) : Now soil quality Index 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. Value of soil physical index(PI), soil fertility Index (FI) and soil microbial activity potential were first bring to homogeneity through linear Indexing formula
(Velasquez et al, 2007).

$$IS = 0.1 + (VS - b) /(a - b) \times 0.9 \text{ -------------------- (iv)}$$

where

a = maximum value of the Index (Is), i.e 35, 30 and 25 in case of physical index, soil fertility index and soil microbial index

b = Minimum value of the Index (Is), i.e. 1.

Now after homogenizing the value of all three index, these three indices were represented in radar graph as a, b and c, respectively, which are the three lines of different lengths originating from a common point ‘O’. By joining the tail ends of these three lines, triangle is formed and the area of that triangle was considered as the Soil Quality Index value.

Overview of Soils of Mandya District

Mandya is predominantly an agrarian district located in the south of the state between 760 19’ and 770 20’E longitude and 120 13’ and 130 04’ N latitude at an altitude of 2500 – 3000 ft. above MSL.

The major rock types of the Mandya district belong to Archaean era and consist of a wide variety of granite, gneisses and schist with associated quartzite and crystalline limestone.

The soil of Mandya district is derived from granites and gneisses and the texture range from red sandy loams to red clay loam very thin on ridges and higher elevations and comparatively thick in valley portions.

The area belongs to agro-ecological sub region 8.2 in central Karnataka Plateau, hot, moist semi arid ESR with medium to deep red loamy soils, low AWC and LGP 120-150 days

Soil Analysis – The need in Indian Perspective

Soil degradation in India is estimated to be occurring on 147 million hectares (Mha) of land due to Inappropriate agricultural practices including excessive and unbalanced use of inorganic fertilizers, poor irrigation and water management techniques, pesticide overuse, inadequate crop residue and/or organic carbon inputs, and poor land use planning.

Soil Analysis – The Present Situation In India

The Need for Soil Health Management and the requirement of Scientific Guidelines in this respect is further justified by the facts that . . .

- The existing NPK consumption ratio in the country is skewed at 8.2:3.2:1 as against the preferred ratio of 4:2:1. indicating the improper usage of chemical fertilizers

- Thus, imbalanced application of fertilizers have caused deficiency of primary nutrients (i.e. NPK), secondary nutrients (such as sulphur), and micronutrients (boron, zinc, copper etc.), in most parts of country.

- According to a study, In India, in general, blanket fertilizer recommendations are followed for N, P & K which rarely matches soil fertility need, and often ignoring secondary and micro nutrients, in the various cropping systems followed by small and marginal farmers

Pic.: Marginal soils require detailed soil analysis towards sustainable crop production.

Soil Sampling in the Project Area

Grid Map for Soil Sampling was prepared for the Project Area at Kalenahalli village. Soil sampling was preceded by actual field traverse to get a preliminary idea regarding the land physiography and the local vegetation.

10 hectare Grid was considered for soil sampling and samples were collected from the project area. As the soil of the project area was found to have a close to 50% gravel content, so the samples were first processed to remove the gravel, then packed properly in zipper pouches and shipped to IORF Laboratory for Soil Quality Analysis. It was also made sure that the soil samples reached destination within 5 days of collection, which was especially critical for authentic microbiological analysis.

Pic.: Soil sampling team at Kalenahali village, Mandya, Karnataka for collection of soil samples under IBM-IORF Sustainability Project

Pic.: Soil sampling team at Kalenahali village, Mandya, Karnataka.

Soil Characteristics in the Project Area

The area is a combination of plain and undulating plains with mostly reddish coloured soil with 40 to 60 % gravel content. Rocks are exposed in few areas and remains unsuitable for agricultural use.

As per textural class (Table 1), the soils varied from sandy loam to sandy clay loam, sand percentage varying from 59 to 86 percent. Most importantly, majority of the soils have low silt percent (<10.0 %) and in some soils, it is as low as 1 – 2 percent only. Due to light texture and very low organic carbon, bulk density is also low (1.26 – 1.48 gcm^3), but presence of small to medium gravels hinder proper root penetration in soil increasing the proneness to abiotic stress.

At the same time, **due to higher sand percent, gravel content and lack of organic matter in soil, soil aggregates in majority area is very low to low and prone to soil erosion** specially in the undulating plains.

Pic.: Soil and landscape of Kalanahalli village, Mandya, Karnataka

Analysis of soil physicochemical and fertility parameters (Table 2) indicated Strongly acidic to Neutral soil pH. The Soil samples were grouped as per dominant land use and it was noticed that soil pH varied widely irrespective of the land use pattern. This component has to be taken into consideration in respect of sustainable crop production.

Soil Organic carbon, is the key element that determines soil quality, fertility, agricultural profitability, and atmospheric carbon dioxide (CO_2) fixation. In the project area, soil organic carbon is one of the most limiting factor as organic carbon status of most soil is poor to very poor and mean value under different land use varied from 0.42 to 0.57 %.

Table 1 : Soil Quality Evaluation of the Project Area under IBM-IORF Sustainability Project.

Sl No	Major Land Use	Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (gcm^{-3})	Aggregates	Soil Depth	Coarse Fragment
1	**Paddy**	60.3 – 82.7 (70.5 ± 3.81)	1.8 – 16.0 (7.1 ± 2.5)	11.4 – 34.9 (22.5 ± 4.15)	Sandy Loam to Sandy Clay Loam	1.26– 1.41 (1.37 ± 0.03)	Very Low to Medium	Moderate Limitation	Moderate to Strong Limitations
2	**Ragi**	71.9 – 80.1 (72.2 ± 2.11)	1.8 – 16.3 (7.5 ± 1.22)	11.6 – 18.3 (20.2 ± 1.86)	Sandy Loam	1.36 – 1.48 (1.42 ± 0.02)	Low to Very Low	Moderate to Strong Limitation	Strong to Very Strong Limitations
3	**Vegetable and others**	70.2 – 86.7 (76.3 ± 3.40)	1.1 – 7.9 (3.9 ± 1.20)	12.2 – 25.9 (19.9 ± 2.60)	Sandy Loam to Sandy Clay Loam	1.34 – 1.41 (1.37 ± 0.01)	Very Low to Medium	Strong Limitation	Strong to Very Strong Limitations
4	**Sugarcane**	59.0 – 84.6 (73.0 ± 2.74)	0.3 – 10.7 (4.1 ± 0.97)	13.8 – 34.5 (22.8 ± 2.25)	Sandy Loam to Sandy Clay Loam	1.28 – 1.35 (1.33 ± 0.01)	Very Low to Medium	Moderate to Strong Limitation	Strong to Very Strong Limitations
5	**Coconut**	58.6 – 85.7 (76.2 ± 2.23)	1.8 – 15.9 (9.8 ± 3.11)	10.5 – 34.3 (14.1 ± 1.66)	Sandy Loam to Sandy Clay Loam	1.29 – 1.43 (1.37 ± 0.01)	Very Low to Medium	Moderate to Strong Limitation	Strong to Very Strong Limitations
6	**Coconut based intercropping**	64.6 – 85.5 (73.3 ± 1.89)	0.3 – 12.6 (4.4 ± 1.03)	7.5 – 30.5 (22.4 ± 1.98)	Sandy Loam to Sandy Clay Loam	1.26 – 1.42 (1.32 ± 0.02)	Very Low to Medium	Moderate to Strong Limitation	Very Strong to Moderate Limitations
7	**Non Agricultural Use**	60.6 – 86.7 (73.0 ± 2.59)	1.1 – 12.7 (6.65 ± 1.35)	10.5 – 30.5 (20.3 ± 2.01)	Sandy Loam to Sandy Clay Loam	1.15 – 1.46 (1.30 ± 0.04)	Very Low to Medium	Moderate to Very Strong Limitation	Strong to Very Strong Limitations

The soil analysis data has been presented in respect of seven different land use types in order to provide a basic idea regarding the soil health status under different anthropogenic use

Soil Available NO_3 indicated the readily available N, and varied widely between 5.6 and 64.0 ppm.

Analysis of soil available NPK indicated low to moderate availability of N and P in most of the soil where as high to very high available potash was recorded in most of the cases. The potash richness of the soils was probably due to the weathering of ancient crystalline and metamorphic rocks generally acid granites, quartz rocks, gneiss, and felspathic rocks.

Soil biological properties *viz.* Soil Respiration, MBC, FDAH, Substrate Induced Respiration, qMBC, qCO_2, qFDA and QR were analyzed and shown in Table 3. In general the low organic carbon and humus content in red soil causes an inherently lower microbial activity, conventional agricultural practices in such soil further depletes the microbial status.

The other biological parameters also depict poor biological activities in the soil which is major cause of concern both in respect of crop sustainability as well as soil erodibility potential.

Pic.: Variation of soil colour in the project area indicated variation of soil characteristics

Table 2 : Soil Quality variation in terms of physicochemical and fertility parameters under dominant land use at Mandya, Karnataka, India in IBM-IORF Sustainability Project.

Sl No	Major Land Use	pH_{water}	ECe	Org. C	Av NO_3	Av-N	Av P_2O_5	Av. K2O	Av- SO_4
		(1:2.5)	($dCmM^{-1}$)	%	(ppm)	< ----------------	(Kg/ ha)	----------------	>
1	Paddy	5.75 – 6.62 (6.06 ± 0.15)	0.44 – 1.30 (0.81 ± 0.15)	0.39 – 0.75 (0.53 ± 0.06)	16.8 – 48.0 (32.7 ± 5.31)	273 – 370 (321 ± 16.9)	13 – 57 (30 ± 8.08)	244 – 691 (420 ± 75.4)	622 – 655 (635 ± 6.28)
2	Ragi	5.01 – 6.68 (5.63 ± 0.37)	0.33 – 0.66 (0.50 ± 0.08)	0.32 – 0.50 (0.42 ± 0.04)	13.4 – 42.7 (25.9 ± 7.18)	276 – 314 (292 ± 7.83)	18 – 45 (27 ± 6.37)	461 – 678 (596 ± 49.8)	722 – 790 (748 ± 15.7)
3	Vegetable and others	5.14 – 6.24 (5.75 ± 0.22)	0.37 – 1.13 (0.71 ± 0.17)	0.36 – 0.96 (0.55 ± 0.11)	6.4 – 39.1 (17.2 ± 5.76)	257 – 395 (304 ± 24.4)	14 – 65 (48 ± 9.23)	312 – 732 (567 ± 11.4)	638 – 689 (665 ± 11.4)
4	Sugarcane	5.28 – 6.50 (6.09 ± 0.11)	0.29 – 1.12 (0.53 ± 0.07)	0.28 – 0.63 (0.4. ± 0.03)	12.2 – 36.8 (23.3 ± 2.38)	232 – 354 (281 ± 13.0)	4 – 87 (30 ± 6.76)	379 – 676 (521 ± 28.7)	554 – 773 (687 ± 18.0)
5	Coconut	5.01 – 6.59 (5.91 ± 0.14)	0.38 – 1.36 (0.73 ± 0.07)	0.35 – 0.72 (0.54 ± 0.03)	9.8 – 37.5 (24.3 ± 2.36)	238 – 364 (279 ± 9.15)	19 – 125 (45 ± 7.07)	529 – 786 (658 ± 19.4)	588 – 756 (665 ± 14.2)
6	Coconut based intercropping	5.67 – 6.71 (6.20 ± 0.12)	0.37 – 1.25 (0.63 ± 0.07)	0.36 – 0.81 (0.50 ± 0.04)	12.2 – 31.2 (19.3 ± 1.90)	213 – 379 (274 ± 11.8)	10 – 137 (48 ± 11.5)	434 – 786 (610 ± 32.4)	588 – 756 (680 ± 16.1)
7	Non Agricultural Use	5.77 – 6.70 (6.08 ± 0.09)	0.34 – 1.74 (0.75 ± 0.15)	0.23 – 1.03 (0.57 ± 0.08)	5.6 – 64.0 (28.0 ± 4.93)	207 – 364 (295 ± 15.9)	11 – 102 (35 ± 9.04)	312 – 698 (536 ± 36.9)	504 – 739 (632 ± 24.8)

Table 3 : Soil Quality variation in terms of microbial properties under dominant land use at Mandya, Karnataka, India in IBM-IORF Sustainability Project.

Sl No	Major Land Use	MBC (µ C/gm dry soil)	BR (mg CO_2 /gm dry soil/day)	FDAH (µg/gm dry soil)	SIR (microgram CO_2 /gm dry soil/hr.)	qMBC	qCO_2	q FDA	Qr
1	Paddy	28.1 – 122.9 (64.9 ± 15.9)	0.022 – 0.073 (0.051 ± 0.01)	10.1 – 35.9 (19.7 ± 4.95)	0.69 – 3.06 (1.61 ± 0.40)	0.49 – 2.51 (1.30 ± 0.35)	0.59 – 1.19 (0.84 ± 0.10)	0.13 – 0.62 (0.39 ± 0.09)	0.024 – 0.048 (0.034 ± 0.01)
2	Ragi	22.8 – 151.6 (66.0 ± 29.0)	0.038 – 0.078 (0.06 ± 0.009)	4.14 – 19.3 (14.4 ± 3.53)	0.56 – 3.78 (1.64 ± 0.73)	0.58 – 3.03 (1.51 ± 0.54)	0.51 – 3.16 (1.44 ± 0.60)	0.13 – 0.48 (0.34 ± 0.08)	0.032 – 0.129 (0.058 ±0.024)
3	Vegetable and others	32.7 – 233.0 (103.8 ± 34.8)	0.009 – 0.159 (0.054 ± 0.03)	9.05 – 32.5 (20.6 ± 4.47)	0.81 – 5.81 (2.58 ± 0.87)	0.62 – 6.47 (2.30 ± 1.07)	0.09 – 1.67 (0.71 ± 0.29)	0.25 – 0.56 (0.37 ± 0.05)	0.003 – 0.067 (0.029 ± 0.01)
4	Sugarcane	36.2 – 148.2 (67.7 ± 10.3)	0.030 – 0.143 (0.069 ± 0.01)	0.42 – 31.0 (13.7 ± 2.73)	0.90 – 3.69 (1.68 ± 0.26)	0.74 – 4.36 (1.71 ± 0.33)	0.46 – 1.74 (1.11 ± 0.12)	0.01 – 0.67 (0.31 ± 0.05)	0.029 – 0.072 (0.045 ±0.005)
5	Coconut	25.4 – 273.2 (74.6± 16.4)	0.019 – 0.29 (0.066 ± 0.02)	6.24 – 40.31 (16.38 ± 2.46)	0.62 – 6.82 (1.85 ± 0.41)	0.47 – 7.81 (1.55 ± 0.49)	0.11 – 11.43 (1.58 ± 0.77)	0.15 – 0.64 (0.29 ± 0.04)	0.004 – 0.465 (0.064 ± 0.03)
6	Coconut based intercropping	29.9 – 117.2 (61.0 ± 8.76)	0.019 – 0.121 (0.072 ± 0.01)	1.20 – 26.41 (14.7 ± 2.15)	0.74 – 2.92 (1.50 ± 0.22)	0.39 – 3.08 (1.37 ± 0.26)	0.37 – 3.11 (1.31 ± 0.23)	0.03 – 0.60 (0.31 ± 0.05)	0.015 – 0.126 (0.053 ± 0.01)
7	Non-Agricultural Use	29.9 – 162.4 (68.5 ± 12.1)	0.010 – 0.147 (0.053 ± 0.01)	3.10 – 37.3 (17.4 ± 3.97)	0.74 – 4.05 (1.70 ± 0.30)	0.52 – 2.24 (1.32 ± 0.19)	0.10 – 1.98 (0.83 ± 0.18)	0.05 – 0.50 (0.29 ± 0.05)	0.004 – 0.080 (0.033 ±0.007)

Note :

BR : Soil Basal Respiration (mg.CO_2.C/gm dry soil per day); **Soil MBC :** Soil Microbial Biomass (µg.CO_2.C/gm dry soil); **FDAH :** Fluorescein di-acetate hydrolyzing activity (FDAH) (µg/gm dry soil); **SIR :** Substrate Induced Respiration (microgram CO2 /gm dry soil/hr.); **qMBC :** Microbial Quotient (MBC per unit Org. C) ; **qCO_2 :** Microbial Metabolic (Soil respiration per unit MBC); **qFDA :** FDAH Quotient (FDAH per unit Org. C); **QR :** Microbial Respiration Quotient (Ration of BR and SIR).

Analysis of soil available NPK indicated low to moderate availability of N and P in most of the soil where as high to very high available potash was recorded in most of the cases. The potash richness of the soils was probably be due to the weathering of ancient crystalline and metamorphic rocks generally acid granites, quartz rocks, gneiss, and felspathic rocks.

Soil biological properties viz. Soil Respiration, MBC, FDAH, Substrate Induced Respiration, qMBC, qCO_2, qFDA and QR were analyzed and shown in Table 3. In general the low organic carbon and humus content in red soil causes an inherently lower microbial activity, conventional agricultural practices in such soil further depletes the microbial status. The other biological parameters also depict poor biological activities in the soil which is a major cause of concern both in respect of crop sustainability as well as soil erodibility potential.

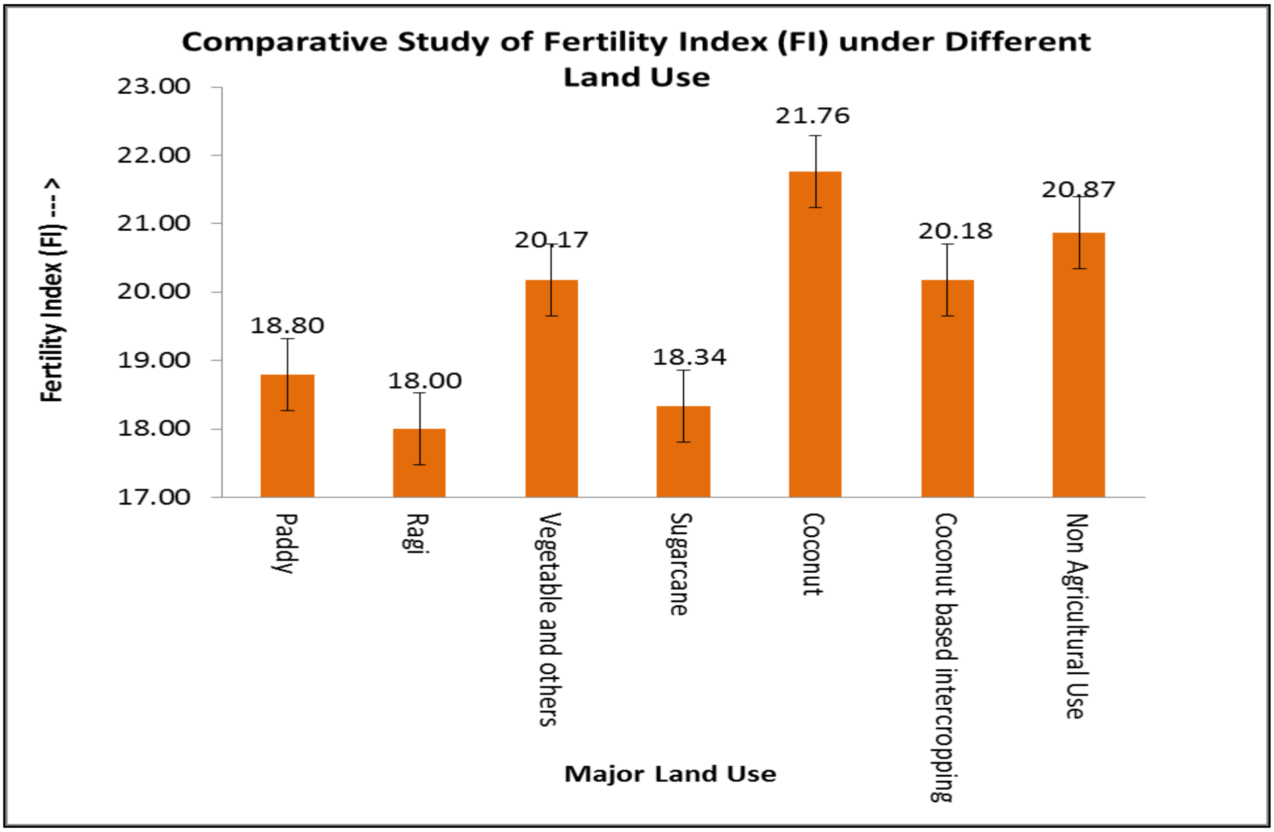


Fig 1 : Comparative Study of **Soil Fertility Index (FI)** under Different Land Use at Mandya, Karnataka in IBM-IORF Sustainability project

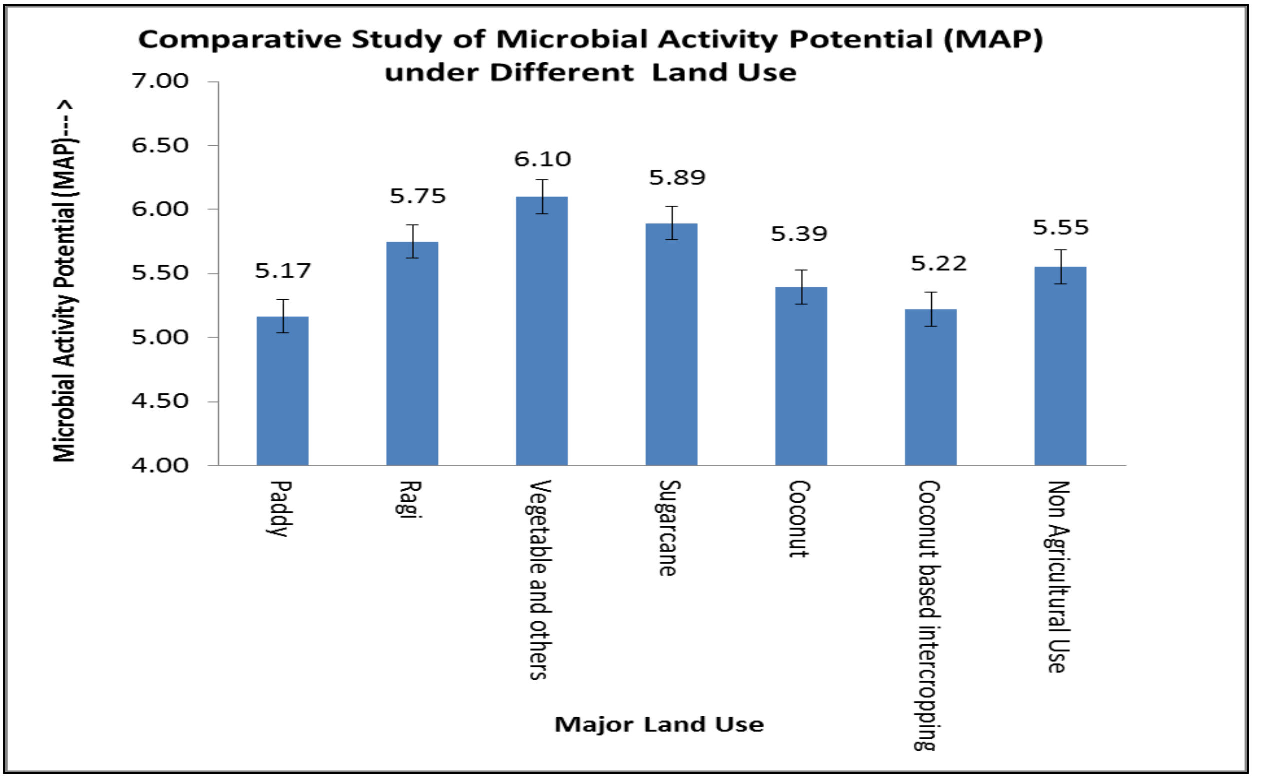


Fig 2 : Comparative Study of **Soil Microbial Activity Potential (MAP)** under in under IBM-IORF Sustainability project

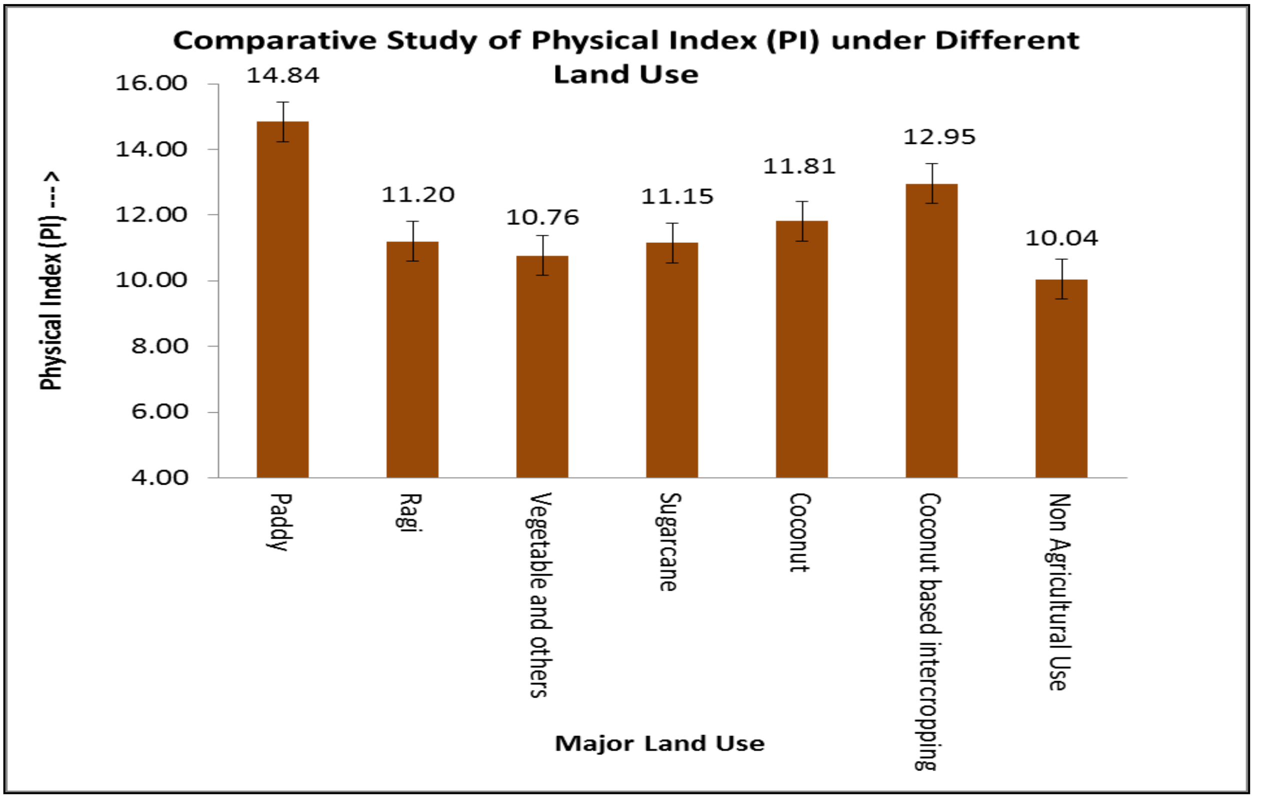


Fig 3 : Comparative Study of **Soil Physical Index (PI)** under Different Land Use at Mandya, Karnataka in IBM-IORF Sustainability project

SOIL QUALITY INDICES under different land use

SOIL FERTILITY INDEX (FI) is a tool for understanding the overall nutritive status of a soil for crop production as well as the extent of management required to sustain a desired yield. This tool was developed by IORF considering seven major soil parameters *viz.* pH, organic carbon, available N, available NO_3, available P_2O_5, available K_2O and available SO_4. A higher FI value indicates a balanced nutritional approach towards sustainable crop production.

This initiative was undertaken to help the famers understand their soil in terms their potential to support the crop nutritional requirements. A soil might have varying status of available- N, P, K and S, but only FI can help understand the overall nutrient supplying potential of their soil in terms of low, moderate, high, etc. **Soil Fertility Index (fig 1) varied from 18.00 to 21.76 (mean value) under different land use. It was highest (FI: 21.7) for coconut plantation and lowest for Ragi (FI : 18.00).**

SOIL MICROBIAL ACTIVITY POTENTIAL (MAP) is actually a tool, which indicates the overall soil microbial status and its activity towards soil nutrient dynamics. It was formulated by IORF taking six major soil biological parameters *viz.* soil microbial biomass, soil enzyme activities: *FDAH (fluorescein diacetate),* microbial quotient (qMBC), microbial metabolic quotient (qCO_2), microbial respiration quotient (QR) and specific hydrolytic activity (qFDA). Higher MAP value indicates a higher potential of the soil as a medium for sustainable crop production and also confirms the presence of the 'Soil Microbiological Barrier' against the soil borne disease causing pathogens.

The MAP value (fig 2) was very low in most of the soil indicating limited biological activity which could be a major limiting factor towards crop sustainability.

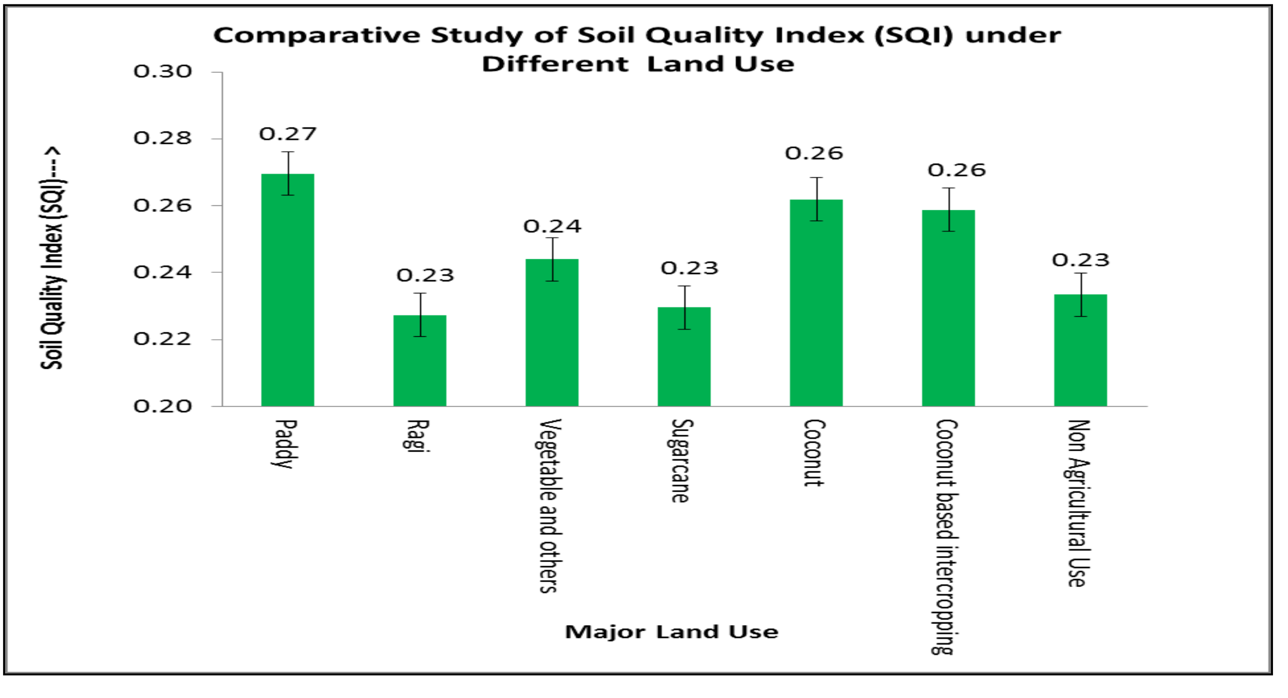


Fig 4 : Comparative Study of **Soil Quality Index (SQI)** under Different Land Use at Mandya, Karnataka in IBM-IORF Sustainability project

SOIL PHYSICAL INDEX (PI) : Physical properties play an important role in determining soil's suitability for agricultural, environmental and engineering uses. The supporting capability; movement, retention and availability of water and nutrients to plants; ease in penetration of roots, and flow of heat and air are directly associated with physical properties of the soil. Physical properties also influence the chemical and biological properties. Knowledge of the physical properties of soil is essential for defining and/or improving soil health to achieve optimal productivity for each soil/climatic condition. Unless the soil physical environment is maintained at its optimum level, the genetic yield potential of a crop cannot be realized even when all the other requirements are fulfilled.

IORF developed Soil Physical Index (PI) by taking five major soil physical parameters *viz.* soil depth, soil coarse fragment (%), soil texture, soil bulk density and soil aggregates (fig 3). **PI value was poor to moderate in most of the soil and the higher content of gravel was found to be the most limiting factor towards any agricultural activity.**

SOIL QUALITY INDEX (SQI) : Soil quality is defined as the capacity of soil to function within natural or managed ecosystem boundaries and to sustain plant productivity while reducing soil degradation. However, soil quality is a complex functional concept and cannot be measured directly in the field or laboratory but can only be inferred from soil characteristics.

IORF developed the 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. **SQI value was found to be very low in most of the soil which is primarily due to poor to very poor microbial activity and limitation w.r.t. soil physical characteristics (fig 4).**

Pic.: Soils in Kalanahalli village, Mandya, Karnataka

Frequency Distribution of Soil Quality Indices / 1

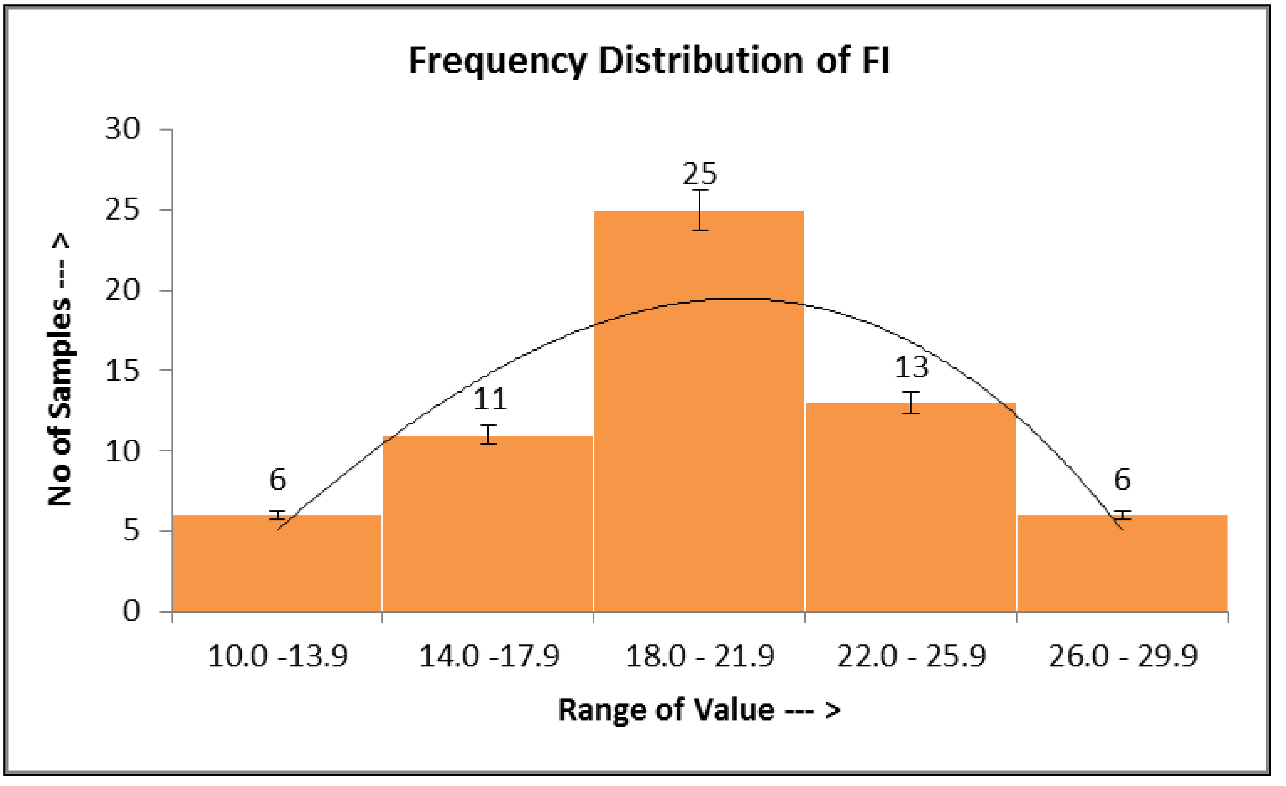


Fig 5 : Frequency distribution of Soil Fertility Index at Kalenahalli village, Mandya, Karnataka

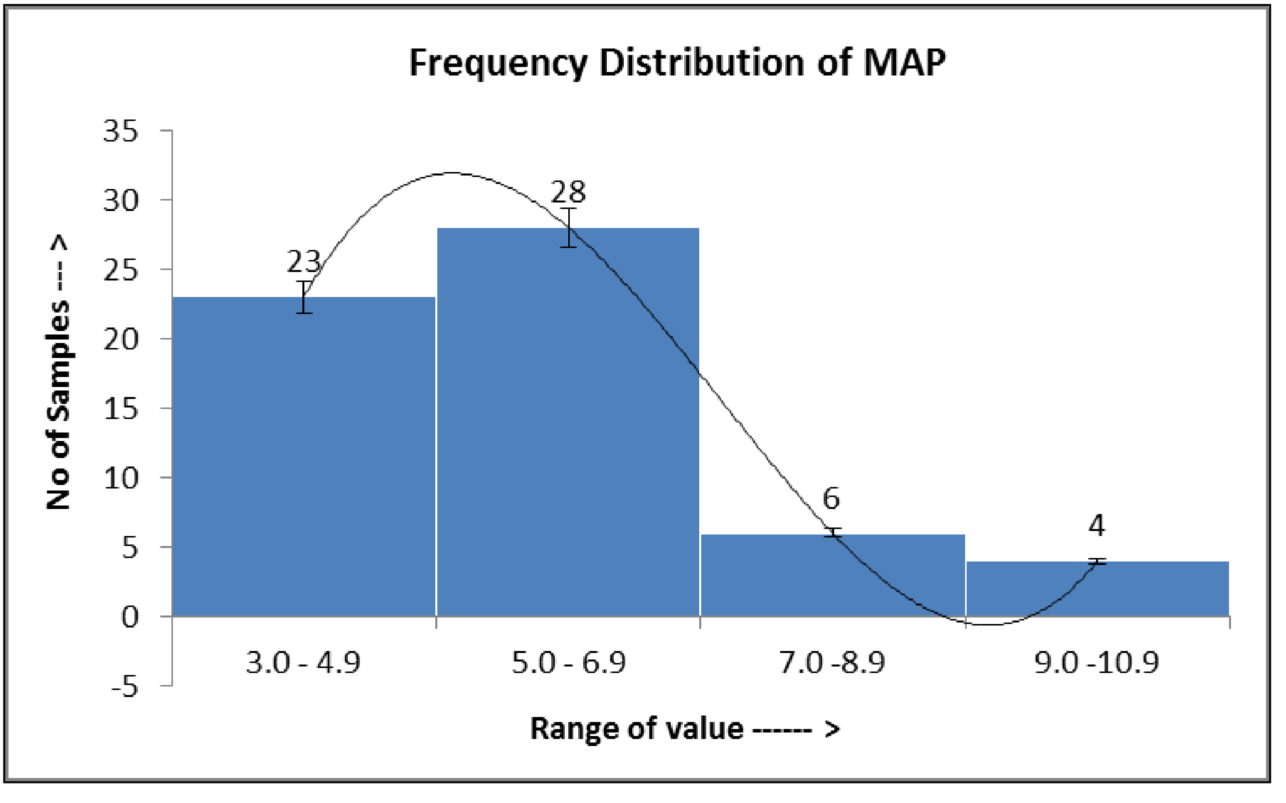


Fig 6 : Frequency distribution of Soil Microbial Activity Potential at Kalenahalli village, Mandya, Karnataka

Frequency Distribution of Soil Quality Indices / 1

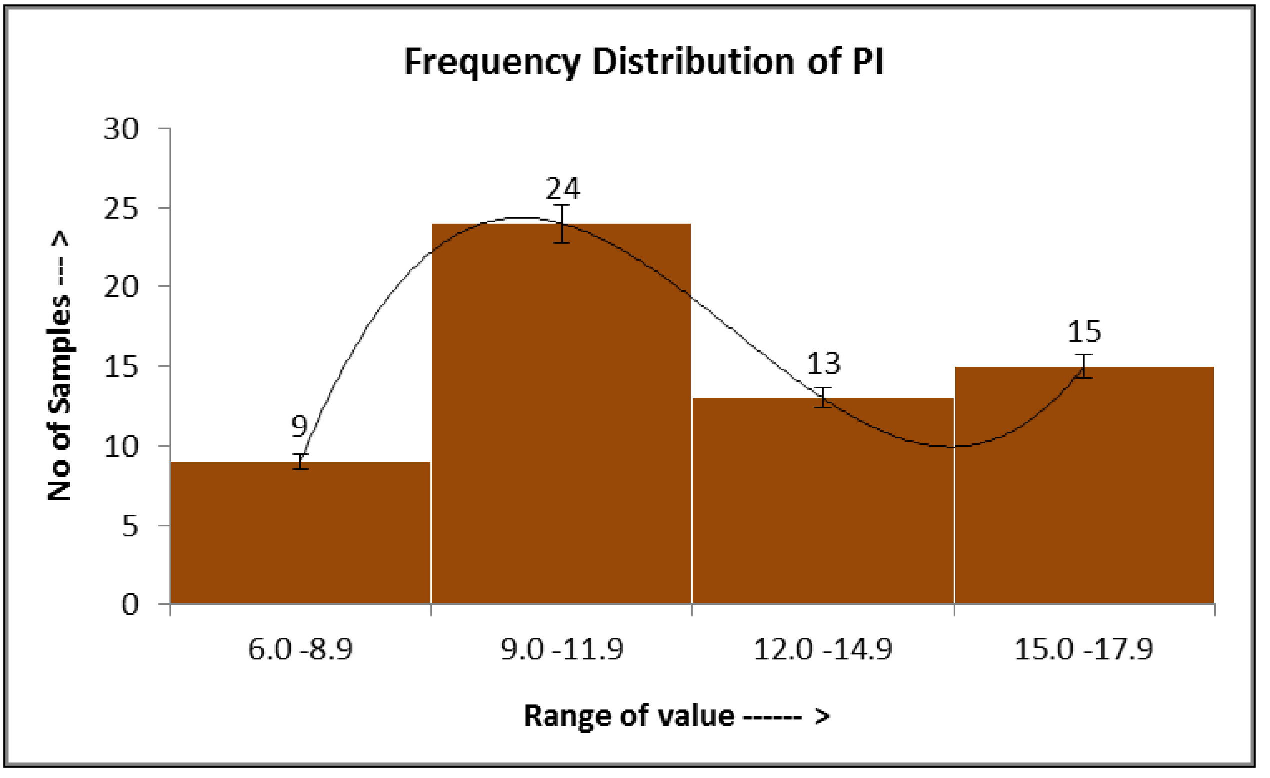


Fig 7 : Frequency distribution of Soil Physical Index at Kalenahalli village, Mandya, Karnataka

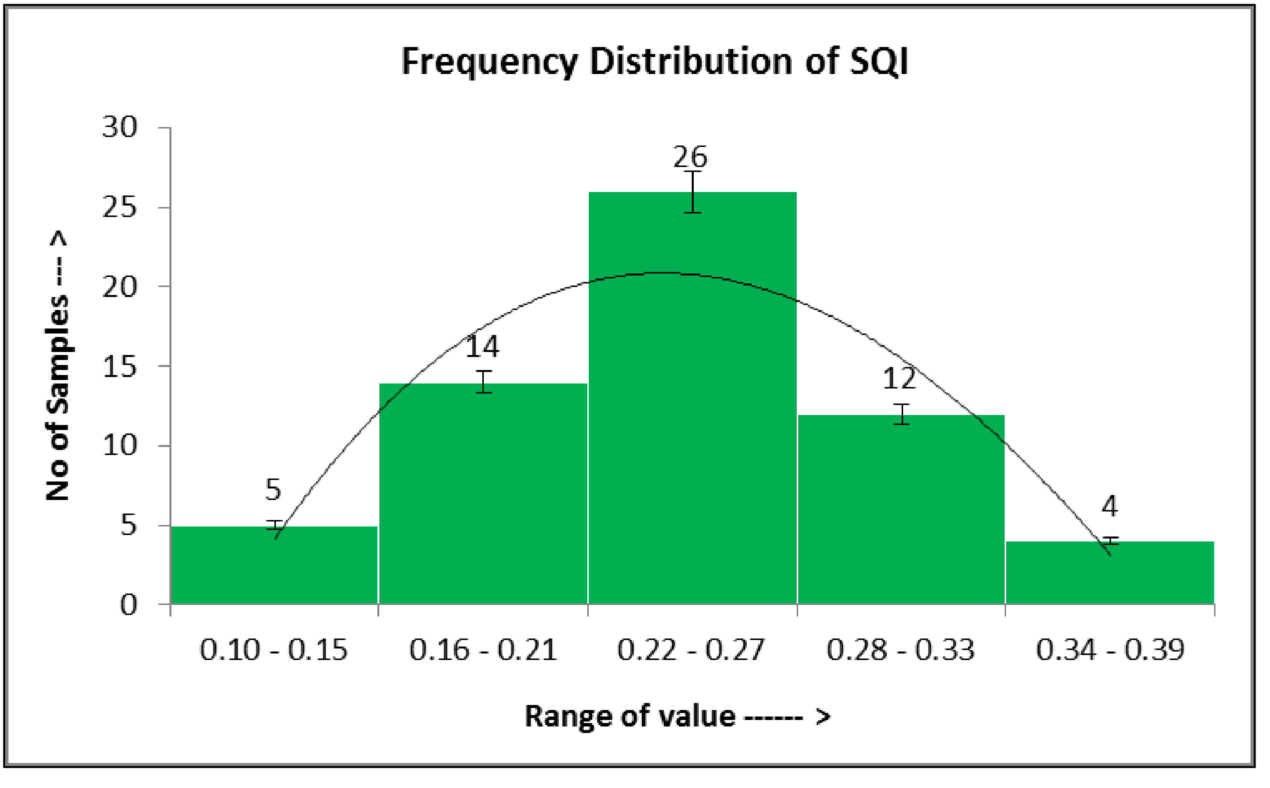


Fig 8 : Frequency distribution of Soil Quality Index at Kalenahalli village, Mandya, Karnataka

Relevance of Soil Resource Mapping

Soil Resource Mapping and development of thematic maps is the most useful tool for identification of potential and problematic areas of any area in order to enable the formulation of an effective and customized soil management program.

Soil evaluation especially in terms of the microfloral activity and soil quality; followed by resource mapping can enable the maintenance of soil resource base while tapping the potential areas simultaneously with the target for better farm maintenance.

It can also help to prevent soil degradation, reduce the costs of remediation when it is necessary, and contribute to issues related to climate change (e.g., reduction of greenhouse gas emissions) and human health (e.g., soil contamination). **Also, without access to information regarding soil quality; farmers are prone to use higher and injudicious amount of fertilizers.** In this respect, incorporation of detailed soil maps in the precision agriculture database can make considerable contributions to decreasing fertilizers (Cullu, 2019).

Significance of Soil Resource Mapping increases manifold especially in respect of Sustainable Soil Management, where judicious application of organic soil inputs has a direct bearing on the practical feasibility and the related economics; especially considering the existential scarcity of resources for on-farm compost production of quality compost in the required quantity.

Pic.: Satellite image of Kalenahalli village, Mandya, Karnataka

Thematic Map 1 - Soil Texture of the study area

Soil texture is the relative proportions of sand, silt, or clay in a soil. The soil textural class is the grouping of soils based upon these relative proportions. Soils with the finest texture are called clay soils, while soils with the coarsest texture are called sands. However, a soil that has a relatively even mixture of sand, silt, and clay and exhibits the properties from each separate is called a loam. Soil texture influences other physical soil properties of soil like; soil permeability, soil structure, soil porosity, soil water retention capacity, and so forth. **It also influences soil resistance to erosion as erosion is easier in soil which is coarse-textured as their particles are loose.** Most importantly, It determines the relative penetration of plant roots in the soil. Where the soil particles are large, roots can penetrate more easily than they do in fine-grained soil which are usually compact. **Finally, soil texture influence soil fertility as it determines the ability of soil to hold nutrients and water for plant use**

Sandy loam soil texture, considered to be a moderate limitation soil textural class; was recorded for majority (55 %) of the area. 33% area comprised of soil with sandy clay loam soil texture, considered to be slight limitation textural class. While loamy sand texture, considered to be a moderately strong textural class in relation to crop productivity potential; was identified for rest of the project area.

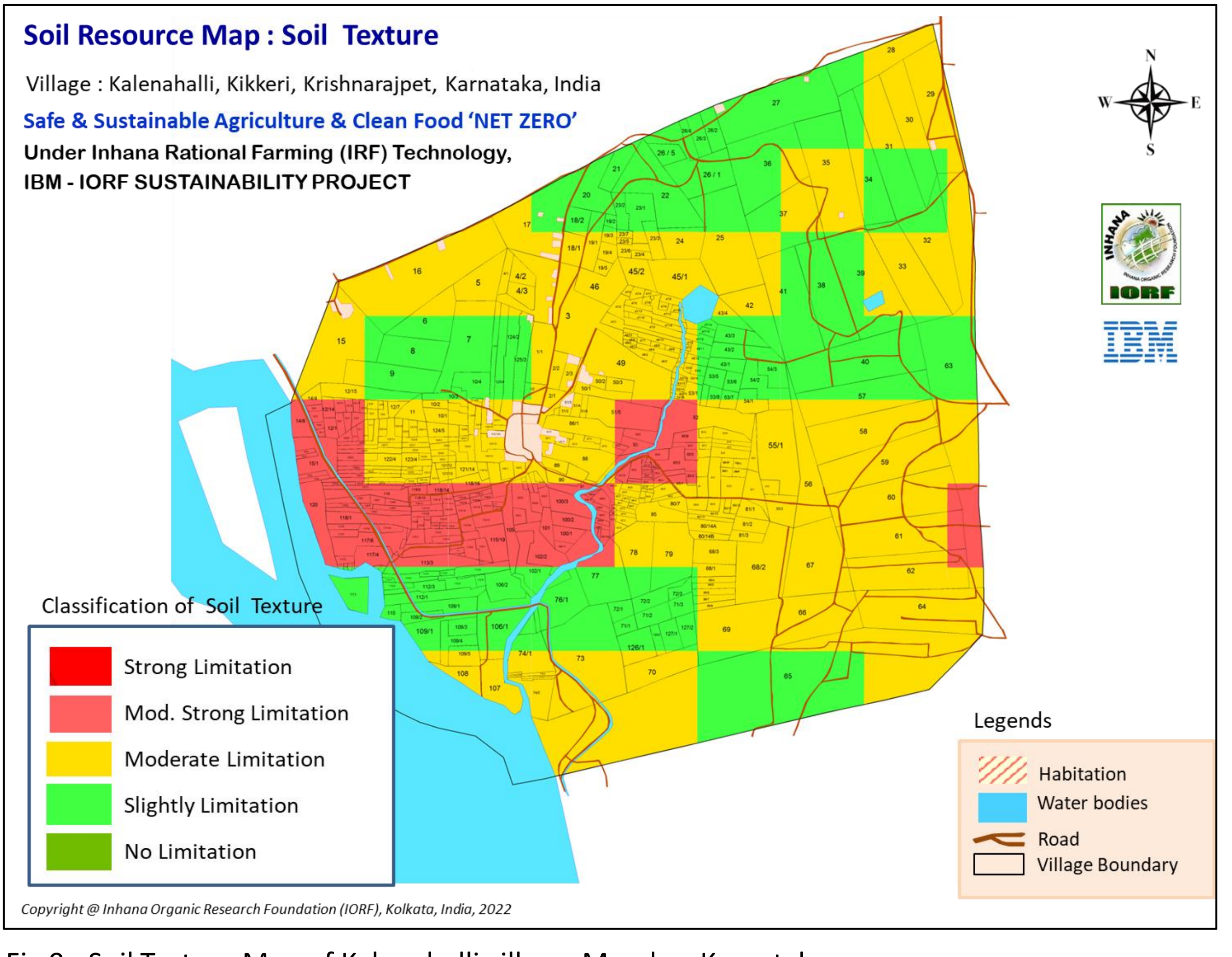


Fig 9 : Soil Texture Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 2 - Soil coarse fragments in the study area

Coarse fragments play an important role in static soil properties such as soil bulk density, porosity, pore size distribution and saturated hydraulic conductivity. In general, these values increase with increasing coarse fragment content (Chow et al., 2007).

Soils with higher amounts of coarse fragments can also increase saturated hydraulic conductivity and macropores, and decrease total porosity, water holding capacity, volumetric water content, water infiltration, and water retention capacity.

It has been reported that soils with high coarse fragments produce lower crop yields, and a low coarse fragment content provides a more favorable condition for plant growth especially in clay soils.

In the project area, coarse fragments is a major limiting factor in the soil offering very strong limitation (>55% content) in 47% area followed by strong limitation (35 – 55% content) in 42% area and moderate limitation (15 – 35% content) in the rest 11% area.

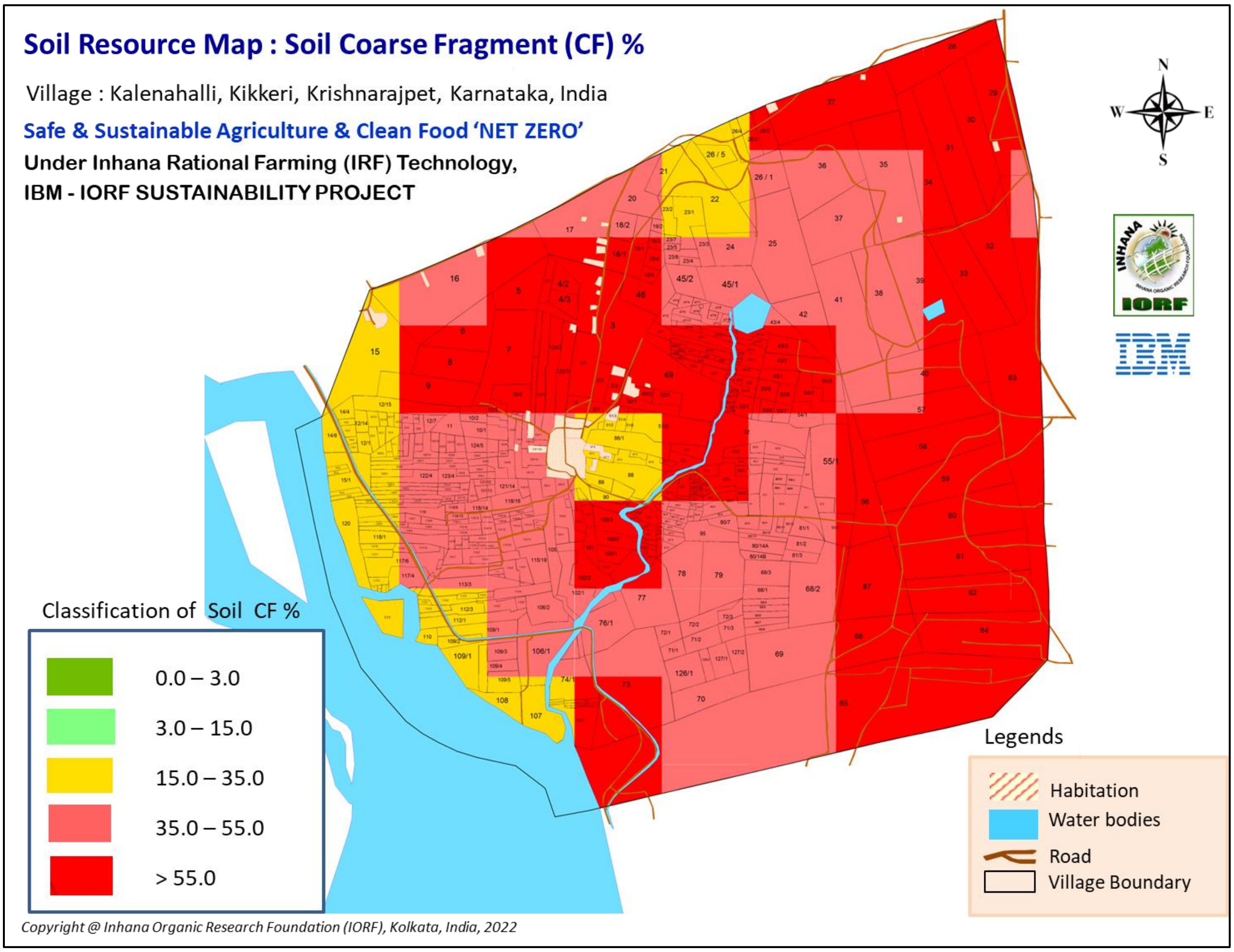


Fig 10 : Soil Coarse Fragment (%) Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 3 - Soil Physical Index (PI) of the study area

Physical properties play an important role in determining soil's suitability for agricultural, environmental and engineering uses. The supporting capability; movement, retention and availability of water and nutrients to plants; ease in penetration of roots, and flow of heat and air are directly associated with physical properties of the soil. Physical properties also influence the chemical and biological properties. Apart from that, improved soil structure can increase soil porosity and enhance nutrient and water recycling, water availability, and biodiversity while reducing water and wind erosion. These improvements in soil quality lead to better soil conditions for crop growth and yields.

At the same time, soil physical properties are of significant importance in determining the abundance of microbes. Microbial diversity varies with soil texture. Sandy soils support the fungal community while clayey soils are conducive for the bacterial community. Larger pore size has a strong correlation in determining the abundance of fungal community. **Organically managed soils having smaller pore size and, higher water holding impedes the pathogenic fungal community by restricting the hyphal growth. Higher clay and silt content are positively correlated with higher microbial population.**

Soil Physical Index was formulated by taking five major soil physical parameters *viz.* soil depth, Soil Coarse Fragment (%), soil texture, soil bulk density and soil aggregates. In the Project Area Soil Physical Index (PI) was poor to very poor in majority (64%) area, while moderate in 21% area.

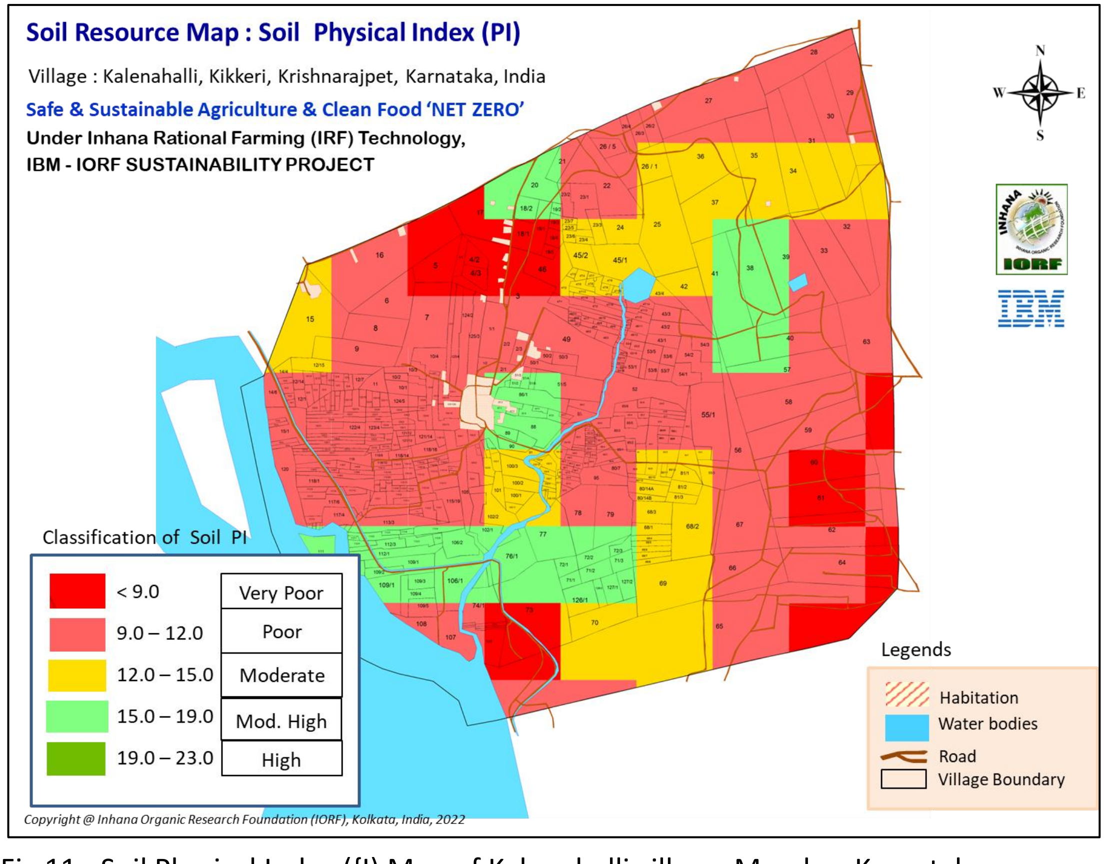


Fig 11 : Soil Physical Index ({I) Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 4 - Soil pH of the study area

In the natural environment, soil pH has an enormous influence on soil biogeochemical processes. Soil pH is, therefore, described as the "**master soil variable**" that influences myriads of soil biological, chemical, and physical properties and processes that affect plant growth and biomass yield. Soil pH affects the amount of nutrients and chemicals that are soluble in soil water, and therefore the amount of nutrients available to plants. Some nutrients are more available under acid conditions while others are more available under alkaline conditions. According to some scientists, Soil pH is more important than nutrients in shaping bacterial communities in agricultural soils, including their ecological functions and biogeographic distribution. **The pH range 5.5–6.5 is optimal for plant growth as the availability of nutrients is optimal.** This range is also the most suitable for most soil microbes, in part because in this range plants grow well and produce more root exudates as a carbon source available for survival and multiplication of microbes.

According to the soil resource map of the project area, **soil pH varied from Strongly acidic to neutral. Analysis revealed that in the Project Area, pH is in the slightly acidic range (5.5-6.5) in the largest area (42 %) followed by moderately acidic (5.51 – 6.0) in 29 % area, neutral (6.50 – 7.00) in 18 % area , while Strongly acidic (5.00 – 5.50) in the rest 11 % area.**

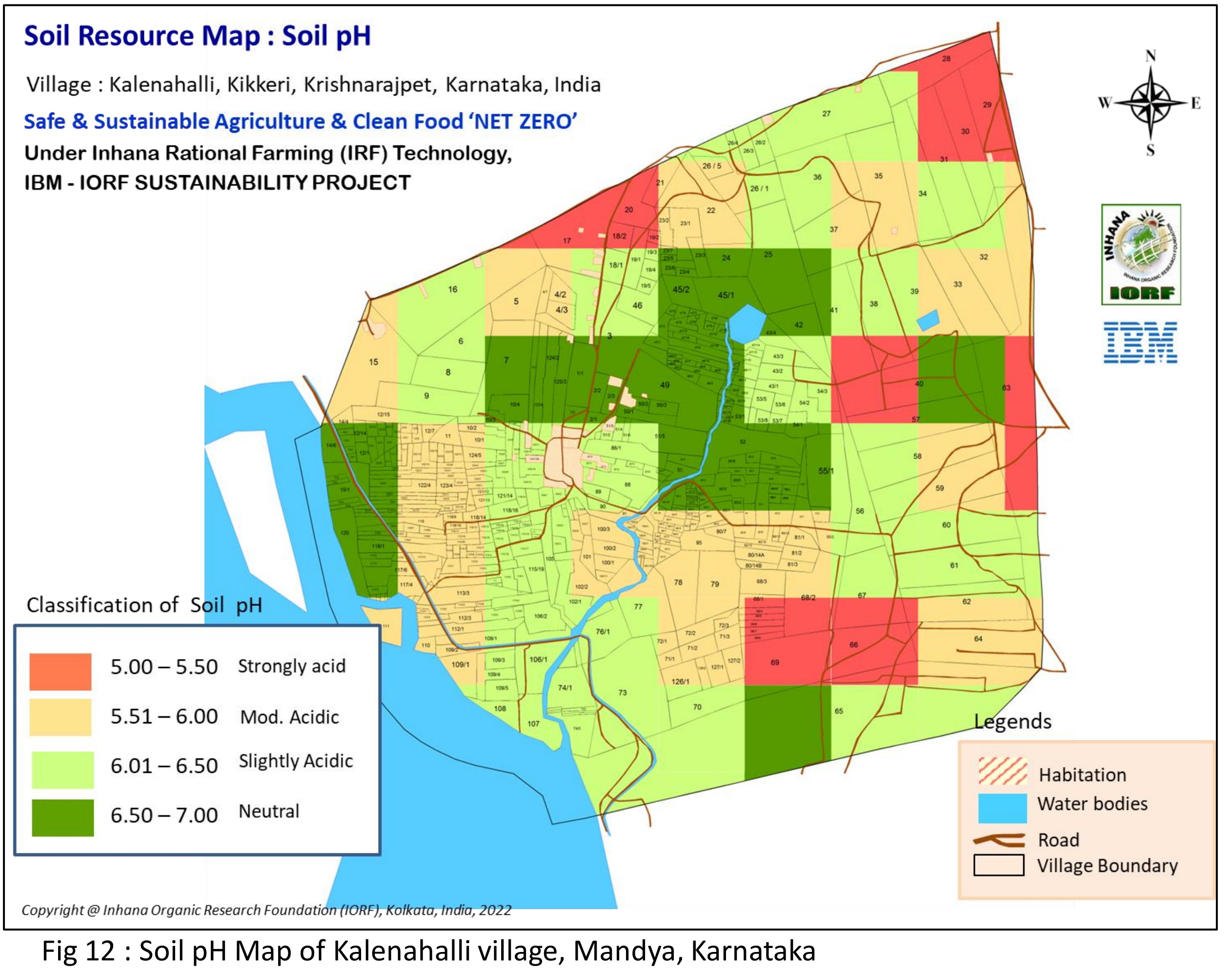


Fig 12 : Soil pH Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 5 - Soil Organic Carbon (%) of the study area

Soil Organic Carbon (SOC) is the key element that determines soil quality, fertility, agricultural profitability, and atmospheric carbon dioxide (CO_2) fixation. The SOC affects physio-chemical and biological properties of soil which simultaneously improves soil structure, water and nutrient retention capacity. Soil carbon is a food source for soil micro-organisms and an important bacteria metabolite, where microbial activity plays an important role in improving soil structure.

High levels of organic carbon help to maintain agricultural production through its positive role in maintaining soil health, raising fertility, reducing erosion and encouraging soil biota. Higher soil organic matter levels cause greater soil nitrogen retention, greater microbial biodiversity, and promote the presence and growth of arbuscular mycorrhizal fungi that colonize the roots of crops and facilitate the movement of plant nutrients from the soil into plants, improving growth and yields. **SOC is gaining more importance in present day because it can act as a NATURAL CLIMATE SOLUTION (NCS) thus has a role in both restoring the carbon sink and protecting against further CO_2 emissions, in response to predicted land-use change and climate change.**

Hence, assessment of SOC formed a very important component of the IBM-IORF Sustainability Project. Analysis revealed that soil organic carbon is a major limitation in the soils of the project area with low (0.51 – 0.75 %) status in a majority (55 %) area followed by moderate (0.76 – 1.00) status in about 38 % area.

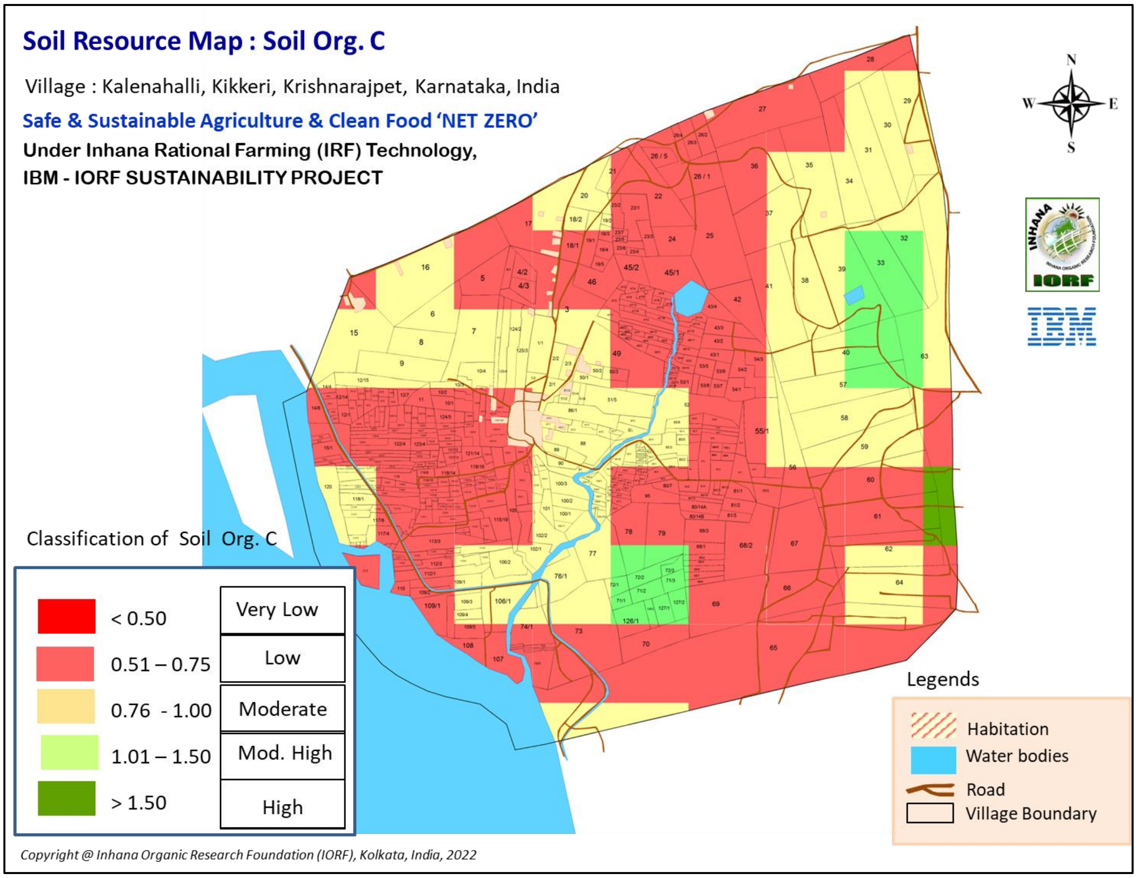


Fig 13: Soil Texture Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 6 - Soil Available Nitrate (mgKg^{-1}) of the study area

Soil texture is the relative proportions of sand, silt, or clay in a soil. The soil textural class is a grouping of soils based upon these relative proportions. Soils with the finest texture are called clay soils, while soils with the coarsest texture are called sands. However, a soil that has a relatively even mixture of sand, silt, and clay and exhibits the properties from each separate is called a loam. Soil texture influences other physical soil properties of soil like; soil permeability, soil structure, soil porosity, soil water retention capacity, and so forth. **It also influences soil resistance to erosion as erosion is easier to the soil which is coarse-textured as their particles are loose.** Most importantly, It determines the relative penetration of plant roots in the soil. Where the soil particles are large, roots can penetrate more easily than they do in fine-grained soil which are usually compact. **Finally, soil texture influence soil fertility as it determines the ability of soil to hold nutrients and water for plant use**

Sandy loam soil texture, considered to be a moderate limitation soil textural class; was recorded for majority (55 %) of the area. 33% area comprised of soil with sandy clay loam soil texture, considered to be slight limitation textural class. While loamy sand texture, considered to be a moderately strong textural class in relation to crop productivity potential; was identified for rest of the project area soils.

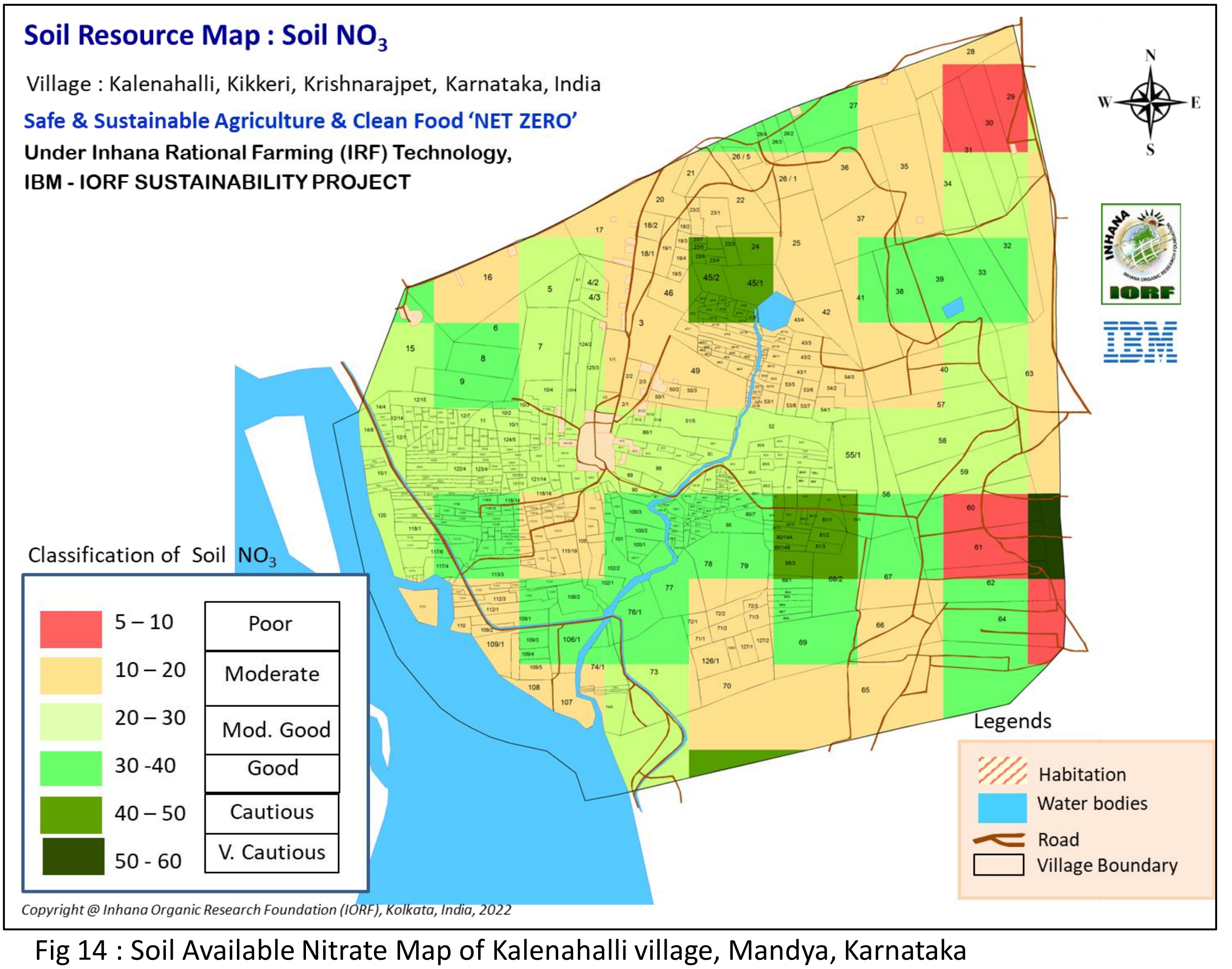


Fig 14 : Soil Available Nitrate Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 7 - Soil Available Nitrogen (Kgha^{-1}) of the study area

Nitrogen is an essential macronutrient for plant function and is a key component of amino acids, which form the building blocks of plant proteins and enzymes. Nitrogen is also a component of the chlorophyll molecule, which enables the plant to capture sunlight energy by photosynthesis, driving plant growth and grain yield. **Reducing the use of N- Fertilizers, one of the major arms of sustainability; is a prime objective of Sustainable Agriculture. And improving the nitrogen use efficiency of the plants and integrated soil management through utilization of micro flora (*self- generated*) rich quality compost are the pathways to achieve that.** But the most critical factor is to assess the status of available- N in soil and evaluate its interrelationship with the Nitrate– N in order to chalk out a Sustainable soil Management Plan.

According to Mahesh Pradhan, a nutrient pollution expert with the UN Environment Program (UNEP), **"Human nitrogen additions to the soil, in the form of fertilizers, reinforce the greenhouse effect: around 60 per cent of nitrous oxide is emitted from fertilized fields, manures and other agricultural sources,"**

Analysis revealed that in the Project Area, available- N is low (200-280 kg/ ha) to moderate (280-360 kg/ ha) in about 90 % area, while a small (10 %) area has a moderately high content (360 - 450 kg/ ha).

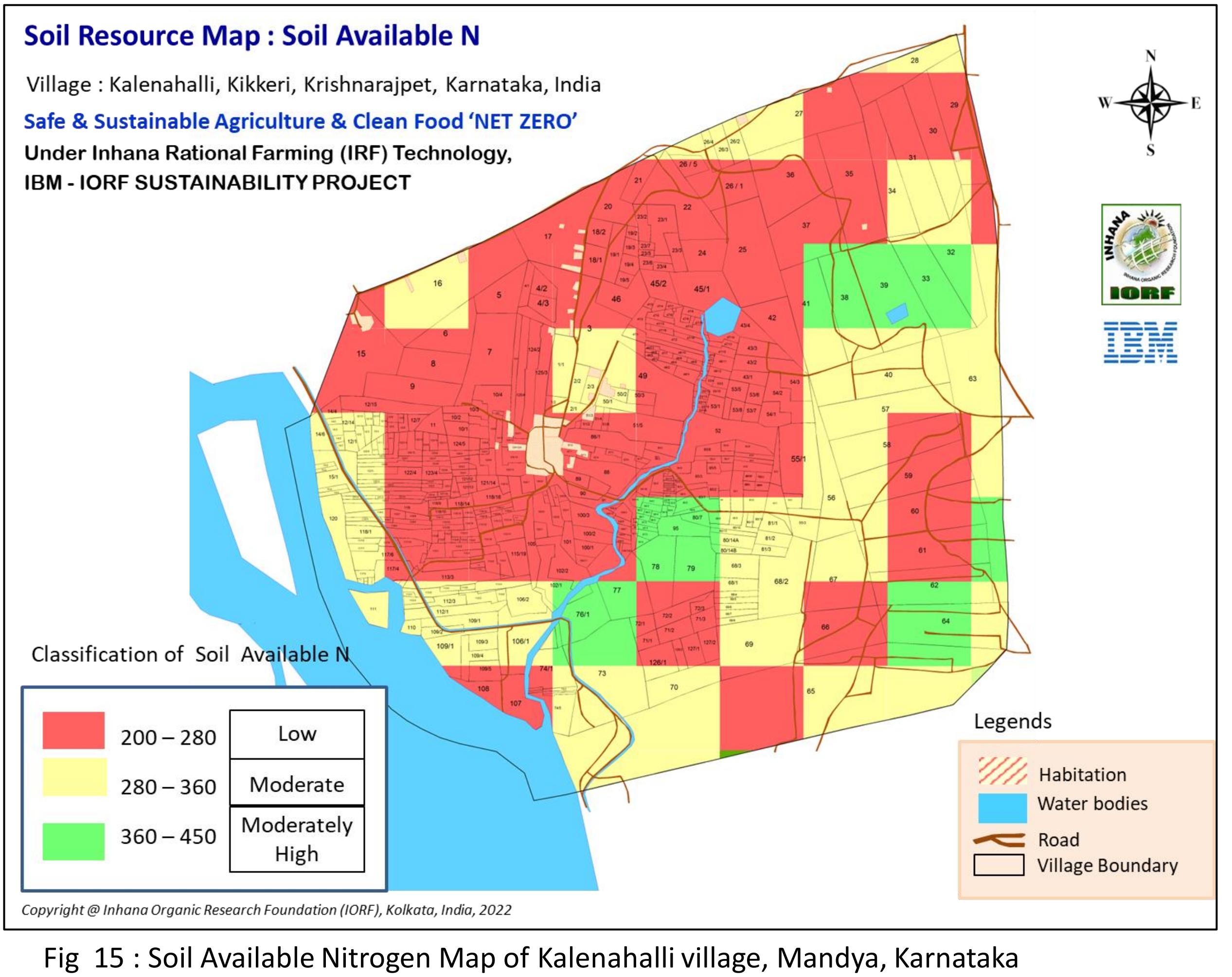


Fig 15 : Soil Available Nitrogen Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 8 - Soil Available Phosphate (Kgha^{-1}) of the study area

Phosphorus is the second most important crop nutrient after Nitrogen. It is an essential macronutrient that plays important role in all crop biochemical processes such as photosynthesis, respiration, energy storage, transfer, cell division, cell enlargement and nitrogen fixation. It is also important in seed germination, seedling establishment, root, shoot, flower and seed development. Phosphorus is also a component of the complex nucleic acid structure of plants, and is, therefore, important in cell division and development of new tissue.

Despite its importance in crop nutrition, availability of the nutrient in soils for plant uptake is limited by several soil factors. Thus, soil phosphate management is a challenging task considering that **only a part of the P added to soil through fertilizer is used by the plant in the year of application. A varying but often substantial part accumulates in the soil as "residual P".** This reserve can contribute to P in the soil solution and utilized by the plant but an efficient process of mineralization is required for the purpose, for which an efficient soil microbial dynamics is important. **Thus, it is essential to measure the status of available phosphate in the soil in order to plan out a sustainable soil management program**.

Soil available phosphate was very low (> 22.5 kg/ha) to low (22.5 – 45.0 kg/ha) in 73 % of the area while moderate (45.0 – 75.0) to moderately high (75.0 – 90.0 kg/ha) status was recorded in about 18% area. Fixation of the soil phosphate in surface soil under low soil pH conditions might be the causative factor for the very low to low available phosphate in majority of the Project area.

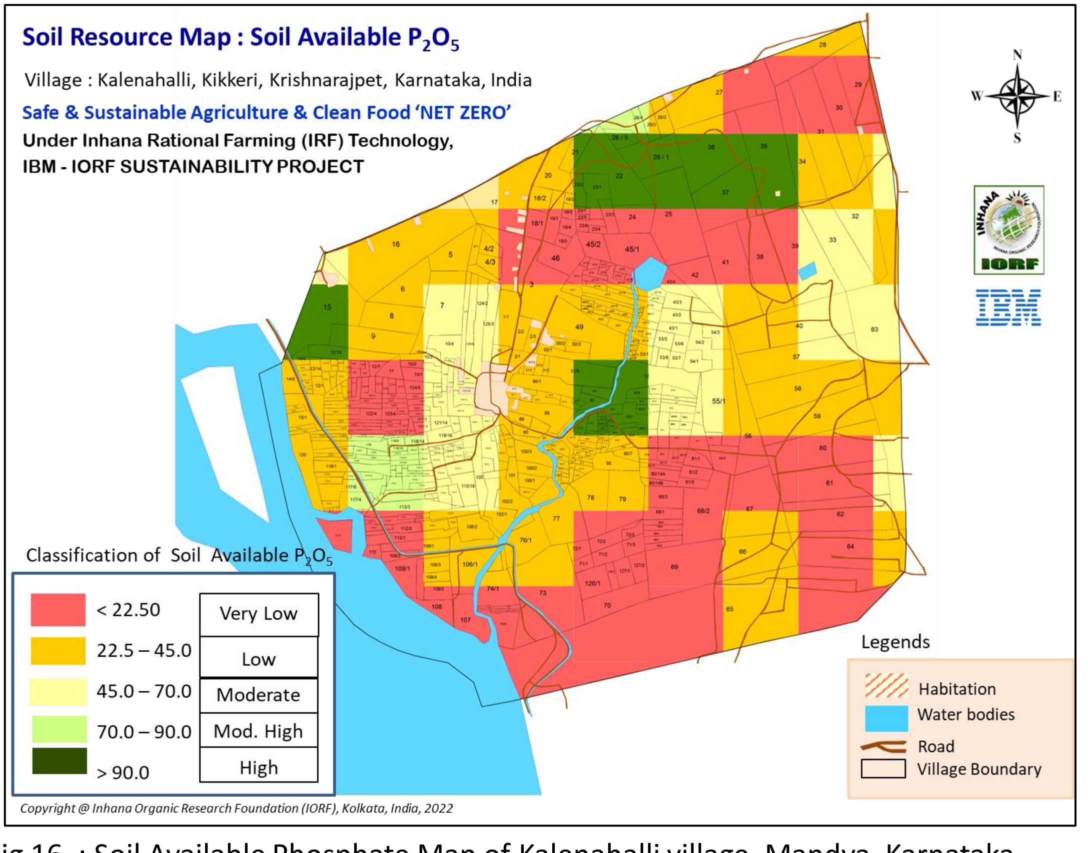


Fig 16 : Soil Available Phosphate Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 9 - Soil Available Potash ($Kgha^{-1}$) of the study area

Potassium (K) is one of the 17 essential nutrients required by plants for growth and reproduction. Good potassium nutrition is vital to consistently improve crop productivity. Potassium's role in the plant is primarily in plant/soil/air-water relations; it also activates certain enzymes, and it aids in moving captured carbon from plant biomass to reproductive material (grain, fruit, and fiber). **Inadequate potassium nutrition leaves the plant more susceptible to different stresses, including water deficit, insect pressure, and pathogen pressure.**

Potassium is fundamental to many metabolic processes through the activation of a large number of enzymes required for chemical reactions. These include the synthesis of proteins and sugars required for plant growth. Only a relatively small proportion of the plant's total potassium requirement is needed for this. **The majority is required for the essential role of maintaining the water content of plant cells.**

Analysis revealed a high (> 450 kg/ ha) potash content in 84 % area of the Project Area followed by moderately high (340 – 450 kg/ha) in about 11 % area. The potash richness of the soils was probably due to the weathering of ancient crystalline and metamorphic rocks, generally acid granites, quartz rocks, gneiss, and felspathic rocks which are rich in potassium.

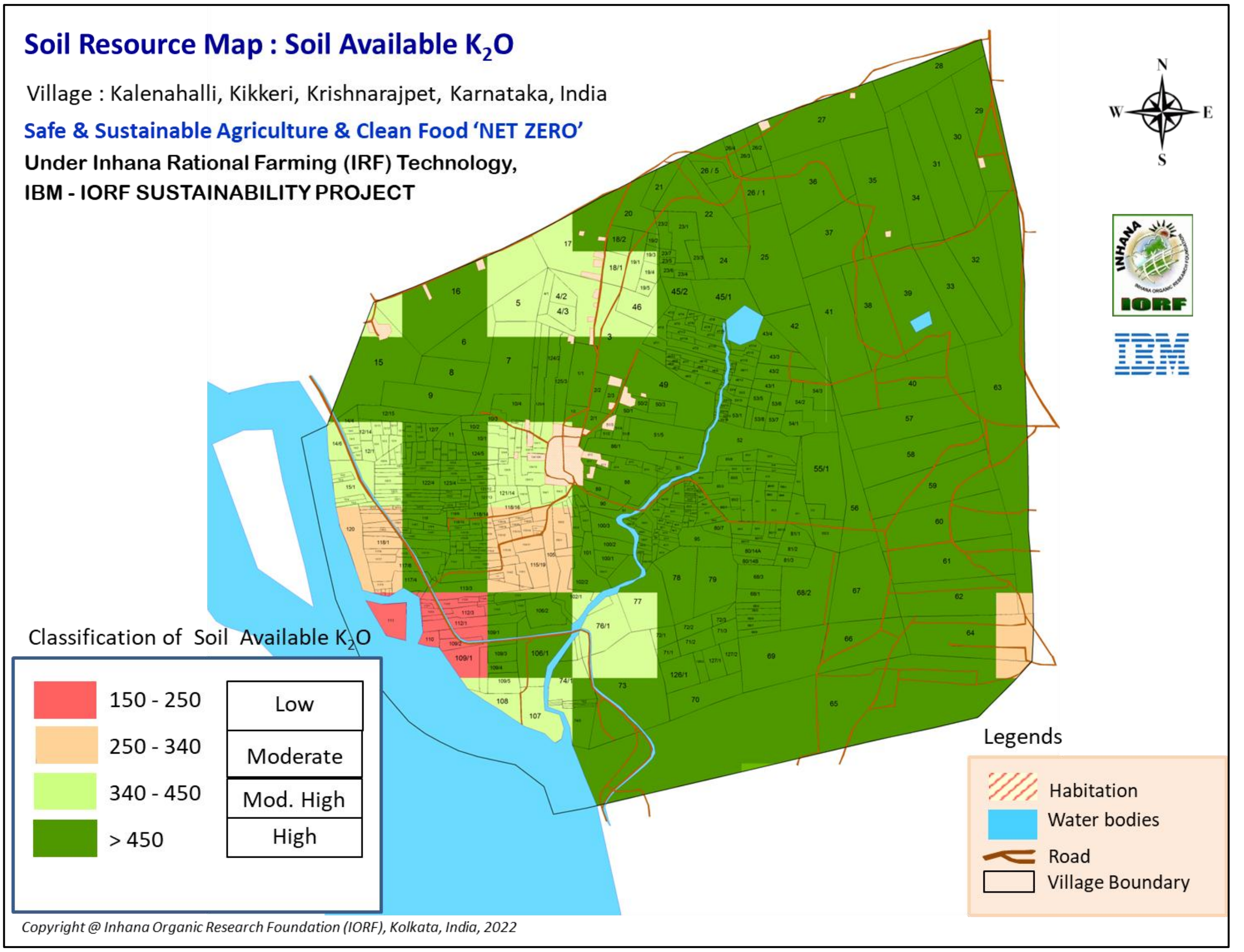


Fig 17 : Soil Available Potash Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 10 - Soil Available Sulphate ($Kgha^{-1}$) of the study area

Sulphur is an essential plant nutrient. It is required for the production of amino acids, which make up the proteins critical to plant growth. Sulphur deficiency can significantly reduce yield in pastures on sandy soils in wet years, when the sulphate form of sulphur leaches below the root zone of pasture plants. Sulphur can only be taken up by plants from the soil solution as sulphate. As with readily-available nitrate, it can be liable to loss through leaching. **The majority of S in most soils is contained in organic matter. Organic- S must be mineralized to the inorganic sulfate anion before it can be taken up by crops.** Hence an efficient soil dynamics is essential for meeting the plants' sulphate requirement.

Analysis revealed a high (> 140 kg/ ha) content of available sulphate in the entire project area soils. The high sulphur content was probably due to the composition of the original parent rock.

High content of sulphur in soil might cause soil contamination and acidification. Besides, it is indirectly responsible for mobilization of phytotoxic chemicals, such as aluminium and some trace elements. Hence, caution should be maintained in respect of this macronutrient especially in relation to the cultivation of field crops.

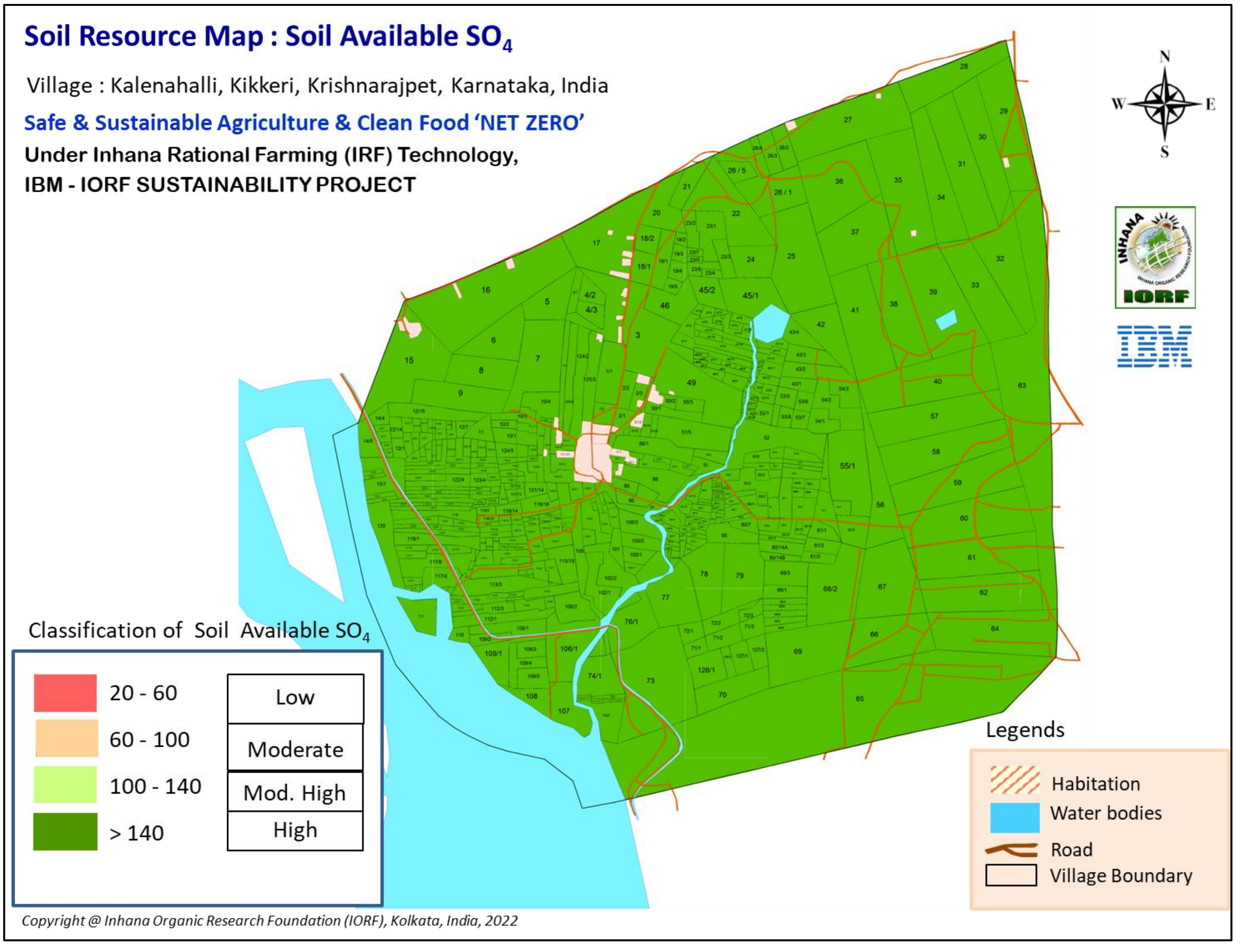


Fig 18 : Soil Available Sulphate Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 11 - Soil Fertility Index (FI) of the study area

Soil Fertility Index (FI) is a tool for understanding the overall nutritive status of a soil for crop production as well as the extent of management required to sustain a desired yield. This tool was developed by IORF considering seven major soil parameters *viz.* pH, organic carbon, soil-Nitrate, available N, available P_2O_5, available K_2O and available SO_4. A higher FI value indicates a balanced nutritional approach towards sustainable crop production.

This index was developed to help the famers understand their soil quality status in terms its potential to support the crop nutritional requirements. **A soil might have varying status of available- N, P, K and S, but only FI can help to understand the overall nutrient supplying potential of their soil in terms of low, moderate, high, etc.**

Fertility Index was found to be moderately high (20-25) in 43%, followed by moderate (15-20) status in 30%, low (10-15) in 17% and high (25-30) in 10% of the Project Area soils. The moderate to high Fertility was mainly due to the high potash and sulphate content in the soil as contributed by the parent material. So though the Fertility content of the soil is high the lack of equilibrium between the nutrient concentration means inconsistent and inadequate availability of plant nutrient in the soil solution.

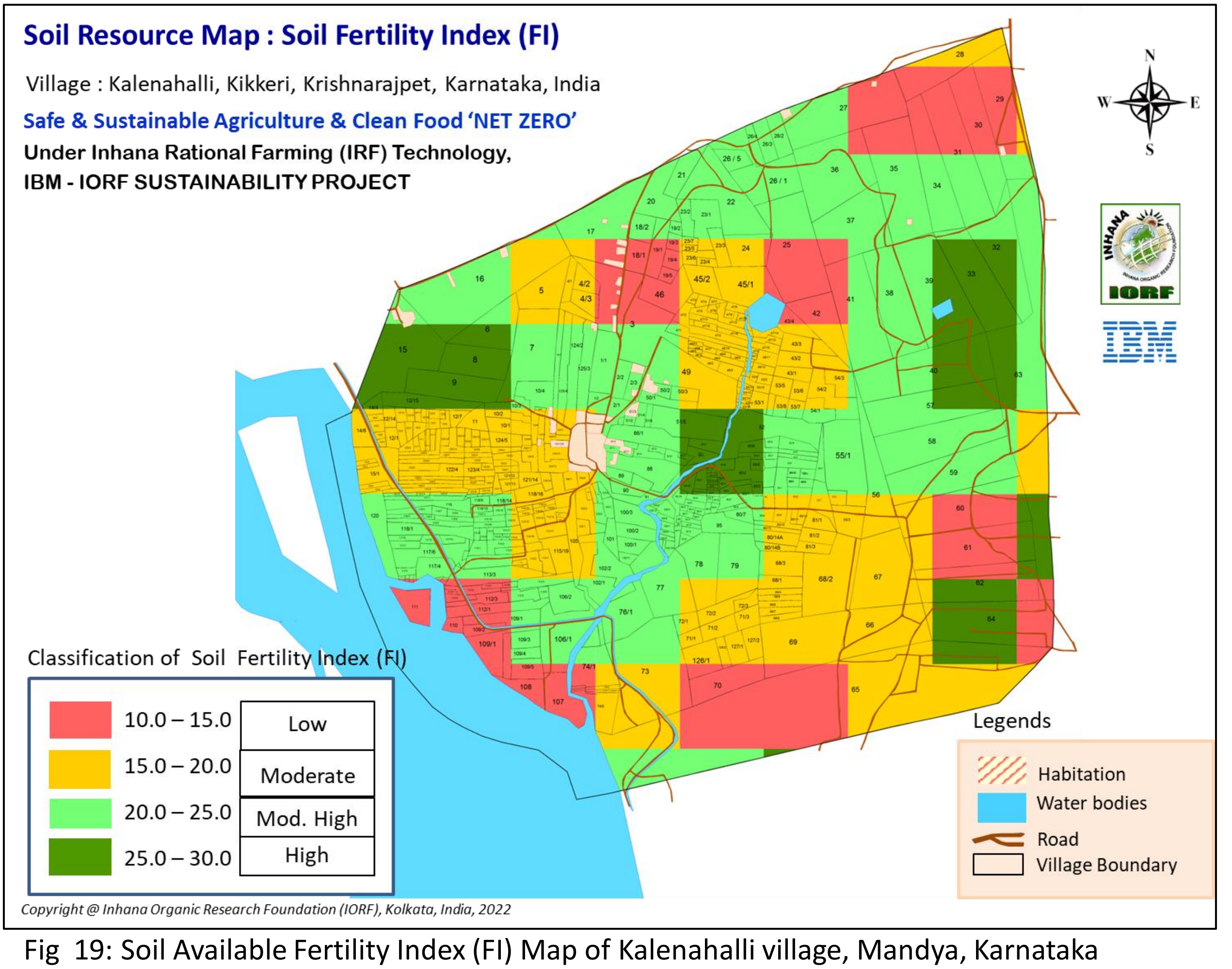


Fig 19: Soil Available Fertility Index (FI) Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 12 - Soil Microbial Biomass Carbon (MBC) of the study area

MBC is the living microbial component of soil organic matter and is considered an indicator of microbial activity, owing to its rapid response to conditions that may alter soil organic matter. SOC contributes positively to soil fertility and crop production. For the formation of the organic pool, soil microbial biomass carbon acts as a key indicator of soil organic carbon by decomposing organic matter and controlling nutrient dynamics which affect the primary productivity of the terrestrial ecosystem.

Soil microbial biomass, the total mass of all organisms in soil, is commonly used to give an estimate of the response of soil microbiota to changing environmental conditions. Microbial biomass C and N can be used for predicting the organic C or N accumulation in organic soils. The sole application of inorganic fertilizers in conventional farming results in less carbon accumulation in microbial biomass. **The readily utilizable carbon source from organic manures in organic farming increases the accumulation of C in microbial biomass.**

The availability of C from the organic substrates and their C/N ratio determines the size of microbial biomass. More amount of C sources is digested and catabolized by microorganisms for their energy resulting in higher microbial biomass carbon. Soil microbial biomass is a major limiting factor in in more than 75% project area soils, and low (8 %) to very low (17 %) in rest area. The finding indicated that the soils were not very much biologically dynamic or active and need sustainable soil management for future crop sustainability.

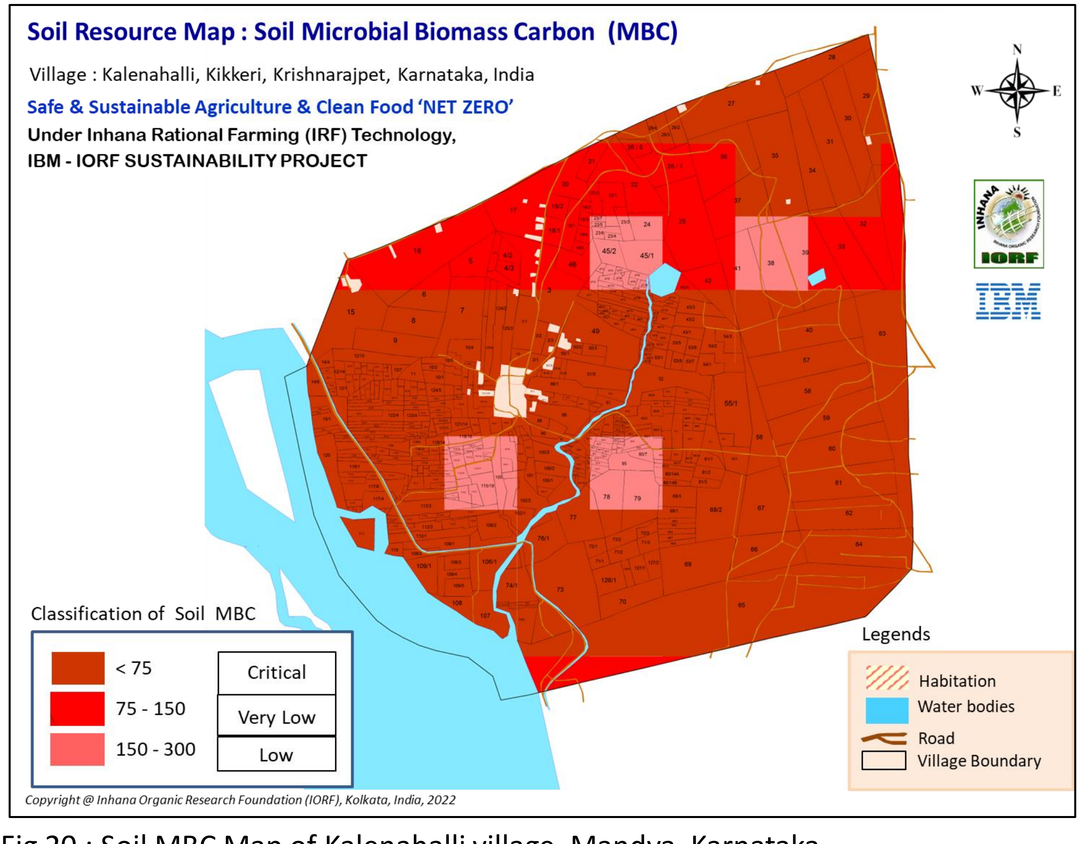


Fig 20 : Soil MBC Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 13 - Soil fluorescein diacetate hydrolysis (FDAH) of the study area

Microbial communities and the enzymes they produce play an essential role in the functioning of the soil environment. They participate in the transformation of soil organic matter (SOM), thereby making nutrients available for plants and degrading any contaminants. Fluorescein diacetate (FDA) hydrolysis is widely accepted as an accurate and simple method for measuring total microbial activity in a range of environmental samples, including soils. Assessment of Hydrolysis of fluorescein diacetate [3′, 6′-diacetylfluorescein (FDA)] has been suggested as a prospective method for determination of total microbial activity because it includes several enzyme classes including lipases, esterases, and proteases.

Over the last few decades FDA hydrolysis has been widely used as a suitable index of the overall activity of enzymes and microorganisms in soil. **Also, the rate of FDA hydrolysis in soil has been suggested as a suitable parameter for the monitoring of soil quality and bio-ecosystem studies**. According to some scientific findings, the farming practices significantly affected the activity of microorganisms in the soil habitat as measured with FDA hydrolysis.

As per analysis, soil FDAH value is critical in more than 91% area, which indicated very poor microbiological functioning in soil. The situation calls for Sustainable Soil Initiatives in order to create a better soil environment for self proliferation of native microflora that is prerequisite for long term crop sustainability.

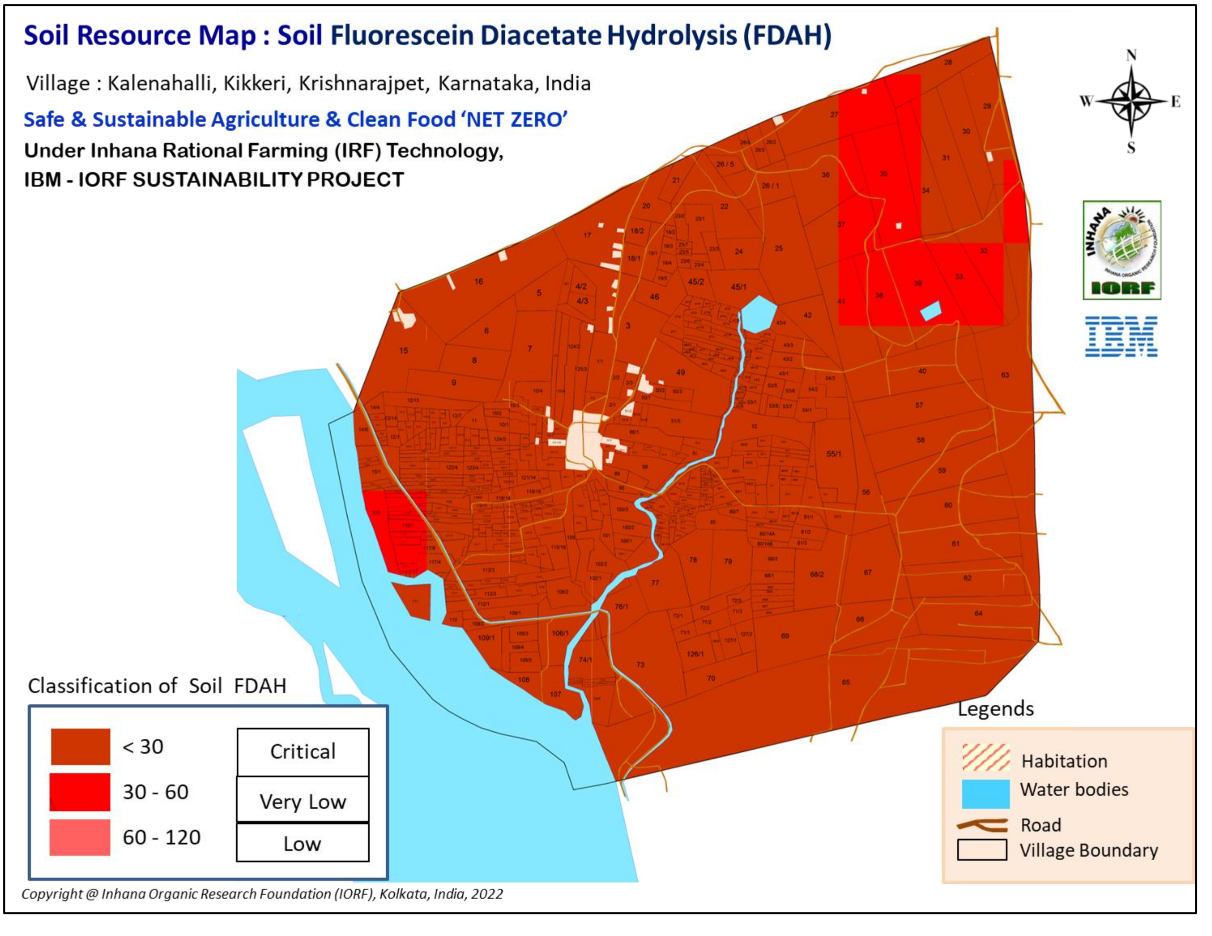


Fig 21: Soil FDAH Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 14 - Soil Microbial Quotient (qMBC) of the study area

Microbial quotient (qMBC) i.e., 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. **It is the ratio that expresses how much soil carbon is immobilized in microbial biomass**.

Microbial metabolic quotient (qMBC) reflects the efficiency of heterotrophic microorganisms to convert organic carbon into microbial biomass and so can be used as more sensitive indicator of soil microbial response to land use, soil management and environmental variables. **Scientific studies have revealed higher increase of qMBC in compost applied soils as compared to conventionally managed plots.** Comparatively higher value of qMBC indicate better soil health with higher concentration of microbes and indicates a higher microbial C immobilization. An increase in the microbial quotient denotes the presence of more active carbon pools in the soil and thus the ratio acts as an indictor of changes in the quality of soil organic matter. Low qMBC value denotes lesser microbial activity and slower nutrient dynamics.

Soil qMBC value was very low (< 1.0) to low (1.0 – 2.0) in 77% of Project area soils while moderate (2.0 – 3.0) to moderately high (3.0 – 4.0) status was observed in 18 % area. The values not only indicate low soil microbial population is low but also poor soil microbial activity as also corroborated by the soil FDAH value.

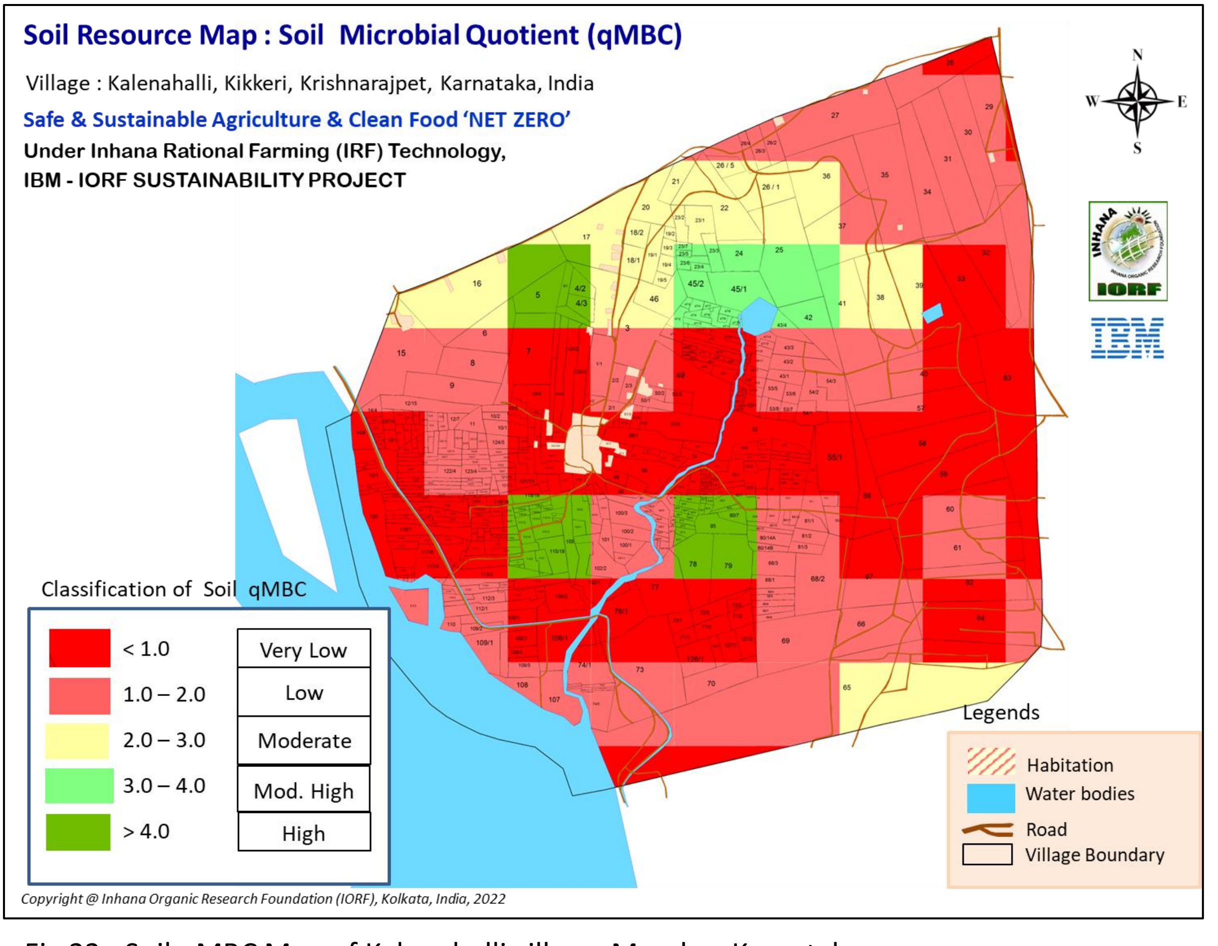


Fig 22 : Soil qMBC Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 15 - Soil Microbial Metabolic Quotient (qCO_2), of the study area

Soil microbial metabolic quotient is an index used to evaluate soil microbial metabolism efficiency, which is often called the basal respiration rate per microbial biomass.

Killham (1985) and Killham and Firestone (1984) showed that soil microorganisms divert more energy from growth into maintenance as stress increases and thus the ratio of respired- C to biomass- C (the metabolic quotient or qCO_2) can be a sensitive indicator of stress. **The qCO_2 has been widely applied in the assessment of the cultivation regime, pollution gradients, effect of temperature, forest ecosystems and acidification.**

High values of qCO_2 usually indicate stressful conditions in disturbed systems and, in general, conventional chemical farming presents higher values in relation to organic cultivation or the natural ecosystems.

Moderately high qCO_2 was observed in about 96% of the Project area which indicated not only poor soil microbial population, but also indicated stressful conditions due to lack of suitable micro-environment.

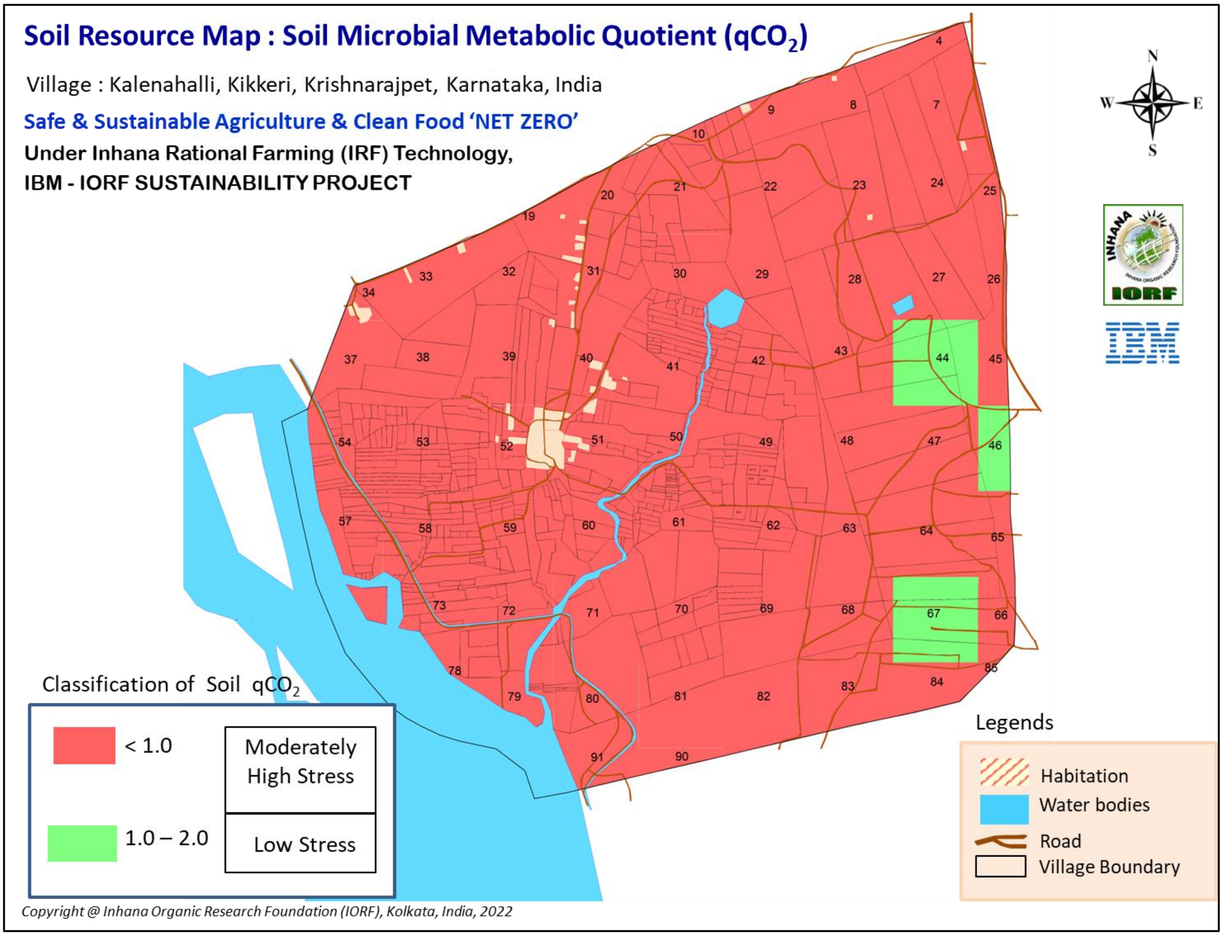


Fig 23: Soil qCO_2 Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 16 - Soil Specific Hydrolytic Activity (qFDA) of the study area

Soil Specific Hydrolytic Activity (qFDA) is measured as Fluorescein diacetate (FDA) hydrolysis per unit organic carbon, and indicates the quality of organic carbon in soil in terms of its dynamism and microbial potential.

Under crop management practice, this index can indicate whether the practice has a sustainable impact on soil or can cause stressful conditions. In general it was found that under intensive conventional crop management using chemical fertilizer and pesticides, vale of this index reduces. On the other hand, sustainable management of soil using soil organic amendments have a positive impact on qFDA value.

qFDA value was found to be very low in the project area which on one hand indicated poor microbial activity, as also corroborated by qMBC and qCO_2 value, moreover it pointed towards the need for urgent action in order to restrict the potential for further soil deterioration and thereby the proneness towards soil degradation.

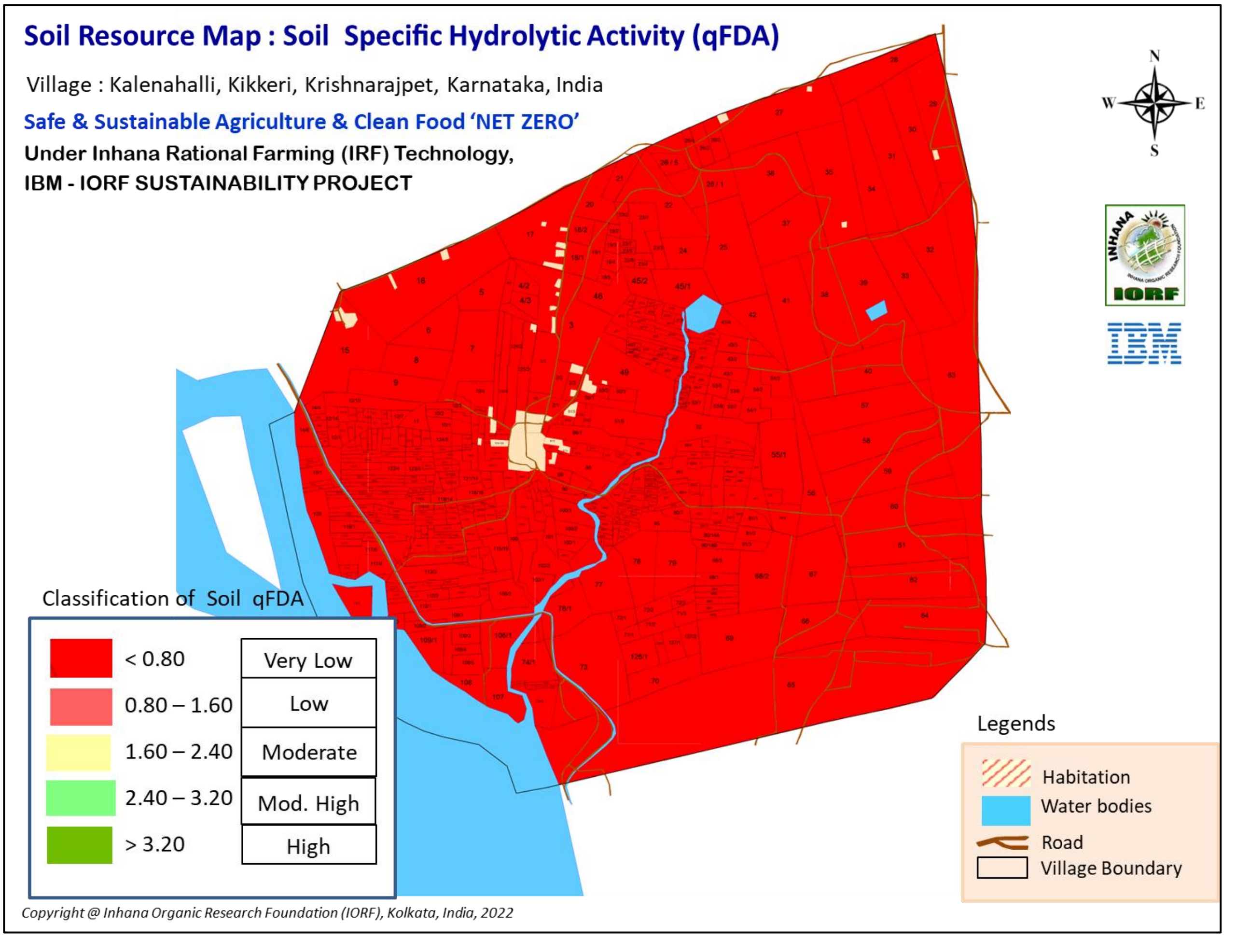


Fig 24: Soil qFDA Map of Kalenahalli village, Mandya, Karnataka

Thematic Map 17 - Soil Microbial Activity Potential (MAP) of the study area

Biological activity in soil is fundamental for plant growth: the biological nitrogen, phosphorus and sulphur cycles increase the bioavailability of nutrients, and the **deposition of organic carbon contributes to soil structure, which is important for reducing erosion** and improving water movement and retention. **Hence, an index to evaluate the overall soil biological activity is of immense importance w.r.t. sustainable crop production.** Detailed investigation of Soil Biology was undertaken by IORF as early as In 2012 and Soil Microbial Activity Potential (MAP) was formulated by taking six major soil biological parameters *viz.* soil microbial biomass, soil enzyme activities: FDAH *(fluorescein diacetate),* microbial quotient (qMBC), microbial metabolic quotient (qCO2), microbial respiration quotient (QR) and specific hydrolytic activity (qFDA).

Soil Microbial Activity Potential (MAP) is actually a tool, which indicates the overall soil microbial status and its activity towards soil nutrient dynamics. Higher MAP value indicates a higher potential of the soil as a medium for sustainable crop production and also confirms the presence of the 'Soil Microbiological Barrier' against the soil borne disease causing pathogens.

Microbial Activity Potential (MAP) of the soil in the Project Area was very low (<8) in 92% area and low (8-10) value in rest area. Microbial Activity Potential (MAP) value again reconfirms the necessity of sustainable farming approach in the project area for reducing the soil degradability potential vis-à-vis ensuring crop sustainability.

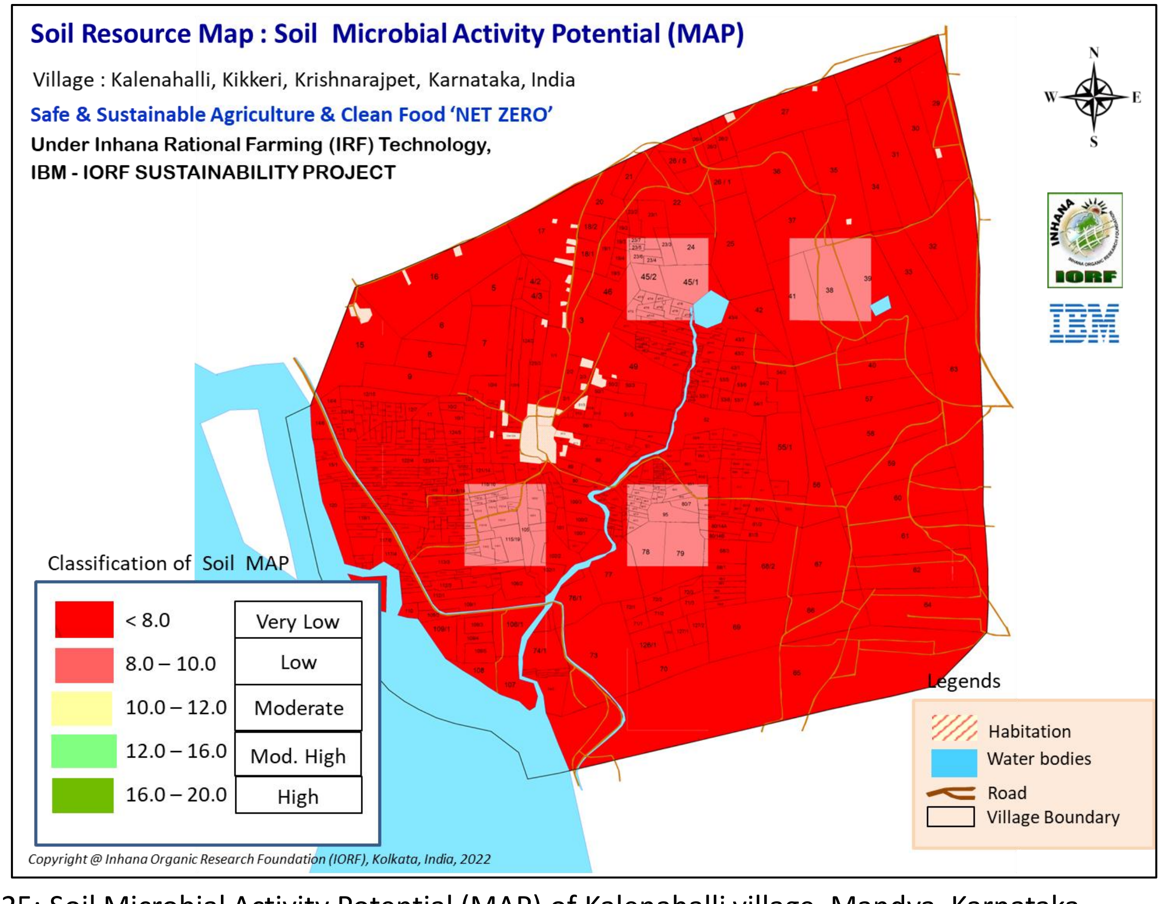


Fig 25: Soil Microbial Activity Potential (MAP) of Kalenahalli village, Mandya, Karnataka

Thematic Map 18 - Soil Quality Index (SQI)of the study area

Soil Specific Hydrolytic Activity (qFDA) is measured as Fluorescein diacetate (FDA) hydrolysis per unit organic carbon, and indicates the quality of organic carbon in soil in terms of its dynamism and microbial potential.

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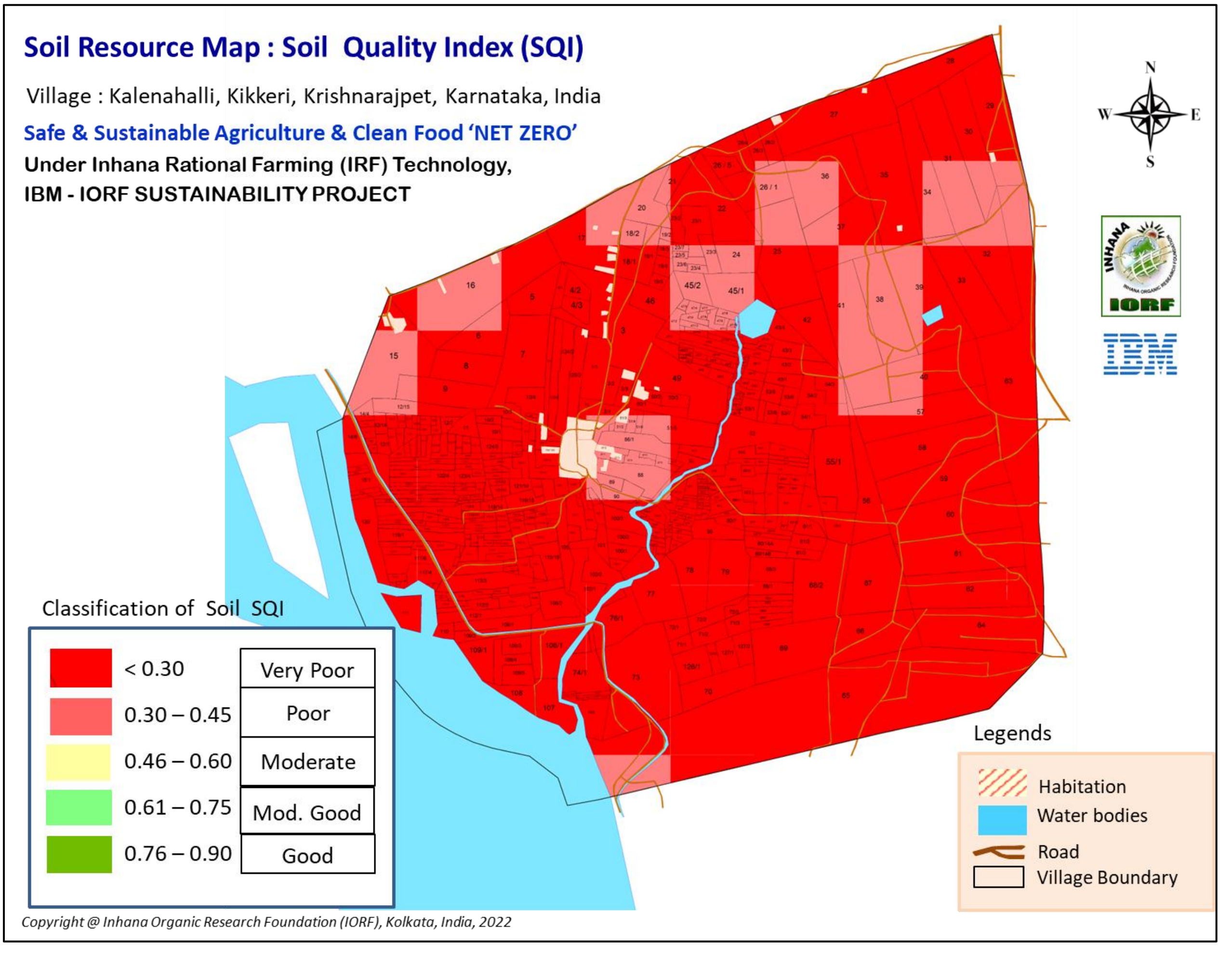

Fig 26 : Soil Quality Index (SQI) Map of Kalenahalli village, Mandya, Karnataka

Soil Health Card – A Fresh Perspective under IBM-IORF Sustainability Project

The Phase-1 Project demonstrated for the 1st Time in India, the Most Exhaustive Soil Analysis Program and development of a **Unique SOIL HEALTH CARD** that provides **25 Soil Quality Parameters Study with comprehensive Soil Microbiological Analysis** – The Most Relevant Component for Soil Health vis-à-vis Sustainable Crop Production. The same soil health card was given to the project farmers at Mandya towards Sustainable Soil Health Management

A SAMPLE SOIL HEALTH CARD

Inhana Organic Research Foundation, Kolkata initiated the Pesticide Free 'Clean Food Movement' from June, 2020 in West Bengal to demonstrate a Model for Safe & Sustainable Agriculture that will deliver SAFE FOOD, while enabling Economic Sustainability across the Food Chain i.e. from the Crop Growers to the Consumers. Looking at the relevence of this program w.r.t. SDG-2, SDG-13 & SDG-15 of the United Nations, IBM pitched in and took up this 'Clean Food' initiative under its Sustainability Program.

Soil Health Assessment forms the first milestone in the journey towards Sustainable Crop Production . Hence in the 1st Phase of this project initiative was taken for providing Every Individual Project Farmer his own 'Soil Health Card' aligning with our mission 'KNOW YOUR SOIL'. And on the occasion of World Soil Day on 5th Dec., 2021, we under took the program for distribution of the Soil Health Cards to our Project Farmers in West Bengal. The Government of India launched the Soil Health Card (SHC) Scheme in 2015, which was a first time crucial initiative post independence. The Soil Health Card developed under IBM-IORF Sustainability Project can serve to strengthen the Govt. SHC Program due its Comprehensiveness in terms of 25 Parameters Soil Quality Analysis especially focusing on Soil Biological Parameters; that actually determines Soil Health and its Dynamics. Also 5 important Soil Indices i.e., Physical (PI), Fertility (FI), Microbiological (MAP), Micronutrient and finally Soil Quality Index (SQI) as overall Soil Health Indicator; was provided in SIMPLE COLOUR CODING to facilitate easy understanding through visual interpretation.

In the 2nd Phase of the Project, a new initiative has been added in Mandya District of Karnataka towards production of SAFEST 'Clean Food' encompassing Human Health, Soil & Environment and to develop a Clean Food 'NET ZERO' MODEL through bioconversion of Coir Pith (a hard to biodegrade waste which is a High GHG Emitter) The relevance of Soil Health Assessment is again critical especially towards showcasing Higher Crop Productivity in these Marginal soils underlain with a murrum zone containing weathered rock. Hence, on the occasion of World Food Day (16th Oct., 2022), we initiate the distribution of these Comprehensive Soil Health Cards to our Project Farmers in Mandya, Karnata.

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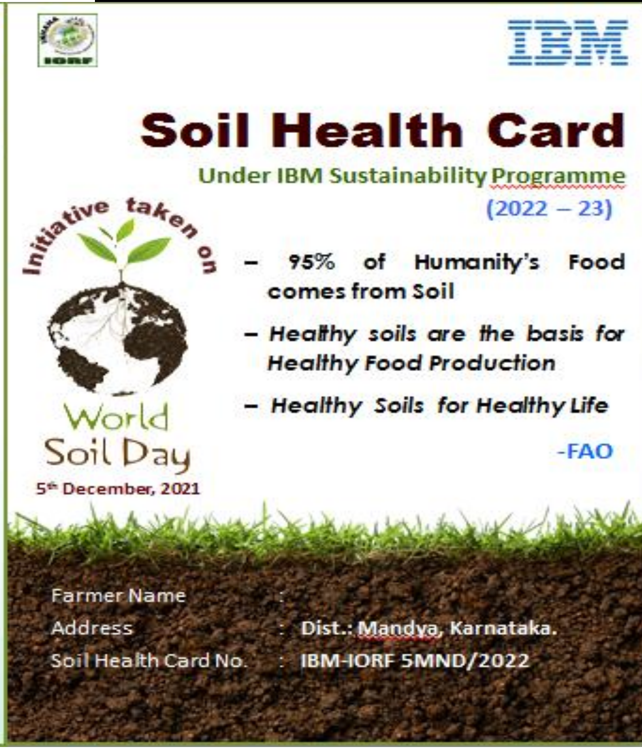
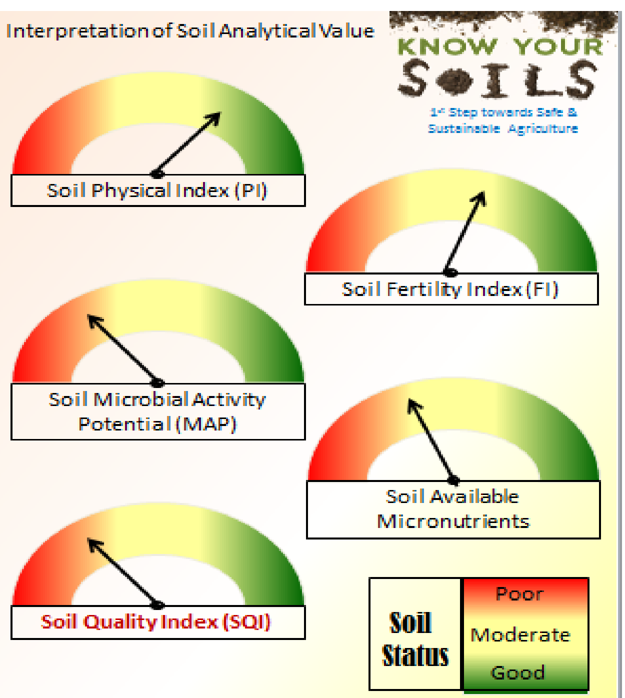


Soil Analysis Data Sheet

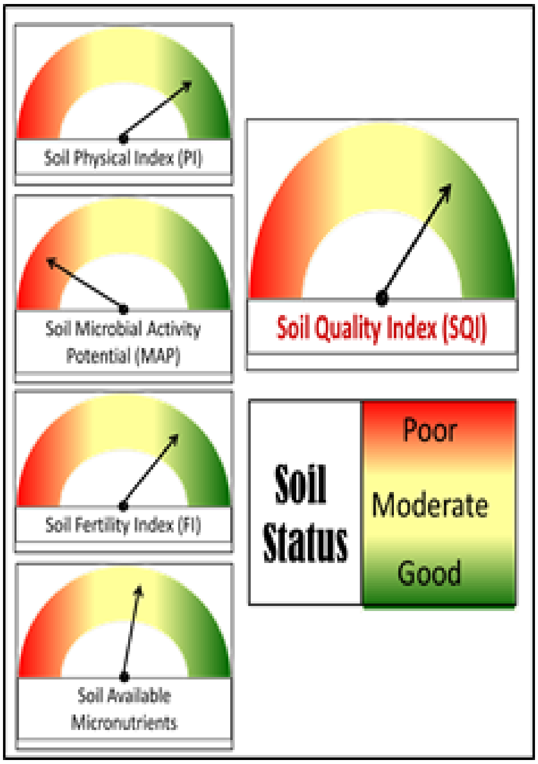
Sl.	Parameters		Ideal Range	Analytical Value
Soil Physical Characteristics				
1.	Sand %	:	20 – 70 %	78.62
2.	Silt %	:	20 – 70 %	10.92
3.	Clay %	:	10 - 40 %	10.46
4.	Soil Texture	:	SL, CL, SCL, SC, LS, SCL	LS-Loamy Sand
5.	Soil Bulk Density (gcm^{-3})	:	1.10 – 1.40	1.42
Soil Physico-chemical Characteristics				
6.	pH_{water}	:	6.5 – 7.5	6.07
7.	EC_e (dSm^{-1})	:	< 1.0	0.40
8.	Organic Carbon (%)	:	> 0.75	0.59
9.	Available NO_3^- (ppm)	:	20 – 40	14.42
10.	Available N ($kgha^{-1}$)	:	280 - 600	329
11.	Available P_2O_5 ($kgha^{-1}$)	:	45.0 – 90.0	88
12.	Available K_2O ($kgha^{-1}$)	:	150 - 340	678
13.	Available SO_4^- ($kgha^{-1}$)	:	60 - 120	349
Soil Biological Characteristics				
14.	Microbial Biomass Carbon ($\mu g.CO_2$.C/gm dry soil)	:	150 - 600	275.12
15.	Soil Respiration (mg.CO_2.C/gm dry soil per day)	:	< 2.0	0.087
16.	Soil FDAH (µg/gm dry soil)	:	120 - 240	25.62
17.	Microbial Quotient (qMBC)	:	2.0 – 4.0	4.66
18.	Microbial Metabolic Quotient (qCO_2)	:	1.00 – 5.00	0.32
19.	qFDAH	:	1.60 – 3.20	0.434
20.	Microbial Respiration Quotient (QR)	:	0.50 – 0.80	0.005
Soil Micronutrients				
21.	Available Fe (ppm)	:	5.0 - 10.0	6.44
22.	Available Mn (ppm)	:	2.0 – 10.0	6.60
23.	Available Zn (ppm)	:	0.60 – 1.50	0.78
24.	Available Cu (ppm)	:	0.20 - 2.00	0.97
25.	Available B (ppm)	:	0.50 – 1.50	1.16

Interpretation of Soil Analytical Value



For Soil Test Based Recommendation, Contact the following Number : IORF (8336061466)

Uniqueness of the IBM- IORF Soil Health Card



Development of **5 Unique Soil Quality Indices along with colour coding** by

IORF

in collaboration with ICAR Institutes, India for easy understanding of soil health status by the farmers towards **Sustainable Soil Health Management**

Pic.: Distribution of Comprehensive Soil Health Card to the project farmers in the presence of IBM Representatives at Mandya, Karnataka

CHAPTER 4 : Development of Model for Reclamation of Degraded Land

Summary

Soil degradation is a severe environmental problem, affecting approximately 1.9 billion ha of land worldwide, and almost 24 billion tons of soil is irrevocably washed or carried away every year. Soil degradation in India is estimated to be occurring on 147 million hectares (Mha) of land which has become a serious issue considering that India supports 18% of world's human population and 15% of world's livestock population, but has only 2.4% of the world's land area.

Under IBM-IORF Sustainability Project at Mandya, Karnataka a Soil Reclamation Program was initiated looking at its importance and relevance specially in respect of Mandya, with marginal soil quality and with an average annual soil loss of 27 tons/ha/yr.

The major highlight of the program is the utilization of coir pith – a toxic material dumped as waste in open lands where it forms a primary source Of METHNE EMISSION. This hard to biodegrade, toxic and GHG emitting waste was transformed into a safe and quality compost utilizing Novcom Composting Technology; towrads sustainable soil health

Inhana Rational Farming (IRF) Technology was adopted for sustainable cultivation of different types of vegetables, maize and lately ginger on the reclaimed land which was otherwise unfit for any type of agriculture. **The highlight of this technology is that it ensured comparable crop yields even in such reclaimed lands that too in the very 1st year of intervention.**

Introduction

According to a new report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystems (IPBES), the principle global driver of **land degradation is the expansion and unsustainable management of agriculture,** fuelled by unprecedented levels of consumption in an increasingly globalized economy. Conventional farming has been causing significant loss of biodiversity and ecosystem services, such as food security, water purification and the provision of energy.

The IPBES report also finds that **land degradation is a major contributor to climate change**, with deforestation alone contributing about 10% of all human-induced greenhouse gas emissions. Another major driver of the changing climate has been the release of carbon previously stored in the soil, with **land degradation between 2000 and 2009 responsible for annual global emissions of up to 4.4 billion tonnes of CO_2**.

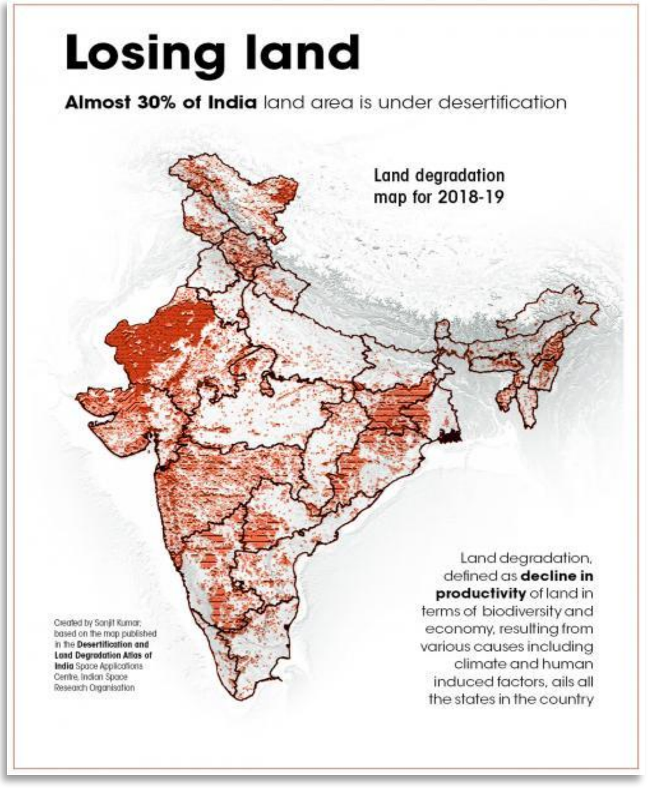
According to a senior UN official – 'Generating three centimeters of top soil takes 1,000 years, and **if current rates of degradation continue all of the world's top soil could be gone within 60 years**'. Unless new approaches are adopted, the global amount of arable and productive land per person in 2050 will be only a quarter of the level in 1960, the FAO reported, due to growing populations and soil degradation.

Present scenario of Land degradation in India

With close to 30 per cent of its geographical area already affected, land degradation is definitely among India's most pressing environmental problems. To make matters worse, almost all Indian states have recorded an increase in degraded land in the past 15 years, with the most rapid increase being noted in the biodiversity-rich northeastern states. These details have been published in the Desertification and Land Degradation Atlas of India, made public in August by the Indian Space Research Organization (ISRO). The numbers, collected for 2018-19, also highlight the stiff challenge India will need to face to achieve its target of becoming land degradation neutral by 2030, announced by the Prime Minister in September 2019 at the United Nations Convention to Combat Desertification. Currently, 97.85 million hectares (mha) of land — an area 2.5 times the size of India's largest state Rajasthan— has already been degraded. Of this, 3.32 mha — an area 22 times the size of Delhi — has been added in the 15 years between 2003-05 and 2018-19.

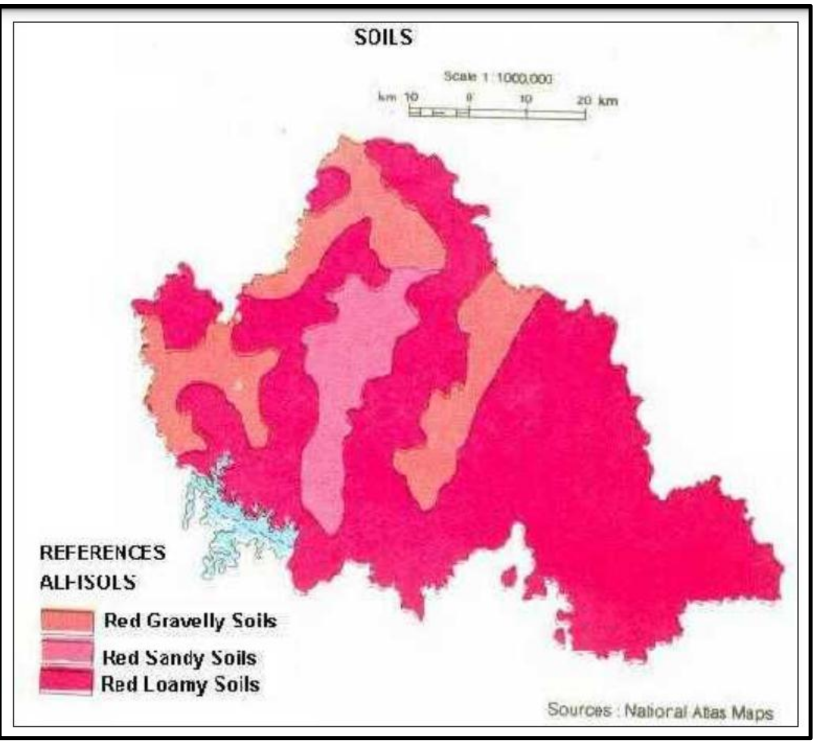
With close to 6.96 million hectares of land undergoing degradation and desertification, **Karnataka is the fifth biggest contributor** to the total geographical area under degradation in India. **In a span of less than a decade, the State has seen over 100 sq km of its area becoming irreversibly degraded**, says a report by the ISRO.

Over the years, nearly 40 per cent to 45 per cent of the area in districts like Kolar have turned uncultivable, owing to mismanagement. In many areas around the Western Ghats, forest land has been converted to agricultural land and eventually the top.



Specially, the crop productivity levels in irrigated command areas have plateaued or started declining rapidly due to the deterioration of soil health. Unscientific and excessive irrigation, growing crops not compatible with the soils and unscientific management of soils are the main causes for the present situation.

Limiting soils of Mandya – more vulnerable in the absence of Sustainable Agriculture Practice



According to PMKSY report on Mandya, soil erosion which occurs at varying rates is a widespread threat to sustainable resource management. The average annual soil loss was 27 tons/ha/yr. Major causes of soil erosion are cultivation without proper soil and water conservation measures in area not suitable for crops, denuded areas without vegetation, cultivated fallow on moderate slopes, degraded forests/pastures on steep slopes and poorly managed forest cover.

Specially in limiting soils like in Mandya, chemical agricultural practice has a more detrimental impact as Synthetic Fertilizers Negatively Impact Soil Health. For example, research has found that synthetic nitrogen fertilizer application decreases soil's microbiological diversity (that is, bacteria, fungi, etc.) or alters its natural microbiological composition in favor of more pathological strains. Some types of nitrogen fertilizer can cause soil acidification, which can affect plant growth. Excessive fertilizer use can also cause a buildup of salts in soil, heavy metal contamination and accumulation of nitrate (which is a source of water pollution and also harmful to humans).

At the same time, presence of pesticide in soil decreases microbial biodiversity in soil; and have adverse effects on earthworms. Some types of pesticides may have effects on soil microbiology; specially the nitrogen-fixing microbes that are important to soil health and fertility.

Study of Soil Organic Carbon Density (SOCD) to assess Soil Carbon Sequestration Potentials

Understanding spatial pattern of Soil Organic Carbon Density (SOCD) and its potential influencing factors in cropland is of paramount importance when evaluating soil quality & its Carbon Sequestration Potential.

Soil Organic Carbon (SOC) is the largest terrestrial carbon pool, therefore playing an important role in the Global Carbon Cycle (Grigal and Harding, 1991; Lal, 2004). Specifically, the global SOC pool of 1500 Pg C contains twice the carbon in the atmospheric pools and three times that of the terrestrial vegetation (Batjes, 1996; Post et al., 1982).

The soil organic carbon density (SOCD) represents the SOC reserves at a certain depth per unit area, which can better reflect variations in the SOCS (Ren et al., 2020). In the last decades, an extensive body of research has been conducted to estimate the SOCD and SOCS parameters in cropland.

However, the SOCD and SOCS of cropland shows enormous variations across different regions and depths.

SOCD is represented by the following equation :

$$SOCD_h = D \times SOC \times BD \times (1 - S/100) \times 10^{-1}$$

where $SOCD_h$ is the total amount of SOC at depth h per unit area (Mg C ha^{-1}); D is thickness (cm); SOC is SOC content (g kg^{-1}); BD is bulk density (Mg m^{-3}); and S is the proportion (%) of coarse (> 2 mm) fragments in the layer.

In the project area, Soil organic carbon density (SOCD) was evaluated to understand the overall soil organic carbon stock in the major root zone (30 cm).

The Study revealed that majority (60%) of the area was under critical to very critical zone. This together with the physical characteristics of soil pointed towards a Higher Potential for Erosion and a low Soil Productivity Potential. A Sustainable Approach of Soil health management was Crucial to prevent further deterioration of soil and to ensure long term crop sustainability.

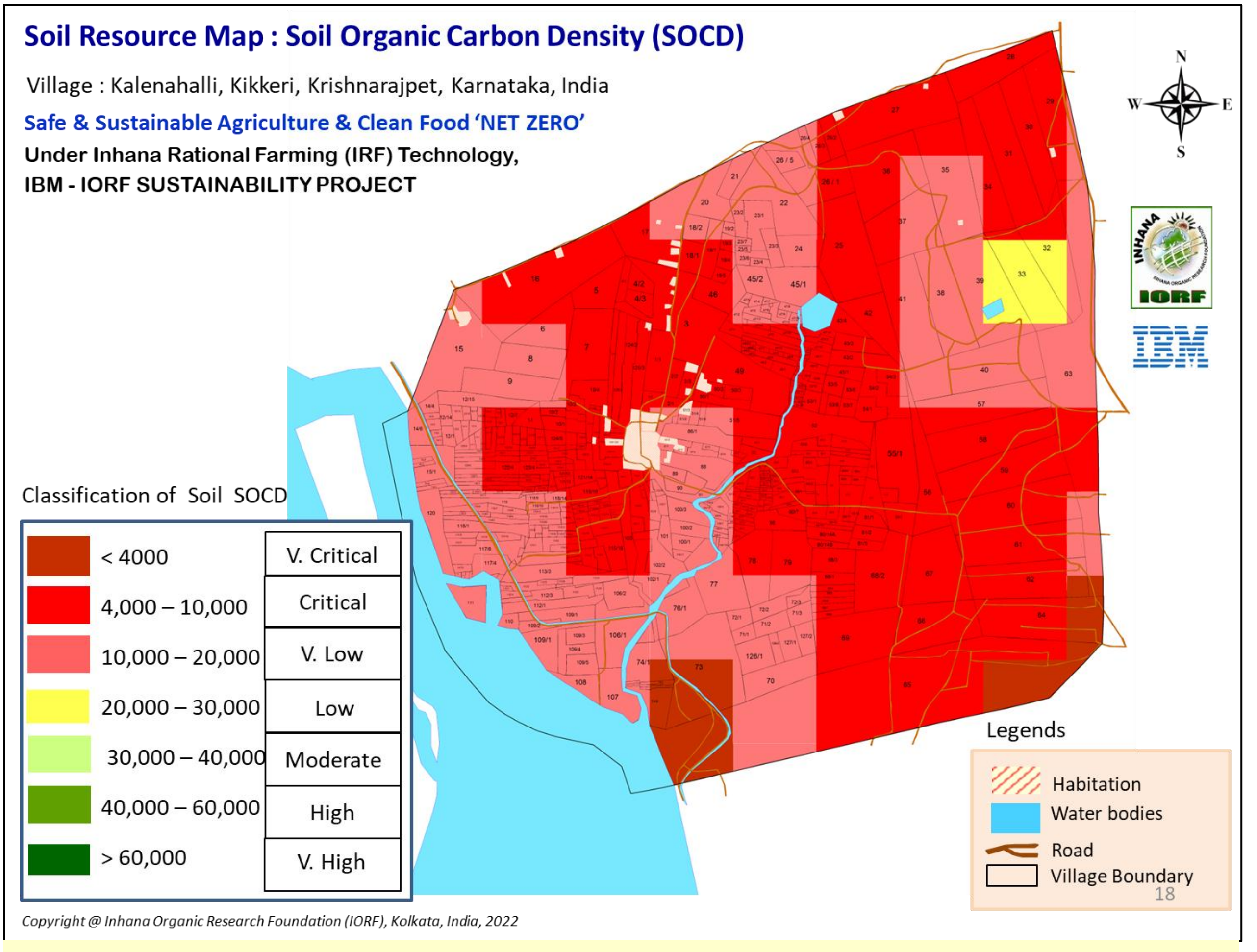


Fig 1 : Soil Organic Carbon Density (SOCD) Map of Kalenahalli village, Mandya, Karnataka

Pic: Soil color indicates low to very low soil organic carbon density (SOCD) at Kalenahalli village, Mandya, Karnataka

Evaluation of the Soil Erodibility Factor (K) in the Project Area to assess the Potential Risk of Soil Erosion

Soil erodibility (K) is the intrinsic susceptibility of a soil to erosion by runoff and raindrop impact.

The soil erodibility factor (K-factor) is the quantitative description of the inherent erodibility of a particular soil; it is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff.

For a particular soil, the soil erodibility factor is the rate of erosion per unit erosion index from a standard plot. The factor reflects that different soils erode at different rates when the other factors that affect erosion (e.g., infiltration rate, permeability, total water capacity, dispersion, rain splash, and abrasion) are the same.

Soil erosion described as a global epidemic is the maximum in India, being 18.5% of the total soil losses from the croplands of the world (Khoshoo 1986). Soil erodibility factor K, which is defined as the rate of soil loss per erosion index unit from a unit plot size (Wischmeier & Smith 1965) is of major importance in soil erosion prediction and control and in the planning of improved farming systems (Lindsay & Gumbs 1982).

Erodibility is a soil property, which is useful reflection of the integrated effect of various sub-processes in regulating rainfall acceptance and soil resistance to particle detachment and transport (Lal 1998). The **Soil Erodibility Factor, K** of Universal Soil Loss Equation represents the vulnerability or susceptibility of soil to erosion, this **is the most important and fundamental property dependent upon soil type (Tripathi & Singh 1993) and it varies with the changes in climatic conditions and land use patterns.**

During the present investigation, K was determined using a simple nomograph (Wischmeier et al. 1971) for soils of different agro-ecological sub region of eastern India with respect to various land use patterns.

The present investigation was undertaken to analyze the comparative effect of Land Use and agro-ecology of soils towards the Degree of Soil Erosion, on the basis of the Soil Erodibility Factor K.

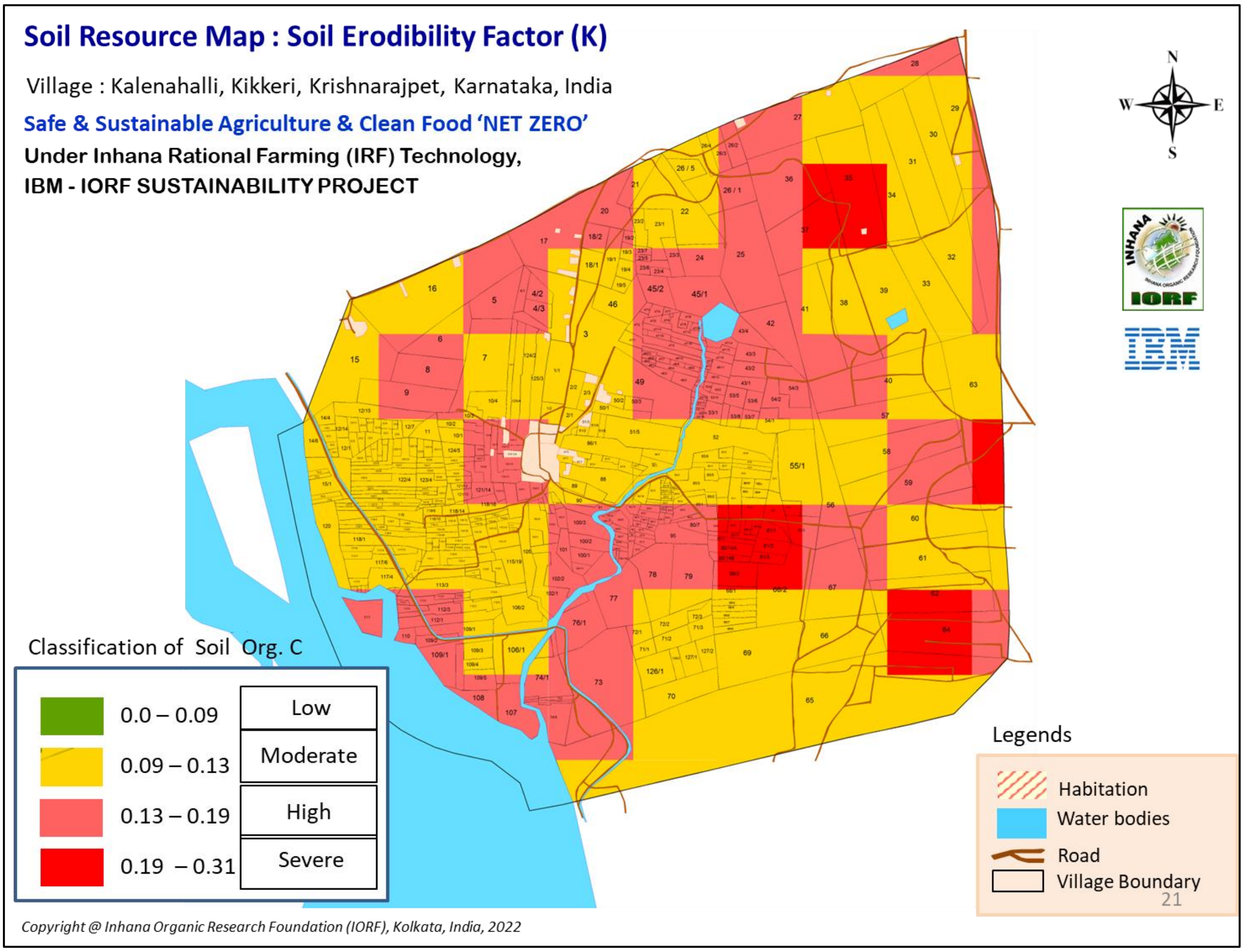


Fig 2 : Soil Erodibility Factor (K) Map of Kalenahalli village, Mandya, Karnataka

The nomograph of Wischmeier et al. (1971) was utilized and the empirical equation to establish the K value is given below:

$$100\ \mathrm{K} = 2.1 \times 10^{-4}(12 - \mathrm{O.\ M})\ \mathrm{M}^{1.14} + 3.25\ (\mathrm{S} - 2) + 2.5\ (\mathrm{P} - 3)$$

where, O. M = Organic matter in percent; M = (% Silt + % Very fine sand) x (100 - % Clay);
S = Soil structural code; P = Profile permeability class.

Evaluation of Soil Erodibility (K) of the project area revealed a moderate soil erosion susceptibility in a majority (57%) area. **Also about 7% and 36% area suffered from severe and high soil erosion respectively, which is a major concern point.**

The evaluation indicated that there was high risk of top soil loss if proper measures are not taken, which is a major concern point for crop sustainability specially considering marginal soils with an inherently poor soil quality.

Development of Degraded Soil Reclamation Model –Importance in Present Time

- Climate Change and Soil Degradation are the two most important challenges threatening crop sustainability and livelihood security and are therefore the cause for global attention. Most interestingly they are also interrelated.
- Soil has a direct relation with Climate Change as **Degraded soils can release 850 billion tons of CO_2 = last 30 years of emission**

(*Conscious Planet- Save Soil, 2022*)

- India is Committed to **Reduce the Total Projected Carbon Emissions by one billion tonnes** from by 2030; and this will require a significant contribution from agriculture & forestry – the largest potential sink w.r.t. GHG Mitigation opportunities.

14th Session of the Conference of Parties of United Nations Convention to Combat Desertification (UNCCD), 2021.

Most Challenging Task towards soil reclamation

SOIL BIOLOGICAL PRODUCTIVITY IS THE KEY
for Reclamation of Degraded Land
Bur restoring Soil Biological Productivity –
has been an Uphill Struggle

The Top 6 inches or 15 cm of Soil in 1 hectare weighs about 22,40,000 kg or 2240 Ton

So if we put even 22 Tons of Compost we are actually adding only about 5 g Organic Matter in 1 kg soil

Consequently , this will provide just 0.1% Organic Carbon in the Top 6” Soil in 1 hectare area

Hence, until this Organic Matter contains Significant Population & Diversity of Self- Acclimatized Micro flora . . .

RESTORATION OF SOIL BILOGICAL PRODUCTIVITY WILL BE TIME TAKING, LENGTHY & UNACCOUNTED

Novcom Composting Technology of IORF can regenerate native microflora within minimum time period through its unique ‘Energy Management’ principle and thus can be a potent tool towards reclamation of degraded land. It was found that due to presence of very high self-generated microflora (in order of one trillion billion per ton compost) Novcom compost can help to rejuvenate soil health in a quick succession of time. Under IBM-IORF Sustainability Program, this technology was adopted to practically exhibit the pathway for reclamation of degraded land in Mandya, Karnataka.

Precondition for an economically viable, socially acceptable and easily adoptable Model for Reclamation of degraded land

- Restoration of Soil Biological Productivity is the key for reclamation of degraded land
- And it is Not the Organic Matter Load or Organic Carbon Load, rather COMPOST MICROBIAL LOAD IS THE KEY to Accomplish the Target.
- Most importantly the Microbial Load should be SELF- GENERATED under the Composting Process and the population should be WELL DIVERSIFIED – this cannot be possible without an EFFECTIVE INTERVENTIONAL TECHNOLOGY
- But RESOURCE SCARCITY for Compost production is a Major Challenge. Moreover, for SCALABILITY the Resource should be ABUNDANT & INEXPENSIVE.
- Biodegradable Waste of any kind especially landfill material can best serve the objective, but technology is crucial for their bioconversion into Safe & Quality Compost.
- Elimination of Synthetic Fertilizers and Sustainable Soil Health Management can Counteract Degradation in Agricultural Lands but that has to be done without compromise in crop yield/

IRF TECHNOLOGY can Ensure Complete Elimination of Synthetic Fertilizer without any Crop Loss through Inhana Soil Health Management

Coirpith Composting with Novcom Composting Technology is the Key behind the Successful Soil Reclamation Model

Coir pith – **this waste form the coir industry forms a major threat to soil, water, ecology and environment, is a very high GHG Emitter and a very hard to biodegrade material due to its very high C:N ratio (> 1: 100) and very high lignin %.**

Under IBM-IORF Sustainability Project **1000 ton of Coirpith was bio-converted towards the objective of Sustainable Soil health Management** – the 1st step towards reclamation of degraded land.

Flow diagram of Soil Reclamation Model under IBM – IORF Sustainability Project

Survey of the area specially in respect of **slope, drainage and any specific feature**

Detailed Soil Analysis

Identification of limitations towards agricultural activity

Ploughing of the land and **removal of stones and gravels** (*as much as possible*)

Soil solarization to eliminate the threat of soil borne pests and plant pathogens (*if any*)

Preparation of quality compost rich in **Self Generated Microbial Population** through bio-conversion of Coir pith – A waste of Coir Industry utilizing Novcom Composting Method

Application of Novcom Coir pith compost @ 40 ton during land leveling operation.

Application of CDS concoction (an indigenous preparation for rejuvenation of soil micro flora).

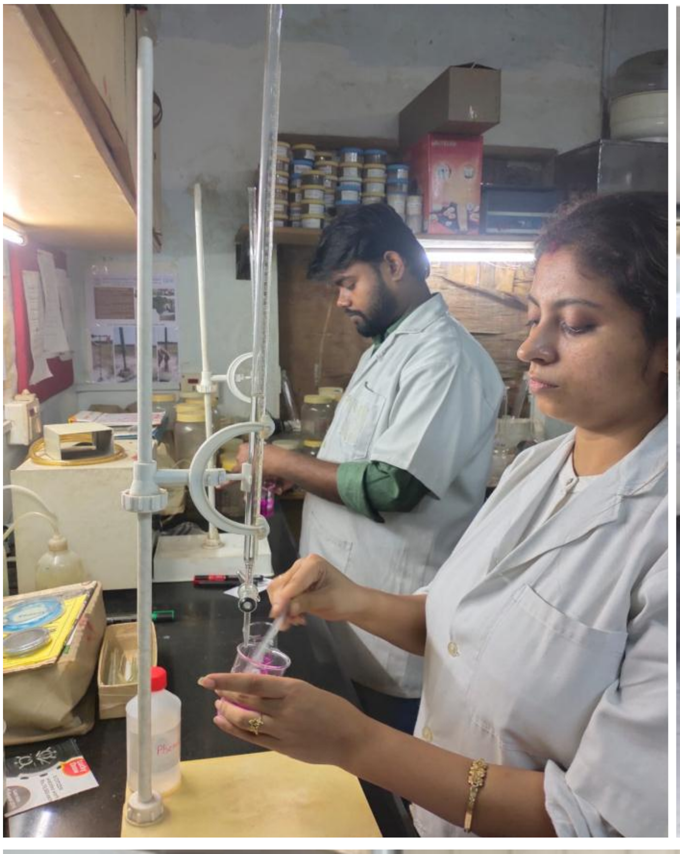
Set up of sprinkler irrigation system for efficient water management

Provide a 15 – 20 day soil rejuvenation time followed by transplanting of vegetable seedlings nourished under **Inhana Plant Health Management (IPHM)** followed by mulching to prevent weed growth

Follow up with Inhana Plant Health Management **(IPHM) for growth and optimization of crop production**

Documentation, Viability Analysis and Study of Environmental Impact

Pic.: Reclamation Model (Step 1) : Selection of land



Pic.: Reclamation Model (Step 2) : Analysis of soil samples in IORF laboratory

Pic.: Reclamation Model (Step 3) : Removal of bigger stones from soil after tillage operations

Pic.: Reclamation Model (Step 4) : Segregation of medium size pebbles during final land preparation

Reclamation Model (Step 5a) : Mixing of coir pith and cow dung as part of Novcom coir pith composting

Pic.: Reclamation Model (Step 5b) : Preparation of Novcom coir pith compost - the most important component towards reclamation of degraded land,

Pic.: Reclamation Model (Step 6) : Mixing of Novcom coir pith compost with pond soils before application in the land

Pic.: Reclamation Model (Step 7) : Application of Novcom compost after final land preparation and mixing with top soil.

Pic.: Reclamation Model (Step 8) Plastic mulching towards weed management as well as preservation of moisture

Pic.: Reclamation Model (Step 9) : Sprinkler irrigation system for minimizing water use and stopping water loss

Pic.: Reclamation Model (Step 10) : Spraying of Inhana Plant Health Management Solutions for harmonious growth and crop sustenance– the most important step in reclamation program.

Pic.: Reclamation Model (Step 11) : Plant Growth under Sustainable Soil health Management using Novcom Coir- pith Compost, and application of Customized Inhana Plant Health Management (IPHM) Solutions, while Eliminating N- fertilizer and Chemical Pesticides.

Pic.: Reclamation Model (Step 12a) : Sustainable crop production in Reclaimed Degraded Land with adoption of IRF Technology

Pic.: Reclamation Model (Step 12b) : Sustainable crop production in Reclaimed Degraded Land with adoption of IRF Technology - a comprehensive Organic Package of Practice.

CHAPTER 5 : Crop Production and Safety Assessment under Clean Food 'Net Zero' Program

Summary

The existential climate change impact is increasing the food security challenge, more so as the world will need to produce about 70 percent more food by 2050 to feed an estimated 9 billion people. This is due to agriculture's extreme vulnerability to climate change. Climate change's negative impacts are already being felt, in the form of increasing temperatures, weather variability, shifting agro-ecosystem boundaries, invasive crops and pests, and more frequent extreme weather events. In this backdrop, the **Clean Food 'Net Zero' Program was initiated** under the IBM-IORF Sustainability Project **at Mandya, Karnataka, India.**

IRF Technology was adopted as the Safe and Sustainable Crop Technology towards the objective of 'Clean Energy for Clean food' focusing on Soil and Plant Health Management. **Thus Clean Food 'Net Zero' means SAFEST Food production- SAFE for human health, soil and environment; with No Crop Loss and No hike in the Cost of Production and finally significant climate action in terms of GHG Mitigation, especially Source Point Methane Mitigation.**

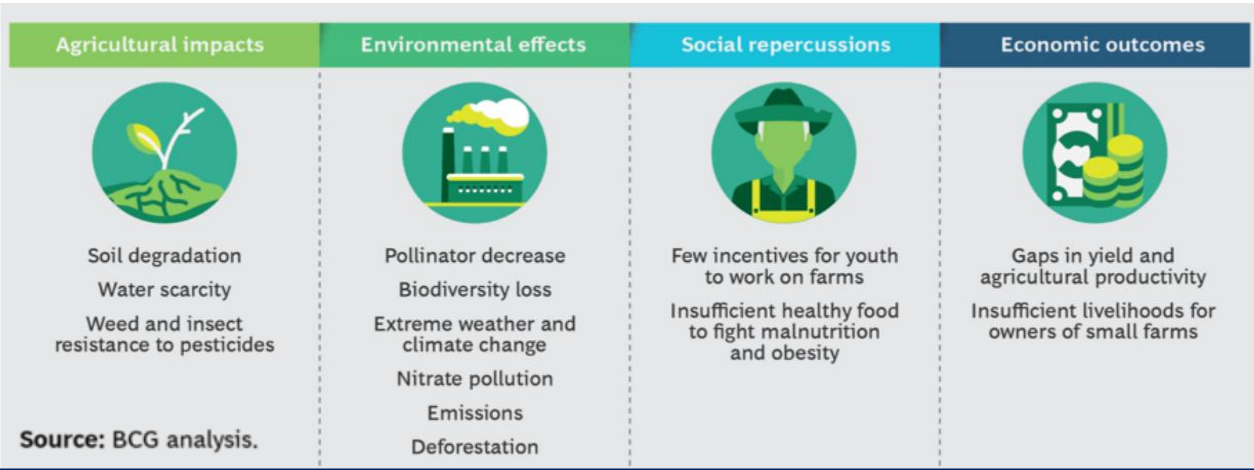
The Safety aspect of Clean Food 'Net Zero' is authenticated through Colorimetric Pesticide Assay Test developed by IORF in the Phase-I Project, which enables safety analysis in the speediest manner and most importantly at 1/10th of the Conventional Cost of Residue Analysis, which is especially relevant for multiple harvest crops like vegetables that have a period small time gap between field harvest and actual consumption.

Introduction

Climate change is sowing the seeds of food crisis in its path. **Agricultures' vulnerability to climate change is reflective in the depleting crop yields especially under the extreme climatic events and the rising pest intensity.** Climate change is now affecting every country on every continent, disrupting national economies and affecting lives, costing people, communities and countries dearly today and even more tomorrow. **The poorest and most vulnerable people are being affected the most, and for a country like India these are basically the marginal and small farmers.**

Agriculture, while being highly vulnerable, is also a major contributor to climate change. In particular, agricultural practices and processes can emit significant amounts of methane and nitrous oxide, two powerful greenhouse gases. According to the OECD, agriculture contributes approximately 17% greenhouse gas (GHG) emissions directly through agricultural activities and an additional 7% to 14% through land use changes. **On the flip side agriculture is the only sector that has both GHG mitigation and adaptation potentials, provided conventional agriculture is transformed into Sustainable Agriculture.**

Besides climate change, **SOIL DEGRADATION** which contributes to 36–75 billion tons of land depletion every year, threatens the global food supply; which implies that now; More Crop has to be Produced from Less Land. **Hence, the major challenge facing mankind today is to produce sufficient food, for the rising human population, from a comparatively lesser land, while combating the climate change impact.**



Consequences of Current Farming Practices

The Pathway to Adopt

So we have to move towards sustainable practice to counteract climate change impact and create more sources of carbon sink. When agricultural operations are sustainably managed, they can preserve and restore critical habitats, help protect watersheds, and improve soil health and water quality. Sustainable farming that addresses the interlinked challenges of food security and accelerating climate change can simultaneously achieve higher productivity, enhanced resilience and reduced emission.

Sustainable agricultural practice is broadly divided into sustainable soil management and sustainable crop management. Sustainable Soil Management in terms of lowering/ eliminating fertilizer use, especially nitrate fertilizers and higher application of microflora (self- generated) rich organic amendments for improving the Soil- C sequestration potential; can serve towards GHG mitigation. At the same time improving crop yields vis-à-vis eliminating chemicals pesticides and fertilizers can serve the adaptation strategies.

Hence, besides Safety of Human Health, a Safe Approach to the Soil and the environment will be crucial to Restore Ecosystem Function Abilities and Deliveries. Two initiatives, i.e., increasing the productivity of Marginal Soils and Reclamation of Degraded Soils for restoring its suitability for agriculture; though herculean tasks can provide significant impact in this arena.

What is Net Zero Commitment?

Net zero refers to the balance between the amount of greenhouse gas emission and the amount removed from the atmosphere through specific action taken. We reach net zero when the amount we add is no more than the amount taken away. As per Paris Agreement, the goal is to limit global warming to well below 2.0, preferably to 1.5 degrees Celsius, compared to pre-industrial levels and to achieve that, we need to achieve net zero greenhouse gas emission by 2050.

However it is clearly understood that **Technological Intervention is prerequisite** for achieving the target in time bound manner.

SUSTAINABLE AGRICULTURE

Best way to attend Net Zero Commitment with Social and Environmental Footprints

According to an estimate by Dr. Lal, the renowned Soil Scientist and the 2020 World Food Prize Winner, **our soil can hold 42 to 78 billion metric tons more carbon.**

But more importantly, Increasing the amount of carbon in soil also makes it more productive for farmers which can only be through Sustainable Farming Approaches.

Sustainable Development Goals

Most Importantly when 'Net Zero' is achieved through Sustainable Agriculture, we simultaneously achieve the Sustainable Development Goals (SDG)

Social & Environmental Footprints

Clean Food Net Zero Program at Mandya, Karnataka

In the Phase-I Project, IORF demonstrated the pathway to produce 'Clean Food'- Safe for Human Health and Sustainable for all, with an impact area in respect of SDG-2 'Access of Safe and Nutritious Food' for all (SDG 2.1). This Project ultimately led to the development of Clean Food 'NET ZERO' Model, which can attend 7 Crucial SDGs.

Application of Safe and Quality Compost in Soil was the primary requirement for this program, but to enable its adoption at scale, the raw material source for compost production needed to be abundant as well as economic.

WASTE of any type especially landfill/ legacy waste/ MSW, etc., perfectly fits the bill. But apparently there is **dearth of Environmentally Safe and Economically Viable Composting Technology/ ies that can transform these Toxic, especially METHANE EMIITING pollutants** into a Safe, Stable and Mature Compost, suitable for agricultural use.

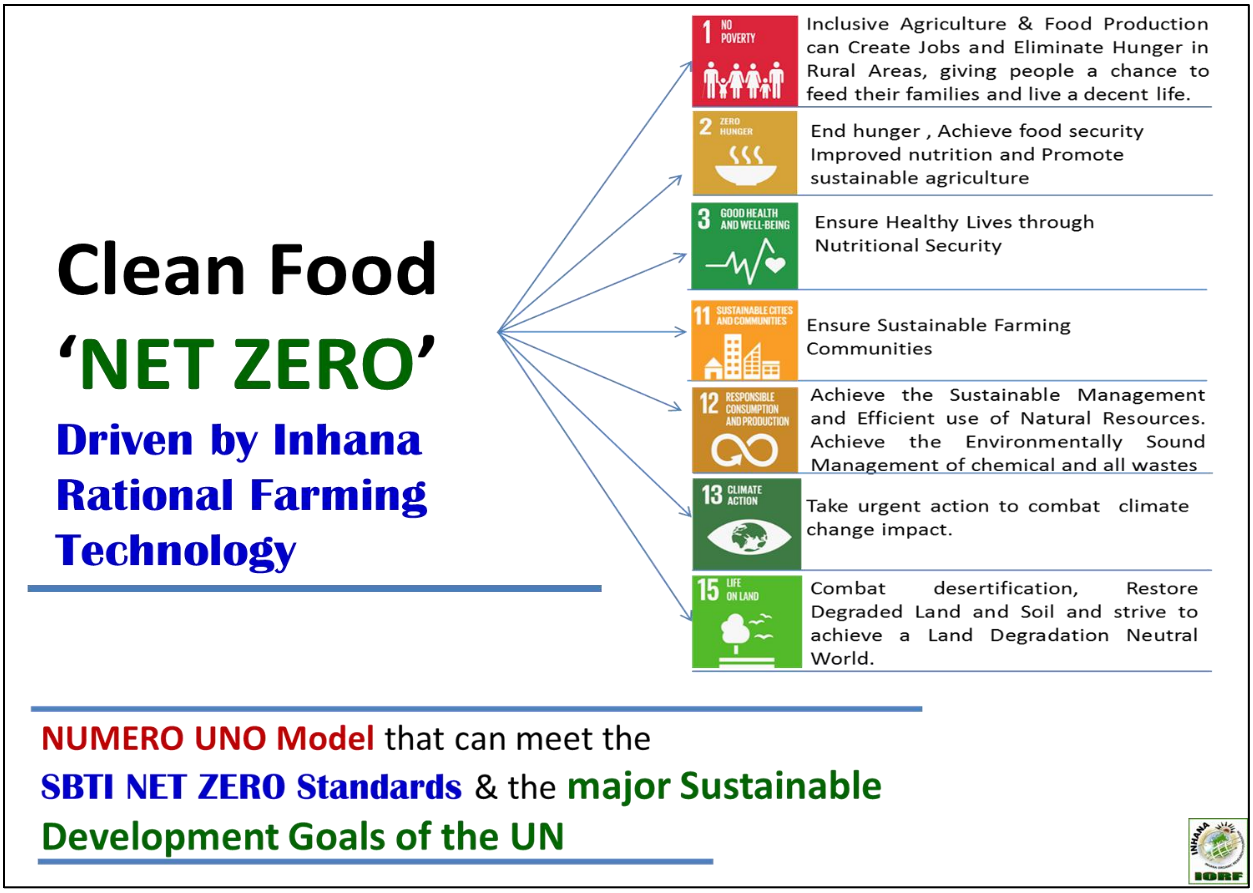
The Mandya District of Karnataka has an abundant source of Coir pith – a toxic, hard to biodegrade, and a very high Methane emitting waste from coir industry. But, considering that so far there is no composting technology which can effectively biodegrade coir pith, hence; it continues to be dumped in open lands and During the rainy season, the tannins and phenols of the coir pith leach out into the soil and the irrigation canals, thereby making agricultural lands unproductive.

Moreover, Coir pith forms a VERY HIGH GHG EMITTER 6.0 mt CO_2-eq per ton of coir pith approx.) – primarily METHANE, which has 75 times Higher Global Warming Potential ($GWP_{24\ years}$) as compared to CO_2, and is also the Precursor to O_3, which itself is a GHG.

This WASTE material from Coir Industry can however, serve as an excellent Soil Rejuvenator when recycled following a Technology Driven Process.

The insight gave the Impetus to IORF to initiate the Clean Food 'NET ZERO' Program at Mandya, in order to demonstrate a **CLIMATE ACTION MODEL** that will actually deliver **SAFEST FOOD –** Safe for Human Health, Soil & Environment.

Clean Food Net Zero Program attends multiple Sustainable Developmental Goals (SDGs)



Opportunity for offsetting GHG emission along with social and environmental impact under Clean Food ‘NET ZERO’ Program.

Under IBM-IORF Sustainability project, we calculated the GHG offsetting potential under ‘Clean Food’ production. Carbon Assessment Tool (ACFA version-1.0) developed by IORF, Kolkata was primarily used for calculation of GHG offsetting/ carbon saving,

As per the primary estimate, 1 kg Clean Food ‘NET ZERO’ production under IRF Technology can offset 250 to more than 500 ton CO_2e per ha and thus a 100 ha ‘Clean Food’ program has the potential to Offset more than 50,000 ton CO_2 eq. GHG which can be the most meaningful way to accomplish the Net Zero Carbon Objective.

District Mandya - the Challenges

The total geographical area of Mandya district is 4,98,244 hectares, out of which 2,48,825 hectares forms the sown area. That means more than half of the district’s total land area is used for agricultural purpose. Agriculture and Allied Sector contributes 4.3% of the GDP of the Karnataka state. But the soils of Mandya district are inherently thin gravelly and underlain with a murrum zone containing weathered rock.

District Mandya - the Challenges

The soils are highly leached and poor in bases and the water holding capacity is low. **The high gravel content of the soil (sometimes up to 50%) coupled with Very Low Soil Organic Carbon means the soil are HIGHLY PRONE TO EROSION and this proneness has become multifold with repeated and high and injudicious fertilizer application. The fact is vividly demonstrated by the MODERATELY ERODED SOILS that measure 249,166 ha and account for about 50.28% of the total geographical area of the district.**

Among the challenges faced by the District Farmers Four, are Critical and Need Immediate Attention to Ensure both Present and the Future Crop Sustainability :

- Soil Degradation
- Increasing Incidence of Pest and Disease
- Rising Cost of Cultivation

While some efforts are being made through programs such as the Integrated Watershed Management, **Effective Models are Still lacking that can Singlehandedly Mitigate all three Constraints.**

Land Characteristics of the Project Area

Very low soil organic carbon (0.5 to 0.6%) and more than 50% Gravel Content pose major challenges w.r.t. crop cultivation especially for vegetable crops. **Another important constraint is the lack of microflora dynamics in soil and the low micronutrient status; which renders moderate to poor Soil Quality Index value. Moreover, the endless rows of a single crop (sugarcane and coconut mono cropping) year after year**, continuous application of chemical fertilizers especially nitrates and lack of soil health management **has initiated the cycle of soil depletion and led to higher and repeated pest leading to a higher application of pesticides and therefore a highly toxic and unsustainable environment that is threatening the farmers' livelihood.** Restoration of Soil Biological Productivity, forms the only Solution to mitigate the Rising Challenges towards Crop sustenance and Farmers' Livelihood security, and application of Safe and Quality Compost in Soil forms the Only Solution towards the Objective.

Inhana Rational Farming (IRF) Technology - *the Driving Force Behind Target Accomplishment*

Intervention of a **NEGATIVE EMISSION TECHNOLOGY i.e. Inhana Rational Farming (IRF) Technology of IORF is the primary driving force behind development of Clean Food 'NET ZERO'** through the approach of '**PLANT HEALTH MANAGEMENT'**

First of a Kind Approach in terms of '**PLANT HEALTH MANAGEMENT**', which is well accepted even by apex organizations like FAO, but **interventions in this aspect is completely lacking not only at national level but also in world agriculture**.

Inhana Rational Farming Technology (IRF) developed by Indian Scientist Dr. P. Das Biswas, is a comprehensive organic crop technology that aims at restoration of soil and plant health, which actually deflates pest pressure due to alleviation of factors responsible for pest – parasite interactions. The package works towards (i) energization of soil system i.e., enabling the soil to function naturally as an effective growth medium for plants and (ii) energization of plant system i.e., enabling higher nutrient use efficiency alongside better bio-chemical functions; that leads to activation of the plants' host defense mechanism.

Soil energization aimed at rejuvenation of soil microflora, is primarily attended by application of on-farm produced Novcom compost (that contains rich population of self-generated micro flora- one trillion billion per ton Novcom Compost; different types of herbal concoctions and adoption of sustainable field practices. However, the technology emphasizes Plant Health Management as a precursor for resilient plant system that can ensure sustainability even under changing climatic patterns. Plant Health Management 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. Each solution has one or more defined functions, but work in an integrated manner when applied in a schedule, for bringing about harmonized plant growth with ensured aggregation of biological compounds responsible for flavour, nutrition and medicinal properties.

How the Clean Food 'NET ZERO' Status was attained

This Program focused on demonstrating the Pathway for Net Zero GHG Emission in Agriculture through GHG Omission from Source , GHG Abatement and GHG Adaptation through High Atmospheric-C capture. The Dual approach of Soil Health Management & Plant Health Management in this program was aimed at attaining these very objectives.

GHG OMISSION FROM SOURCE POINT was demonstrated through Novcom Composting Technology that enabled Bioconversion of raw coir pith – a landfill waste, especially a High METHANE Emitter; into Stable, Mature and Non- phytotoxic compost within a shortest period of time (30 days).

GHG Omission from Source Point through bio-conversion of Coir pith –

Coir pith, a waste from coir industry forms a major threat to soil, water, ecology and environment and a is a major source of GHG Emission (6.0 mt CO_2-eq per ton approx.) – primarily **METHANE**, which has 75 times Higher Global Warming Potential as compared to CO_2.

1000 ton Novcom Coir Pith Compost was produced under this Project utilizing **NOVCOM COMPOSTING TECHNOLOGY**, which has been applied in the project sugarcane fields, paddy fields as well as Model Farm for cultivation of a wide variety of vegetables and demonstration of coconut based intercropping model.

GHG ABATEMENT through Inhana Soil Health Management (ISHM)

On- farm produced **Novcom Coir pith Compost** at 40-50 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 coir pith to a quality compost through Novcom composting Technology and application of this compost for sustainable soil management and removal of synthetic chemical fertilizers are the keys towards attending Clean Food ‘Net Zero’ objectives.

Adaptation to Climate Change was exhibited through the adoption of **INHANA PLANT HEALTH MANAGEMENT (IPHM),** driven by **Inhana** ‘**ENERGY SOLUTIONS**’.

IPHM has been adopted towards reactivation of Plant Physiology. The approach ensures **higher agronomic efficiency towards Sustained/ Higher Crop Yields**, meaning **Higher atmospheric- C capture- a critical measure for Adaptation to Climate Change**

Moreover, IPHM works towards **Curtailing the Accumulation of Ready Food Source** for Pests, in Plants’ Cell Sap & **Enhancement of Host- Defense** of Plants t**o Discourage Disease and Pest Incidence leading to the ELIMINATION OF PESTICIDE**

The Dual approach of Soil & Plant Health Management in this program demonstrated the pathway towards production of **Clean Food ‘NET ZERO’.**

Crop		Yield (Tonne/ ha) under Conventional Farmers' Practice	Clean Food 'NET ZERO' Yield (Tonne/ ha)
BRINJAL	:	15.4-23.4	26.1
RADISH	:	14.1-18.4	19.6
FRENCH BEANS	:	7.4-9.4	10.8
CAULIFLOWER	:	18.4-24.6	26.1
CABBAGE	:	20.6-24.4	28.1
KNOL KHOL	:	16.6-18.7	20.2
CAPSICUM	:	12.1-14.6	15.8
CUCUMBER	:	13.4-15.1	16.2
TOMATO	:	21.1-26.6	28.4

Pic.: Clean Food 'Net Zero' Vegetables under IBM-IORF Sustainability Project

Pic.: Clean Food 'Net Zero' Vegetables under IBM-IORF Sustainability Project

Development of Clean ‘NET ZERO Vegetables / 2

Crop		Yield (Tonne/ ha) under Conventional Farmers’ Practice	Clean Food ‘NET ZERO’ Yield (Tonne/ ha)
CHILLI	:	8.1-10.6	11.4
PUMPKIN	:	18.4-22.6	24.4
BITTER GOURD	:	9.4-11.6	12.4
BOTTLE GOURD	:	15.6-18.4	21.6
RIDGE GOURD	:	16.0-18.0	24.6
OKRA	:	9.2-10.8	11.6
SPINACH	:	10.2-12.4	12.8
CORIANDER	:	3.62-4.20	4.25
RED AMARANTH	:	12.0-16.0	16.2



Pic.: Clean Food ‘Net Zero’ Vegetables under IBM-IORF Sustainability Project

Pic.: Clean Food 'Net Zero' Vegetables under IBM-IORF Sustainability Project

Pic.: Clean Food 'Net Zero' Vegetables under IBM-IORF Sustainability Project

Development of Clean 'NET ZERO' at Mandya, Karnataka

Crop		Yield under Conventional Farmers' Practice	Yield under Clean Food 'NET ZERO'
PADDY (Kg/ha)	:	3850-4250	4020-4650
MAIZE (MT/ha)	:	2.70 - 3.20	2.94 – 3.46
GINGER (MT/ha)		8.6 - 12.4	9.2 - 13.7
SUGARCANE (MT/ha)	:	95-122	110-128
COCONUT (nuts/ ha)	:	6500-7600	7000-7800
PAPAYA (MT/ ha)	:	37.4-48.6	45.6-52.4

Pic.: Clean Food 'Net Zero' Vegetables under IBM-IORF Sustainability Project

Pic. Farm visit of Clean Food Net Zero Sugarcane at Mandya, Karnataka under IBM-IORF Sustainability project

Pic. Farm visit of Clean Food Net Zero Ginger at Mandya, Karnataka under IBM-IORF Sustainability project

Clean Food 'NET ZERO'- a Model for CLIMATE ACTION in Agriculture, SDG (1,2, 3,11,12,13, 15) - Achievements and Improvement of Farm Productivity

On an average, yield of all the crops under Clean Food 'NET ZERO' Model was close to **10% higher as compared** to yield obtained under the conventional farmers' practice.

In the case of few crop varieties like Bottle Gourd, French Beans, Cabbage., etc. **about 15-20% higher yield was obtained**, under this model.

This Higher Crop Yield (*especially in the case of paddy*) is a Stupendous Achievement considering that it was obtained under complete elimination of N- fertilizers and chemical pesticides.

The results indicated the relevance of Inhana Plant Health Management (IPHM) and the effectiveness of Novcom Coir- pith Compost, towards Climate Resilient, Safe & Sustainable Crop Production.

Also, the demonstration of Coconut- based Model brought forth an adoptable pathway for improving farm productivity, especially relevant for the declining productivity of the coconut plantations, which is jeopardizing the farm economics.

Pic. Farm visit of Clean Food Net Zero Paddy at Mandya, Karnataka under IBM-IORF Sustainability project

SAFETY ASSESSMENT OF CLEAN FOOD ‘NET ZERO’ : a Fresh Perspective from IORF- in the Food Safety Arena

The UN recognizes that “there is no food security without food safety” . . . that it is not enough to produce **SUFFICIENT FOOD** and ensure everyone has access to it, but the food must be **SAFE AND NUTRITIOUS**.

But pesticide monitoring in food is often most difficult in countries where that monitoring is arguably most needed. This is because the present chromatographic techniques can precisely determine the presence of every chemical at the minute level but the process is **hugely expensive, complex, time-consuming and require specific resources and infrastructure** which offer major hindrance towards regular analysis for monitoring of food safety.

Especially for a country like India, with absolute dominance of marginal farmers in vegetable cultivation, lack of awareness, resource scarcity, inability to take economic risk and flaws in maintaining the standard practices w.r.t. chemical usage enhances the availability of pesticides in food product.

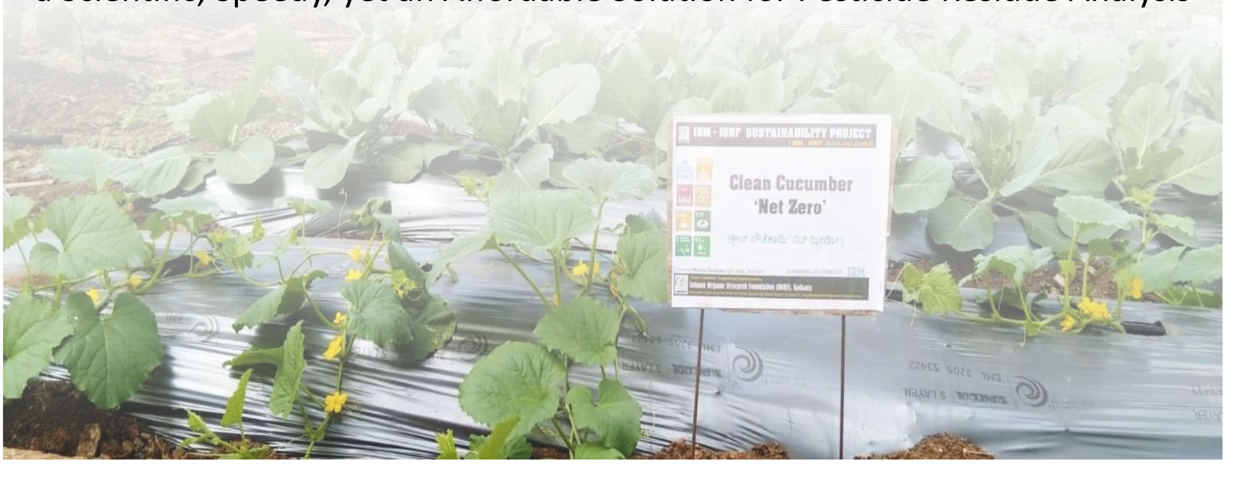
Moreover the short time gap between the field harvest of vegetables and their consumption, limits the scope for safety analysis even if the infrastructure and economics is not considered.

Clean Food means SAFETY authenticated by Actual Residue Analysis. Most Importantly as the Clean Food primarily comprised short duration, multiple harvest- Vegetable Crops, hence, batch wise residue assessment was necessary.

In this background **an effective, speedy, yet an affordable method** was needed to enable pesticide residue analysis in situations of limited resources more so for Safe and Sustainable Agriculture; to comply the requirement for SDG-2 of the United Nations, more meaningfully SDG- Target 2.1 (SAFE, Nutritious and sufficient food all year round).

Colorimetric Assay Test

a Scientific, Speedy, yet an Affordable Solution for Pesticide Residue Analysis



Colorimetric Pesticide Assay Test : a Path breaking Exercise in the field of FOOD SAFETY

The Colorimetric Pesticide Assay Test has been utilized round the globe to identify pesticides residues in food products both in a quantitative and qualitative manner.

However, there is lack of information regarding any comprehensive approach towards utilization of this test method in formulating a protocol towards safety evaluation of food crops especially vegetables in terms of detecting the presence/absence of the major pesticide groups

Inhana Organic Research Foundation (IORF), Kolkata in collaboration with Krishi Vigyan Kendra (Nadia, ICAR) developed the Protocol for Colorimetric Pesticide Assay Test of vegetables. The development was done in three basic aspects:

- **Most Authentic and Speedy Measurement of the major groups of pesticides**, that are used during vegetable crop production.
- **Identifying the collective presence/ absence of the pesticide residues up to the lowest-group specific permissible limits** (same type of pesticides in terms of chemical structure).
- **Standardization of the Method** towards its effective utilization for large scale Pesticide Residue Study in the most economical manner.

The newly standardized Colorimetric Pesticide Assay Test Protocol can enable **detection of the collective presence/ absence of pesticides up to group specific- lowest permissible limit; for more than 90 percent of the pesticides- permitted for use in India, for most of the banned chemicals, as well as chances of residual presence in case of chemicals like DDT and its isomer**.

In addition; this Assay Test can be also utilized for detecting the presence/ absence of toxic heavy metals and a wide range of other toxic substance of known/unknown origin related to human health and safety.

A limiting point w.r.t. the study of individual pesticide residue is that, their individual presence might be below the detectable limit (0.01 ppm) or the MRL, but the value might go up in respect of their collective presence as a group; which ever is considered for 'SAFETY' evaluation. The Colorimetric Pesticide Assay Test also takes care of this problem because of **scope for detection of the Collective Presence/ Absence of the Pesticide Residues upto the Lowest-Group Specific Permissible Limits**

Colorimetric Pesticide Assay Test for Safety Analysis of crops grown under Clean Food ‘Net Zero’ Program

The ‘Clean Food’ Project (Phase- I) led to Clean Food ‘NET ZERO’ Model; with the potential to Alleviate both the CAUSE (Climate Change) & the EFFECT (Food Insecurity) with a New Dimension of uplifting Small & Marginal farmers’ livelihood.

In Phase- II Project, Development of Clean Food ‘NET ZERO’ (CFNZ) means a Model for SAFEST Food Production- SAFE for Human Health, Soil & Environment. **Hence, here again the Primary Safety (*for human health)* is ensured through actual analysis following the Colorimetric Pesticide Assay Test.**

Comparative Safety Assessment of 18 different varieties of vegetables (*viz. brinjal, radish, French beans, cabbage, capsicum, cucumber, tomato, chilli, red amaranth, bitter gourd, etc.*) developed under **Clean Food ‘NET ZERO’ Model (in Model Farm)** was done **vis-à-vis organic vegetables (market source) as well as the conventionally grown counterparts.** A total of **224 Samples** were studied for the purpose. Safety Authentication of other crops like **paddy, maize, ginger, papaya, sugarcane and coconut** was also undertaken for which samples were collected from the fields and plantation belonging to the CFNZ Project farmers .

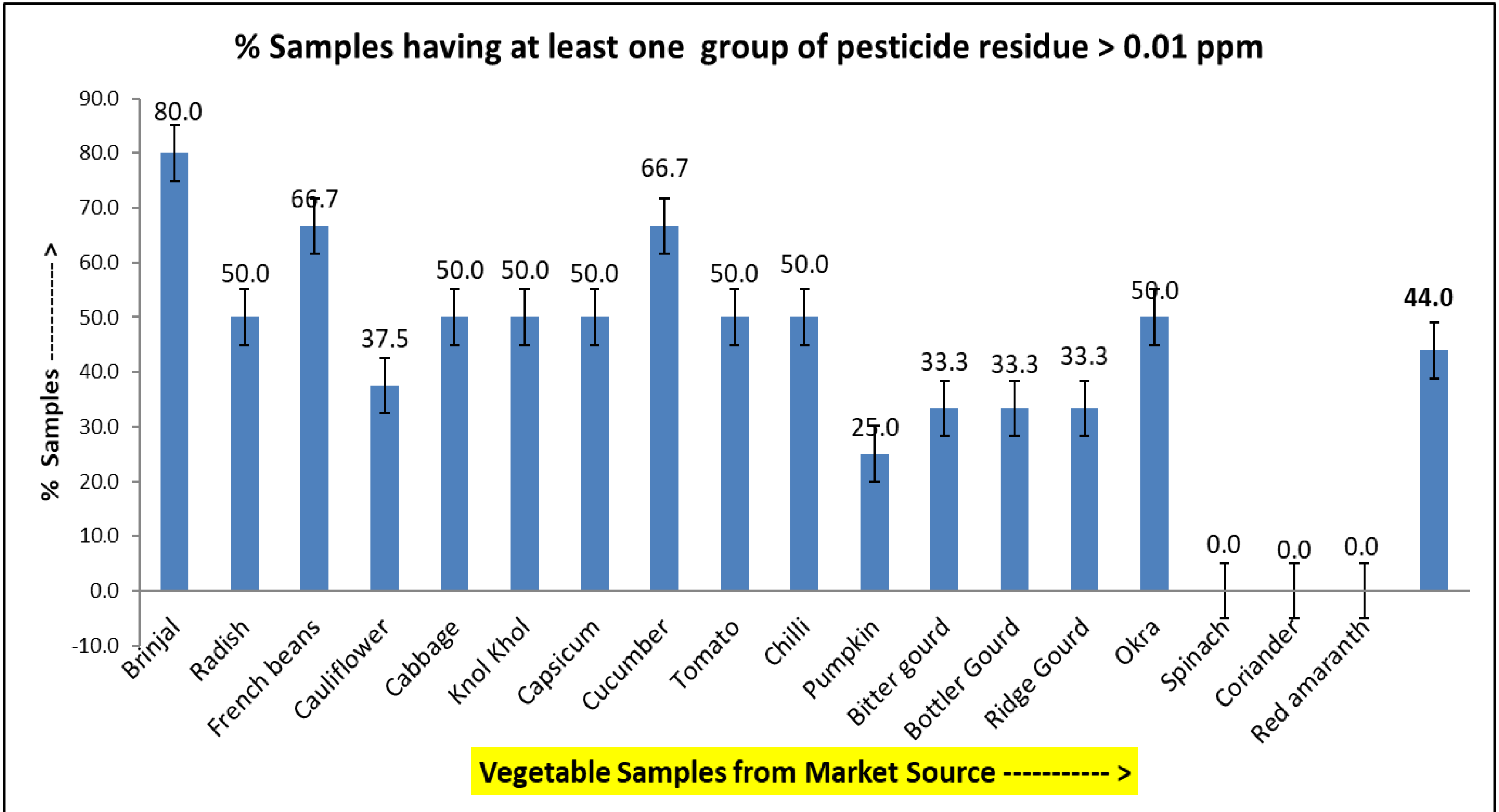
While No Residue was detected in respect of the Clean Food ‘NET ZERO’ and Organic Samples; **44% *(on an average)* of the conventionally grown vegetables were found to be tainted with pesticides.**

Out of the conventionally grown vegetables, chances for pesticide residue was found to be highest in the case of brinjal followed by French beans, cucumber and lowest for pumpkin.

Table 1 : Analysis of Pesticide residue of vegetable samples collected from different source as per Colorimetric Pesticide Assay Test under IBM-IORF Sustainability Project at Mandya, Karnataka.

Sl No	Vegetables	Summer (Period : January - February)				Samples having atleast one group of pesticide residue > 0.01 ppm [Clean Food/ FSSAI Organic Standard)			
		Vegetable from Market Source	Clean Food 'NET ZERO' from **MODEL FARM**	Organic Vegetables	Total	Vegetable from Market Source	Clean Food 'NET ZERO' from **MODEL FARM**	Organic Vegetables	Total
1	Brinjal	10	3	3	16	8	-	-	8
2	Radish	6	3	3	12	3	-	-	3
3	French beans	6	3	3	12	4	-	-	4
4	Cauliflower	8	3	3	14	3	-	-	3
5	Cabbage	8	3	3	14	4	-	-	4
6	Knol Khol	4	3	3	10	2	-	-	2
7	Capsicum	6	3	3	12	3	-	-	3
8	Cucumber	6	3	3	12	4	-	-	4
9	Tomato	8	3	3	14	4	-	-	4
10	Chilli	10	3	3	16	5	-	-	5
11	Pumpkin	4	3	3	10	1	-	-	1
12	Bitter gourd	6	3	3	12	2	-	-	2
113	Bottle Gourd	6	3	3	12	2	-	-	2
14	Ridge Gourd	6	3	3	12	2	-	-	2
15	Okra	8	3	3	14	4	-	-	4
16	Spinach	6	3	3	12	-	-	-	-
17	Coriander	4	3	3	10	-	-	-	-
18	Red amaranth	4	3	3	10	-	-	-	-
Total		**116**	**54**	**54**	**224**	**51**	-	-	**51**

Fig. 1 : **Analysis of Pesticide residue of vegetable samples collected from Local Market Source at Mandya, Karnataka; using the Colorimetric Pesticide Assay Test, under IBM-IORF Sustainability Project.**



Pic. : Different stages of analysis towards Safety authentication of Clean Food 'Net Zero' utilizing Colorimetric Pesticide Assay Test

Pesticide Residue Analysis Report of Clean Food 'NET ZERO' from Project Farmers' Field

INHANA LABORATORY

Science IN HArmony with NAture

Sample Collected by : Mr. K.P. Mallesh, Mandya, Karnataka

No : CATPR/ IL/2023/C102 Date : 27.02.2023

Name of Applicant : IORF Clean Food Project Team

Address : Ground Floor, 168 Jodhpur park, Kolkata - 700068

Description of sample : Crop (18 Samples)

Mark on Sample : Approximately 500g each in sealed packed separately and signed by Mr. K.P. Mallesh

Sample Received on : 21.2.23

Analysis Started on : 22.2.23

Analysis Completed on : 27.2.21

Colorometric Assay test of Pesticide Residues / 1

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm)		Result	
			Visual	Spectro-photometer	Visual	Spectro-photometer
Sample 1: Sugarcane (3 samples)						
1.	Organochlorine	Paulini & Rurbaud, 1957	0.05	0.01	BDL	BDL
2.	Organophosphate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
3.	Carbamate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
4.	Neonicotinoid	Nwanisobi & Egbana, 2015	0.05	0.01	BDL	BDL
5.	Synthetic Pyrethroid	Suate et al, 2020, Mahaed E et al 2014	0.05	0.01	BDL	BDL
6.	Phenylpyrazole	Mahaed E et al 2014	0.05	0.01	BDL	BDL
7.	Triazine, Paraquat	Mahaed E et al 2014 Lionetto , 2013	0.05	0.01	BDL	BDL
8.	Heavy metals (Cu, Zn. Hg. As, Cd, Pb)	Mahaed E et al 2014 Frasco et al. 2005	0.05	0.01	BDL	BDL

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Colorometric Assay test of Pesticide Residues / 2

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm)		Result	
			Visual	Spectro-photometer	Visual	Spectro-photometer
Sample 2 : Ginger (3 samples)						
1.	Organochlorine	Paulini & Rurbaud, 1957	0.05	0.01	BDL	BDL
2.	Organophosphate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
3.	Carbamate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
4.	Neonicotinoid	Nwanisobi & Egbana, 2015	0.05	0.01	BDL	BDL
5.	Synthetic Pyrethroid	Suate et al, 2020, Mahaed E et al 2014	0.05	0.01	BDL	BDL
6.	Phenylpyrazole	Mahaed E et al 2014	0.05	0.01	BDL	BDL
7.	Triazine, Paraquat	Mahaed E et al 2014 Lionetto , 2013	0.05	0.01	BDL	BDL
8.	Heavy metals (Cu, Zn. Hg. As, Cd, Pb)	Mahaed E et al 2014 Frasco et al. 2005	0.05	0.01	BDL	BDL
Sample 3 : papaya (3 samples)						
1.	Organochlorine	Paulini & Rurbaud, 1957	0.05	0.01	BDL	BDL
2.	Organophosphate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
3.	Carbamate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
4.	Neonicotinoid	Nwanisobi & Egbana, 2015	0.05	0.01	BDL	BDL
5.	Synthetic Pyrethroid	Suate et al, 2020, Mahaed E et al 2014	0.05	0.01	BDL	BDL
6.	Phenylpyrazole	Mahaed E et al 2014	0.05	0.01	BDL	BDL
7.	Triazine, Paraquat	Mahaed E et al 2014 Lionetto , 2013	0.05	0.01	BDL	BDL
8.	Heavy metals (Cu, Zn. Hg. As, Cd, Pb)	Mahaed E et al 2014 Frasco et al. 2005	0.05	0.01	BDL	BDL

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Pic. : Different stages of analysis towards Safety authentication of Clean Food 'Net Zero' utilizing Colorimetric Pesticide Assay Test

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Colorometric Assay test of Pesticide Residues / 3

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm)		Result	
			Visual	Spectro-photometer	Visual	Spectro-photometer
Sample 4: Paddy (3 samples)						
1.	Organochlorine	Paulini & Rurbaud, 1957	0.05	0.01	BDL	BDL
2.	Organophosphate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
3.	Carbamate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
4.	Neonicotinoid	Nwanisobi & Egbana, 2015	0.05	0.01	BDL	BDL
5.	Synthetic Pyrethroid	Suate et al, 2020, Mahaed E et al 2014	0.05	0.01	BDL	BDL
6.	Phenylpyrazole	Mahaed E et al 2014	0.05	0.01	BDL	BDL
7.	Triazine, Paraquat	Mahaed E et al 2014 Lionetto , 2013	0.05	0.01	BDL	BDL
8.	Heavy metals (Cu, Zn. Hg. As, Cd, Pb)	Mahaed E et al 2014 Frasco et al. 2005	0.05	0.01	BDL	BDL
Sample 5 : Maize (3 samples)						
1.	Organochlorine	Paulini & Rurbaud, 1957	0.05	0.01	BDL	BDL
2.	Organophosphate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
3.	Carbamate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
4.	Neonicotinoid	Nwanisobi & Egbana, 2015	0.05	0.01	BDL	BDL
5.	Synthetic Pyrethroid	Suate et al, 2020, Mahaed E et al 2014	0.05	0.01	BDL	BDL
6.	Phenylpyrazole	Mahaed E et al 2014	0.05	0.01	BDL	BDL
7.	Triazine, Paraquat	Mahaed E et al 2014 Lionetto , 2013	0.05	0.01	BDL	BDL
8.	Heavy metals (Cu, Zn. Hg. As, Cd, Pb)	Mahaed E et al 2014 Frasco et al. 2005	0.05	0.01	BDL	BDL

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Colorometric Assay test of Pesticide Residues / 4

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm)		Result	
			Visual	Spectro-photometer	Visual	Spectro-photometer
Sample 16 : Coconut (3 samples)						
1.	Organochlorine	Paulini & Rurbaud, 1957	0.05	0.01	BDL	BDL
2.	Organophosphate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
3.	Carbamate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
4.	Neonicotinoid	Nwanisobi & Egbana, 2015	0.05	0.01	BDL	BDL
5.	Synthetic Pyrethroid	Suate et al, 2020, Mahaed E et al 2014	0.05	0.01	BDL	BDL
6.	Phenylpyrazole	Mahaed E et al 2014	0.05	0.01	BDL	BDL
7.	Triazine, Paraquat	Mahaed E et al 2014 Lionetto , 2013	0.05	0.01	BDL	BDL
8.	Heavy metals (Cu, Zn. Hg. As, Cd, Pb)	Mahaed E et al 2014 Frasco et al. 2005	0.05	0.01	BDL	BDL

*BDL : Below Detectable Limit

Remarks : The Test results indicates that the tested products are equivalent to FASSI Organic Food Standard in terms of Maximum Residual Limits (MRLs) of Insecticides under selected pesticide group in Organic Foods

Note :

Vegetable samples were extracted as per standard QuEChERS method (Anastassiades et al, 2003)
The result relate only to the test Item
The report shall not be reproduced except in full, without written approval of the laboratory

The Colorometric Assay test of different Pesticide Residues has been standardized by Nadia Krishi Vigyan Kendra, ICAR, BCKV and Inhana Organic Research Foundation (IORF), Kolkata

Inhana Organic Research Foundation 168 Jodhpur Park Kolkata-68

Head, Inhana Laboratory

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Clean Food ‘NET ZERO’ Safety Assessment- **THE MOOT POINTS**

- **Clean Food ‘NET ZERO’** – SAFEST FOOD – SAFE for Human Health, Soil & Environment
- Also SAFETY is the Cursor for **SUSTAINABILITY.**
- For Safety Authentication of Clean Food ‘NET ZERO’, especially for Multiple Harvest Crops like vegetables- **Batch wise Testing was a must**.
- But the Conventional Process of Pesticide Analysis is **COSTLY & TIME CONSUMING**– due to high investment, lack of infrastructure, resources and technical manpower.
- **Hence, frequent Safety Assessment of Produce especially vegetables is beyond question** because majority of the growers are small and marginal land holders.
- So the Need was felt for a Process/ Method that would enable **Pesticide Residue Assessment in the most Authenticated Manner** but at the same time **will be SPEEDY & ECONOMICAL**.
- The **Colorimetric Pesticide Assay Test developed in Phase-1 of the IBM-IORF Sustainability project** came out as the Right Solution considering that it can enable **Both Qualitative & Quantitative Residue Analysis,** at **1/10th of Conventional Cost and Time required for Analysis** *(respectively).*

Pic. : Clean Food ‘Net Zero’ Safety authentication utilizing Colorimetric Pesticide Assay Test

CHAPTER 6 : Coconut based 'Net Zero' Intercropping towards development of Farm Economics

Summary

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. In this respect, coconut based intercropping can help out in improving the output and economic return from these plantations.

However, considering that **continuous application of synthetic inputs** like chemical fertilizers and pesticide **in these limiting soils** (having <0.5 % organic carbon and mere 5 – 10 % clay content), has already initiated the cycle of degradation **and is reducing soils' carrying capacity; only those intercropping models that encompass safe and sustainable agriculture, can ensure the desired benefits.**

Coconut based 'Net Zero' Intercropping Model under IBM-IORF Sustainability Project not only **enhanced System Productivity By 442 % with incorporation of vegetables as intercrop,** the initiative also **enhanced the Energy Efficiency** (in terms of crop productivity per unit of energy investment w.r.t nutrient management) **by 822 %. GHG assessment was also done under this Program.** The major mitigation was obtained from coir pith bioconversion into Novcom Coir pith compost that was utilized for soil health management of the coconut trees as well as the vegetables which were grown as intercrops. Another area for mitigation is the elimination of unsustainable inputs like chemical fertilizers and pesticides.

However, in the case of the project area the framers' practice of nutrient management in coconut is not very organized, hence; effort is being made to work out a proper evaluation in this respect. So far it is indicated that **this agriculture model, can potentially offset more than 500 MT CO_2 eq /ha, and it can be one of the most suitable program for any Net Zero Initiative.**

Introduction

Coconut forms a major crop in the project area, and when grown as a monoculture, often leads to farmers distress mainly due to crop loss associated with the pest and disease incidences and market price fluctuations. Coconut based cropping system helps in utilizing the available space, effectively and in a sustainable manner. According to previous findings, coconut monocropping planting systems and growth habits effectively used only 22% of the land area, while canopy space utilization was around 30%, and solar radiation was around 45%.

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.

Coconut-based intercropping, which allows other agricultural crops to grow under the canopy, not only offers scope for improving crop biodiversity and farm productivity, but also forma a means to sequester carbon, according to a new study that cites Kerala as an example. Coconut-based farming system (CBFS) involving nature-based solutions can sustainably manage, and restore natural and modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.

Pic.: Coconut cultivation is one of the major Agricultural Activity in the area

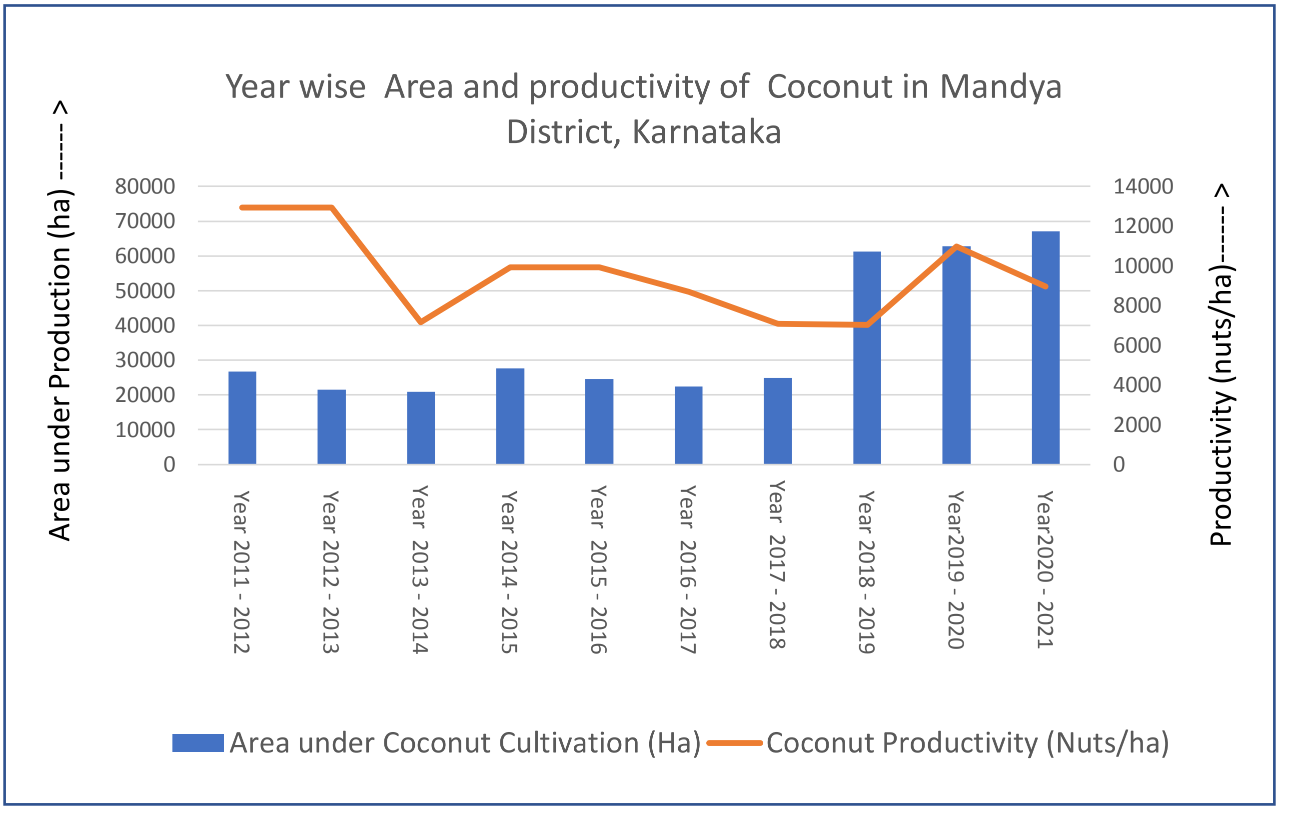


Fig. 1 : Year wise area under coconut cultivation and coconut productivity in Mandya District, Karnataka, India

According to the data available from Coconut Development Board, Ministry of Agriculture, Government of India, presently about 67106 ha area is under coconut cultivation and the average productivity is 8,955 nuts per ha. 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

Pic. : Coconut cultivation at Mandya, Karnataka.

Development of a Coconut based Net Zero intercropping Model under IBM-IORF Sustainability Project at Mandya, Karnataka

Under IBM-IORF Sustainability Project, an effort was generated to introduce Coconut- based Intercropping Model to open up the scope for **improving crop diversity as well as farm productivity** especially concerning the **marginal soil**. 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 in the soil which was practically unfit for field crops especially vegetables.

18 different types of vegetables 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.

Pic.: Coir pith waste was bio-converted using Novcom Composting Technology and utilized for management of the poor quality red gravely soil towards production of different vegetables under IBM-IORF Sustainability Project at Mandya, Karnataka.

For management of soil in the coconut plantation, about 40 ton of Novcom Coir pith compost was applied per hectare. Apart from vegetables other crops like maize, ginger was also transplanted. 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.

Pic.: Vegetables grown under Coconut based 'Net Zero' Intercropping Model through adoption of IRF Technology under IBM-IORF Sustainability Project at Mandya, Karnataka.

After transplanting 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. Whatever minor problem occurred, it was easily controlled by on-farm neem based concoctions.

Pic.: Application of Inhana Plant Health Management Solutions towards harmonious plant growth and higher productivity under IBM-IORF Sustainability Project at Mandya, Karnataka.

Performance of vegetables under Coconut based 'Net Zero' Intercropping at Mandya, Karnataka

Crop performance was evaluated as coconut equivalent yield of vegetables (nuts/ha) and total system productivity was calculated as per the following formula :

$$\text{Coconut equivalent yield of intercrops (nuts ha}^{-1}) = \frac{\text{Yield of intercrop (kg ha}^{-1}) \times \text{Market price of intercrop (₹ kg}^{-1})}{\text{Market price of coconut (₹)}}$$

$$\text{Total system productivity (nuts ha}^{-1}) = \text{Yield of coconut (nuts ha}^{-1}) + \frac{\text{Yield of intercrop (kg ha}^{-1}) \times \text{Market of price intercrop (₹ kg}^{-1})}{\text{Market price of coconut (₹)}}$$

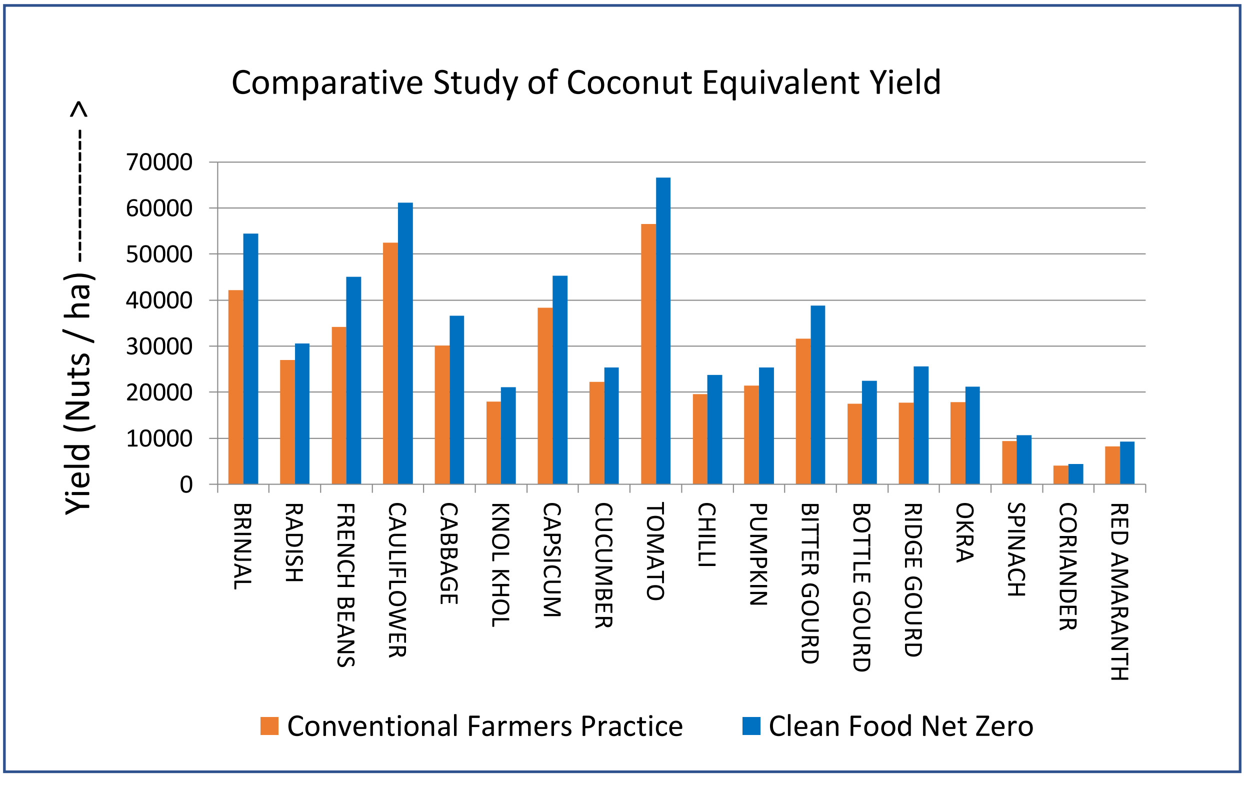


Fig. 2: Coconut Equivalent Yield of vegetables under Coconut based 'Net Zero' intercropping at Mandya District, Karnataka, India

The results showed that in all the cases crop productivity under Clean Food 'Net Zero' program was higher than the average crop yield under conventional farmers' practice. On an average, Coconut Equivalent Yield was 21 % higher under Clean Food 'Net Zero' program, which is significant considering the very first year of cultivation.

Total system productivity of Coconut based Net Zero intercropping was also measured under and compared with coconut monocropping under different management practice. I ncorporation of vegetables as intercrop under Clean Food 'Net Zero' Program, System Productivity was found to increase by 442 % w.r.to sole cultivation of coconut under conventional farmers practice

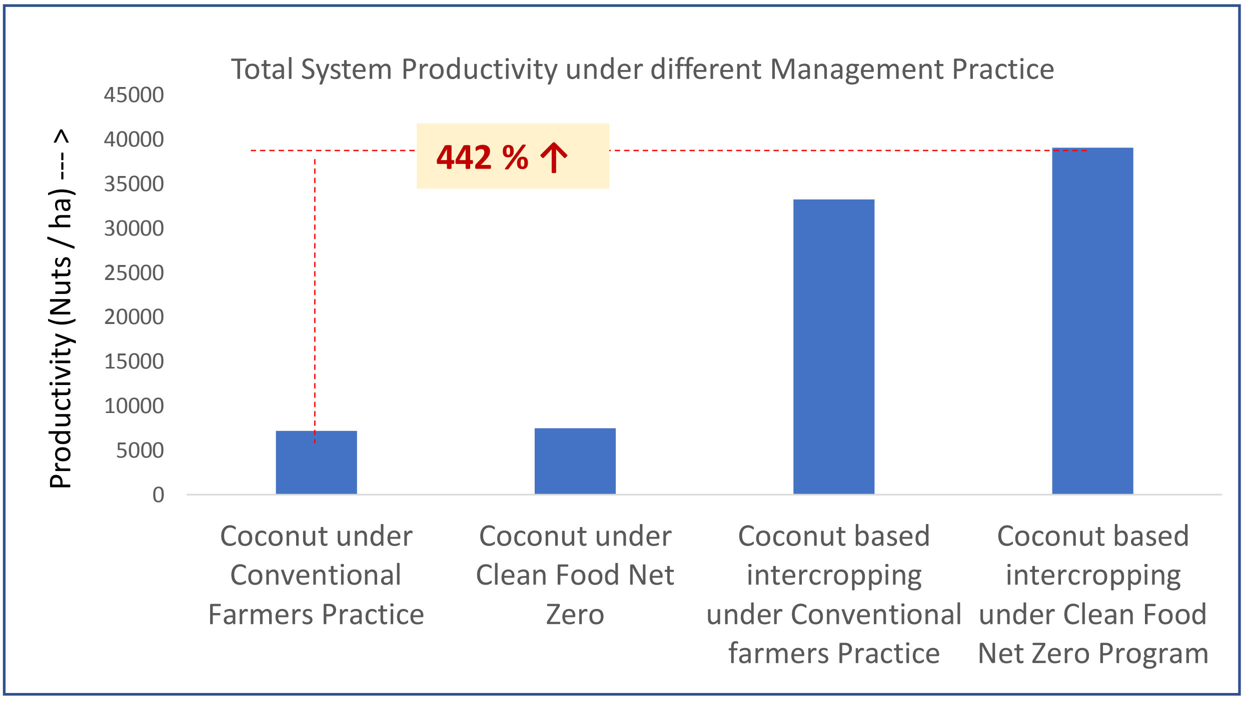


Fig 3: Total System Productivity of coconut based intercropping under coconut based 'Net Zero' intercropping at Mandya District, Karnataka, India

Impact of Clean Food Net Zero Program on Soil Quality

Soil samples were taken at the initiation of the study and at the last end of the harvesting stage to study the impact of soil health management under clean food 'Net Zero' program. Though the initiative is a litte bit in hurry towards reaching to a conclusive note , but wanted to note the indication from the program. The initial study confirms that the soil is very poor in terms of soil carbon and fertility status as well as soil microbial activity. Above all presence to small to medium size gravels in more than 50 % (by weight) make the soil practically unsuitable for any sensitive crop cultivation. We try to remove the gravel part from the surface soils as much as possible for better crop growth before starting other soil health management activities

Table 1 : Soil Physical Quality Evaluation of the Project Area under IBM-IORF Sustainability Project.

Sl No	Major Land Use	Gravel %	Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (gcm^{-3})	Aggregates	Soil Depth
1	Coconut based Vegetable intercropping (Pre Management Soils)	58.99	80.33	7.68	11.99	Loamy Sand	1.41	Very Low to Medium	Moderate Limitation
2	Coconut based Vegetable intercropping (Post Management Soils)	58.00	80.33	7.68	11.99	Loamy Sand	1.31	Low to Very Low	Moderate to Strong Limitation

Table 2 : Soil Quality variation in terms of Physicochemical and Fertility Parameters in Project Plots at Mandya, Karnataka, India in IBM-IORF Sustainability Project.

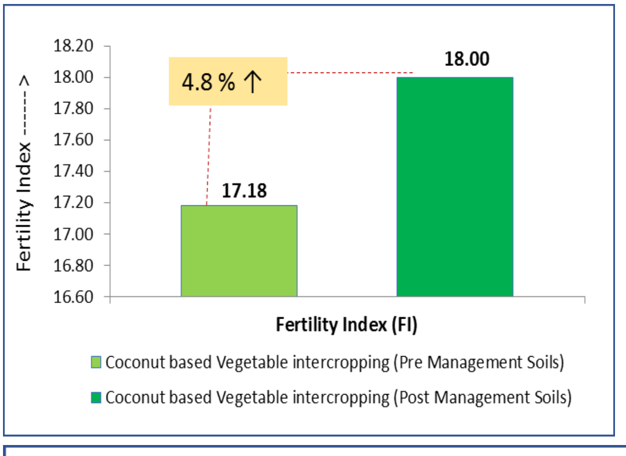
Sl No	Major Land Use	pH_{water} (1:2.5)	ECe ($dCmM^{-1}$)	Org. C %	Av NO_3 (ppm)	Av-N	Av P_2O_5	Av. K2O	Av- SO_4
						<-------------------- (Kg/ ha)			------------------->
1	Coconut based Vegetable intercropping (Pre Management Soils)	6.02	0.053	0.54	21.00	163.07	59.14	813.12	429.32
2	Coconut based Vegetable intercropping (Post Management Soils)	6.17	0.061	0.61	23.00	294.78	65.12	817.29	409.3

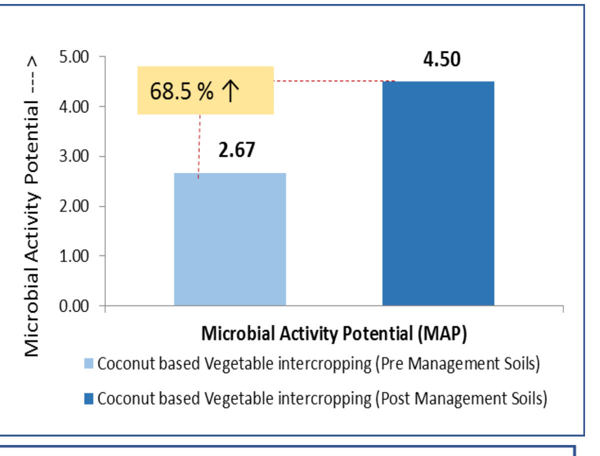
Table 3 : Soil Quality variation in terms of microbial properties in Project Plots at Mandya, Karnataka, India in IBM-IORF Sustainability Project.

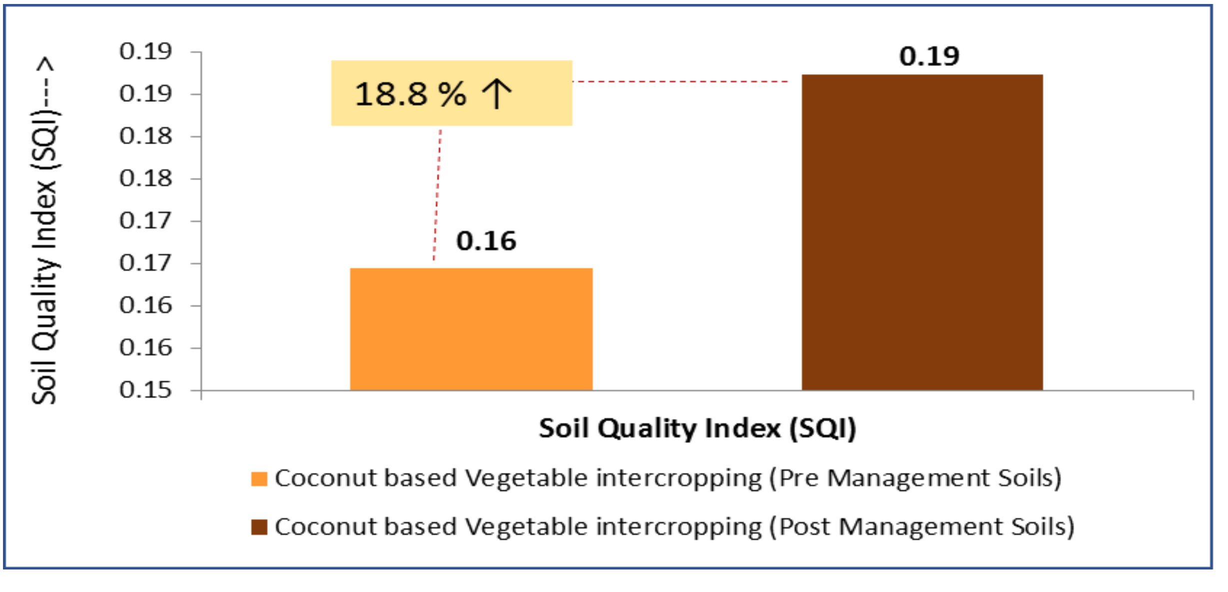
Sl No	Major Land Use	MBC (µ C/gm dry soil)	FDAH (µg/gm dry soil)	Total Plate Count c.f.u. (per gm. Moist soil)		
				Bacteria X 10^4	Fungi X 10^3	Actinomycetes X 10^3
1	Coconut based Vegetable intercropping (Pre Management Soils)	105.70	20.63	63	12	22
2	Coconut based Vegetable intercropping (Post Management Soils)	109.27	21.27	86	17	27

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

Comparative study of Soil Quality Indices of Pre and Post soil samples in Coconut based 'Net Zero' Intercropping







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 (about 13 %) 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 (Table 2).

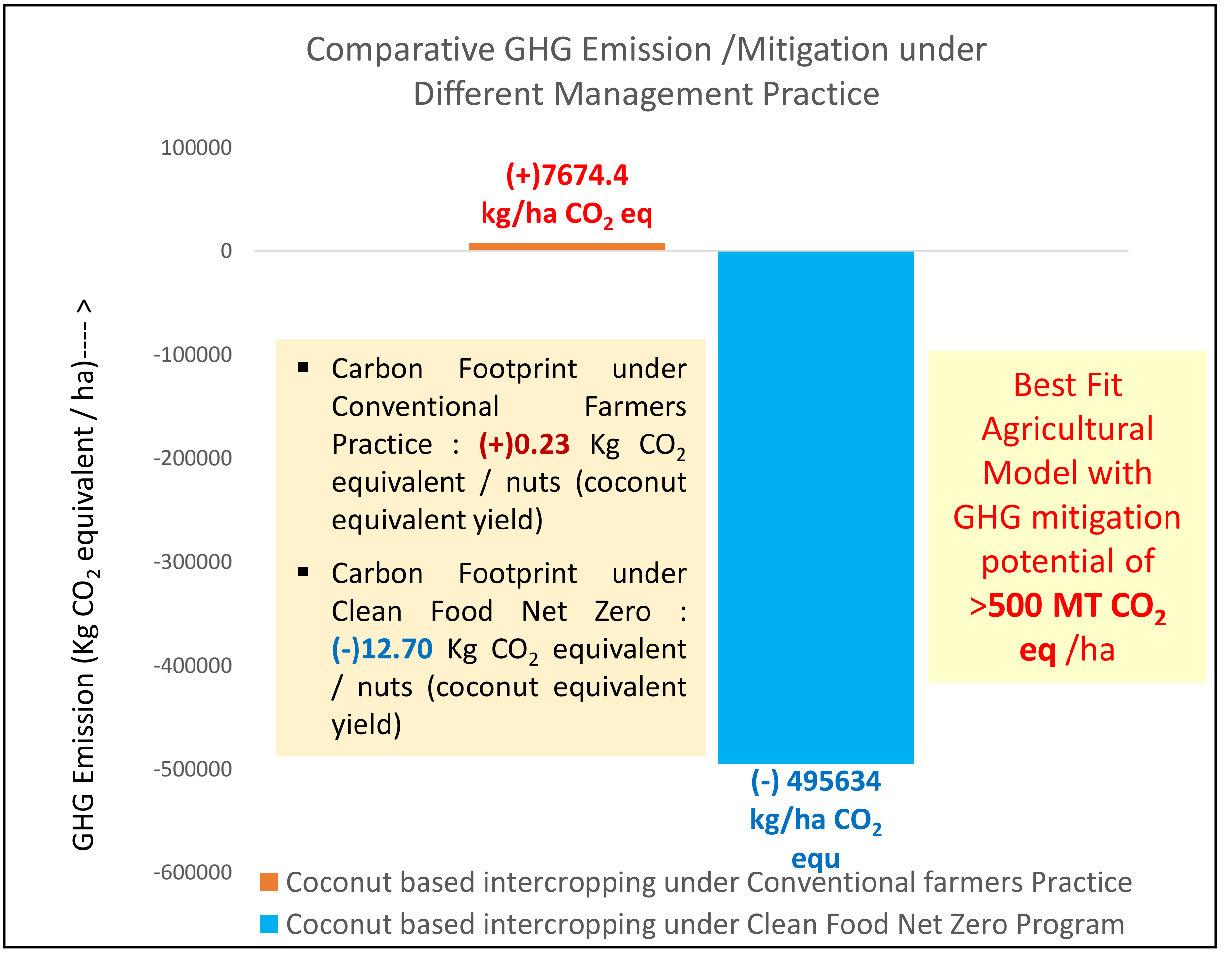
Soil micro-organisms play a significant role in regulating the dynamics of organic matter decomposition and availability of plant nutrients.. Comparatively higher value of soil microbial pollution, soil MBC and its activity (indicated by FDAH activity) etc. post soil analysis indicated the favourable role of Novcom coir pith compost towards soil micro flora rejuvenation. This was probably due to very high (one trillion bellion 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.

The results indicated that, Coconut based inter-cropping systems under clean food net zero program with adoption of IRF technology improve the soil properties and productivity of the soil by keeping the biotic and abiotic components of the soil medium in a state of dynamic equilibrium and sustaining the biochemical processes of dissolution and synthesis through rejuvenation of soil microflora. In the presence of diverse species under coconut there is continuous replenishment of plant nutrients in the system through the process of nutrient recycling and addition which helps towards better crop –productivity w.r.to conventional farmers practice..

Coconut-maize net zero intercropping is presently going on in the Project Area

Evaluation of GHG Emission / Mitigation under Coconut based 'Net Zero' Intercropping at Mandya, Karnataka

Evaluation of GHG Emission/ Mitigation under Coconut based 'Net Zero' Intercropping at Mandya, Karnataka was done through ACFA (Vision 1.0) which was developed as per latest IPCC guideline. From the analysis database, it was understood that, there was significant GHG mitigation under Coconut based 'Net Zero' Intercropping in comparison to its counterpart under conventional farmers' practice.

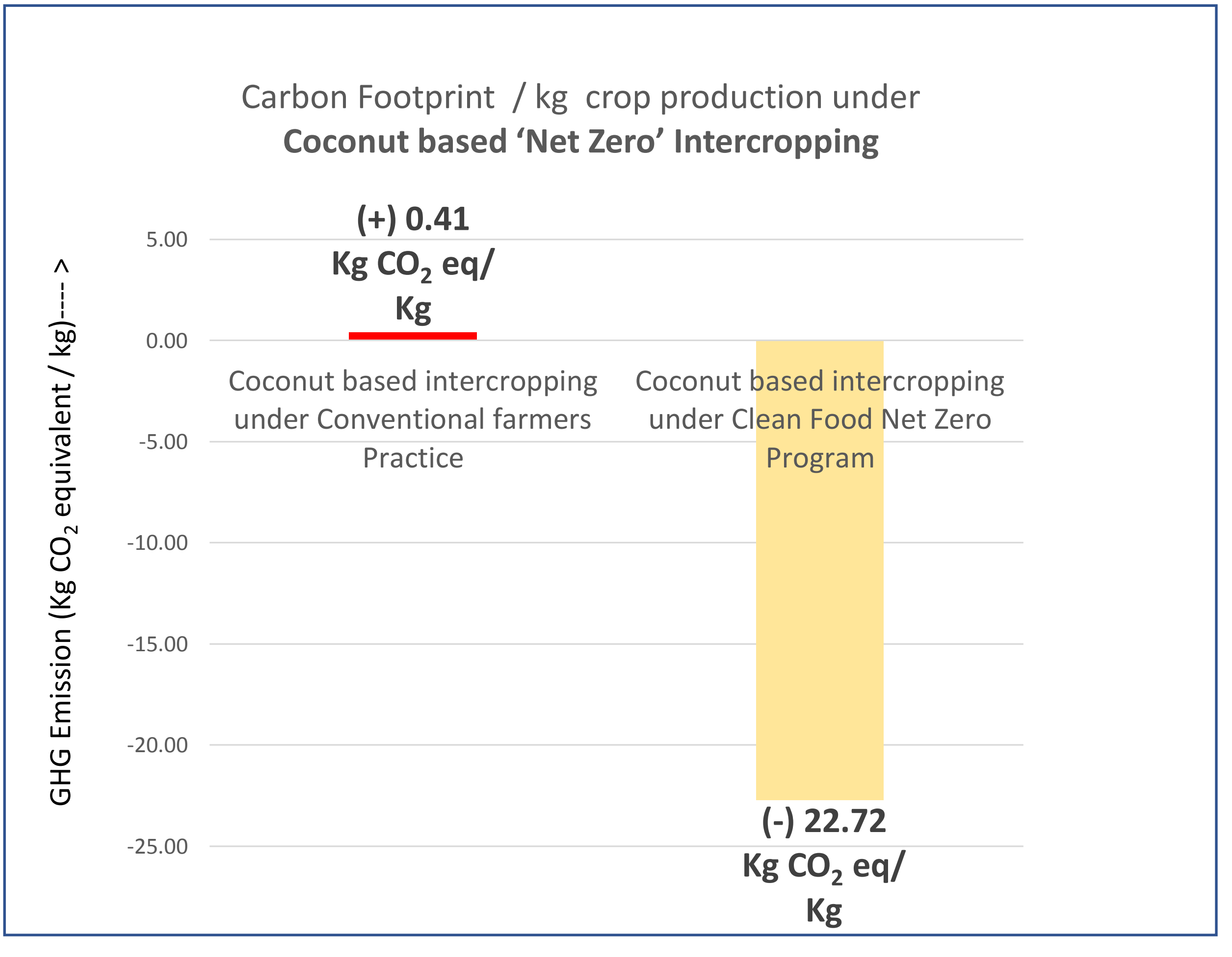


Net C-footprint under Coconut based 'Net Zero' Intercropping is (-)12.93 kg CO_2 equivalent / Nuts (coconut equivalent yield)

The findings revealed that while under conventional farmers' practice there was GHG emission of about 7.67 MT CO_2 eq/ ha; under Clean Food Net Zero Program, around 495.6 MT CO_2 eq / ha was offset which could have a meaningful contribution in respect of climate action and attending NET ZERO Objectives. So coconut based 'Net Zero' intercropping model not only enhanced the return potential of the farmland per ha by 442 %, at the same time it helped to mitigate more than 500 MT CO_2 eq/ha.

Carbon Footprint based on Harvestable Biomass under Coconut based 'Net Zero' Intercropping at Mandya, Karnataka

Evaluation of carbon footprint per kg harvestable yield under Coconut based 'Net Zero' Intercropping at Mandya, Karnataka was done through ACFA (Vision 1.0) which was developed as per latest IPCC guideline. The study showed that under conventional farmers' practice carbon foot print was (+) 0.41 kg CO_2 equivalent / kg crop production. However with introduction of Clean Food Net Zero program, carbon footprint was down to (-)22.72 kg CO_2 equivalent/ kg crop production. This indicated that with adoption of **Coconut based 'Net Zero' Intercropping model, we can offset about 22.72 kg CO_2 eq/ per kg of crop production and thus this agriculture model can be one of the most suitable program towards the Net Zero Objective.**



Net C-footprint under Coconut based 'Net Zero' Intercropping is (-)23.13 kg CO_2 equivalent/ Kg crop production

Evaluation of Energy Usage under Coconut based 'Net Zero' Intercropping at Mandya, Karnataka

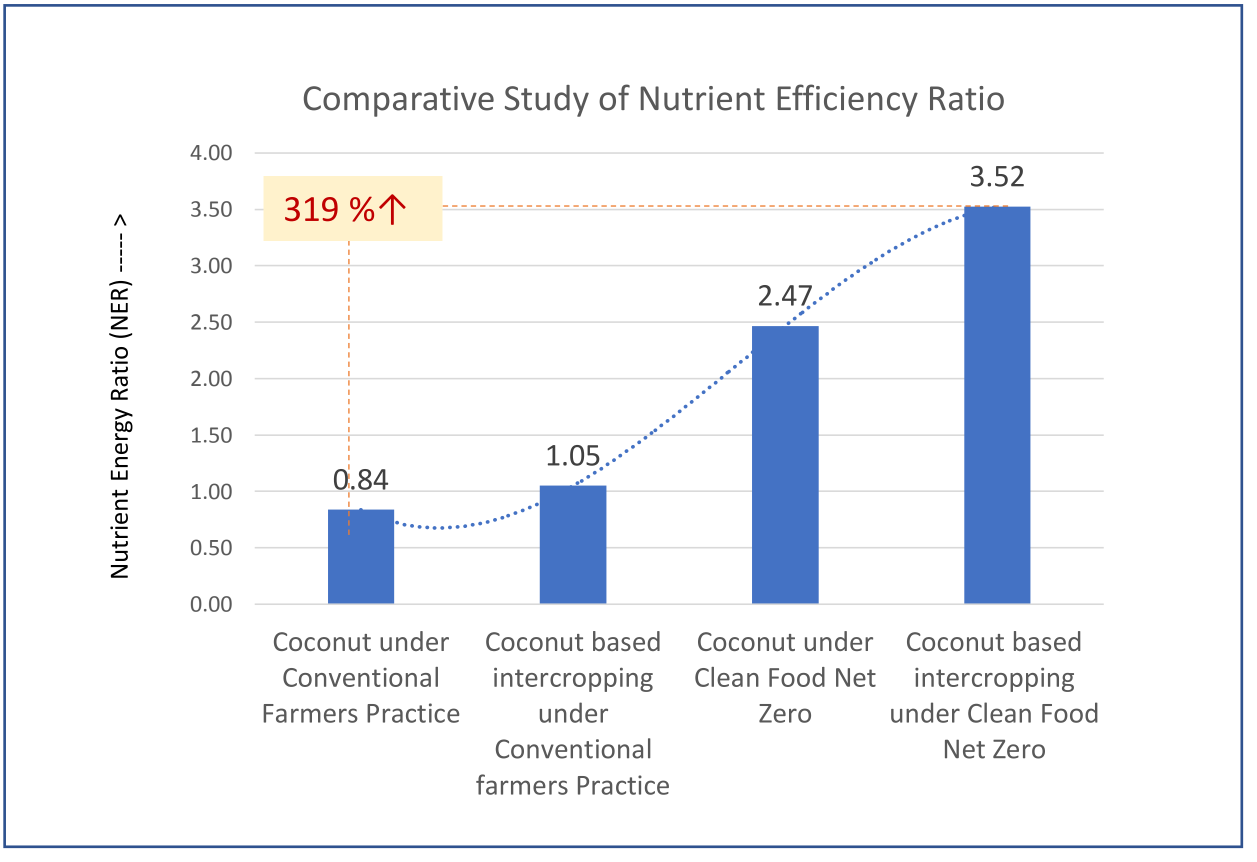
Assessment of energy use pattern in crop production is necessary towards efficient utilization of the available natural resources, for energy conservation and to minimize losses during different unit operations. It helps to minimize energy costs and waste without affecting production and quality. Thus, energy auditing of crop production would attempt to harmonize energy consumption and its application.

Coconut based intercropping model is an approach to showcase efficient energy use in terms of higher renewable energy sources and elimination of energy intensive non renewable inputs. **In the present study, evaluation of energy usage under Coconut based 'Net Zero' Intercropping model specially focused on energy transition w.r.t. crop nutrient management. This is because a switch over from conventional practice to sustainable agriculture specifically impacts this component of crop production.** Under Clean Food 'Net Zero' Program, synthetic fertilizers were removed through Soil Health Management utilizing **Novcom coir pith compost** and the change in energy utilization under this model was studied in comparison to Conventional Farmers' Practice; in respect of two major energy indices *viz.* Nutrient Energy Ratio (NER) and Nutrient Energy Productivity (NEP).

Coconut based 'Net Zero' Intercropping under IBM-IORF Sustainability Project at Mandya, Karnataka

Comparative study of Nutrient Energy Ratio (NER) under Coconut based 'Net Zero' Intercropping at Mandya, Karnataka

Nutrient Energy Ratio (NER) is the ratio of total energy use in nutrient management and total energy output. Higher NER denotes higher efficiency in nutrient management and better crop response, while **a low NER indicates higher risk of pollution and more spill over effect**

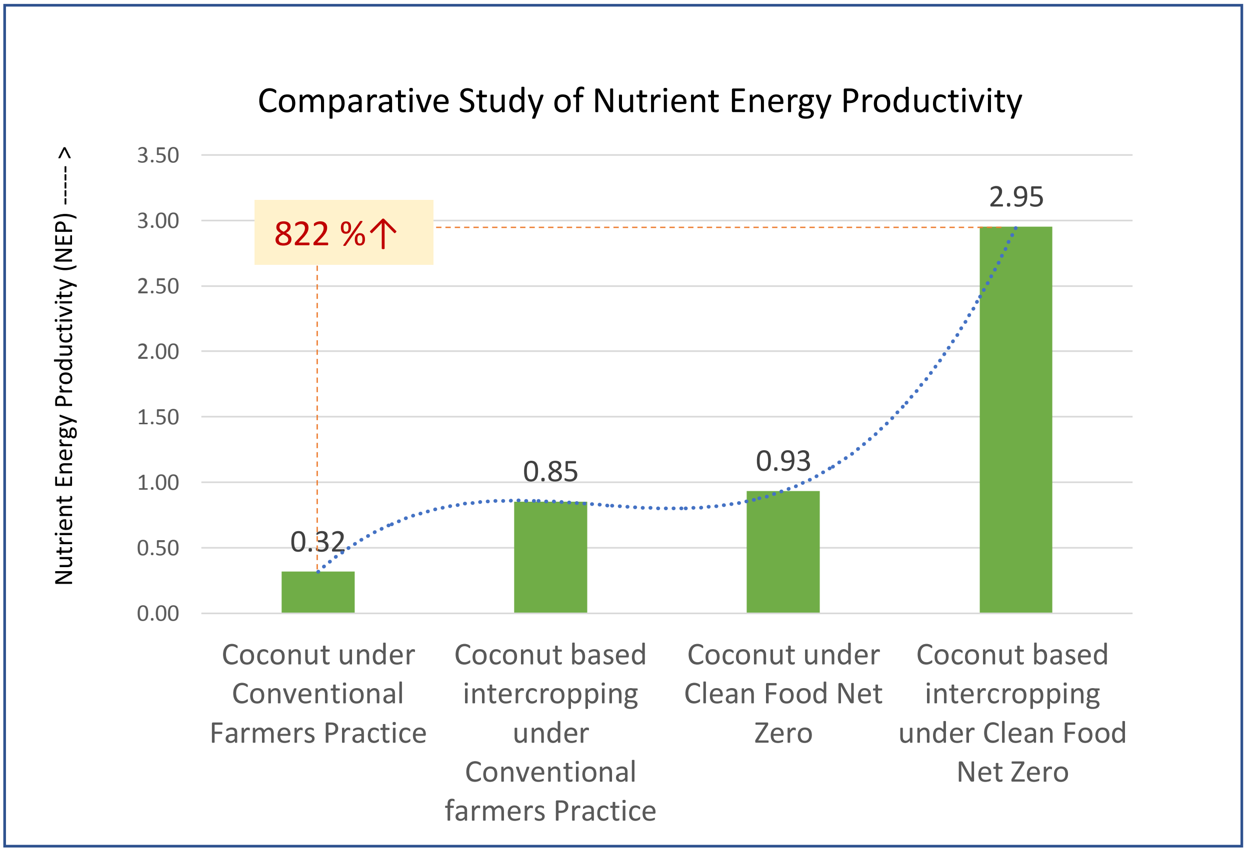


Comparative study of Nutrient Energy Ratio (NER) under Coconut based 'Net Zero' Intercropping at Mandya, Karnataka indicated that there was increase of Nutrient Energy Ratio in coconut based intercropping in comparison with sole cultivation of coconut . But most significant fact was there was a quantum jump of Nutrient Energy Ratio value (from 1.05 to 3.52) with change of management practice.

Introduction of Clean Food Net Zero program through adoption of IRF Technology for better crop productivity and bioconversion of coir pith through Novcom composting technology towards elimination of synthetic fertilizers enabled significant energy transition. The NER value enhanced about 3.4 times under Clean Food Net Zero program indicating one of the most energy efficient coconut based intercropping model.

Comparative study of Nutrient Energy Productivity (NEP) under Coconut based 'Net Zero' Intercropping at Mandya, Karnataka

Nutrient Energy Productivity (NEP) is the ratio of total crop production and total energy use for nutrient management in same unit of area and expressed in kg/MJ. Nutrient energy productivity actually denotes the total nutrient energy spent for unit utilizable biomass generation. Thus this index can work as a sustainability indicator specially considering that conventional farming production system demands more energy for every unit of food production.



The NEP value increased significantly (up to a 822%) under Coconut based 'Net Zero' Intercropping program, as compared to that recorded for sole coconut cultivation under conventional farmers practice. This significantly higher efficiency in terms of nutrient energy productivity was primarily due to the intervention of IRF Technology which not only enabled the elimination of non renewable energy sources; but did so without incurring any crop loss.. Moreover the stupendous enhancement of the NEP value under Coconut based 'Net Zero' Intercropping program indicates that it can potentially serve as the Best Fit Agricultural Model towards the Net Zero Objective.

CHAPTER 7 : GHG Mitigation Under Clean Food Net Zero Program

Summary

Agriculture is the most vulnerable to climate change, but it is also the second largest GHG emitting. On the flip side it is also the only sector that can make a significant contribution towards both GHG mitigation and adaptation; provided it can reduce its reliance on the unsustainable inputs like chemical fertilizers and pesticides and adopt renewable energy sources.

Hence, the sustainability quotient of any non- chemical crop production initiative will be primarily determined by the systems' GHG mitigation potential. Under IBM-IORF Sustainability Project, the Clean Food 'Net Zero' (CFNZ) Model not only demonstrated **Profound GHG Mitigation, especially in terms of METHANE ABATEMENT**; which is a major solution towards the NET ZERO Carbon Goal; but at the same time of GREATEST SOCIAL RELEVANCE due to the development of SAFEST FOOD @ SAME COST – HENCE, SUSTAINABLE FOR ALL.

A unique Carbon Footprint Assessment Tool (ACFA version 1.0) was also developed as per IPCC guidelines, to evaluate the GHG Mitigation Potential under CFNZ Model; **considering that No Such Tool is available suitable for India specific assessments**. As per analysis, it was indicated that production of vegetables under CFNZ program at Mandya potentially offset 13.78 kg CO_2 equivalent per kg crop production and thus a 100 ha Clean Food Net Zero Program can offset about 24,833 MT CO_2 eq. per year.

Introduction

Agricultural lands make up approximately 37% of the global land surface, and agriculture is a significant source of greenhouse gas (GHG) emissions, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Agriculture accounts for 52 and 84% of global anthropogenic methane and nitrous oxide emissions. These GHGs are responsible for the majority of the anthropogenic global warming effect. Agricultural GHG emissions are associated with soil tillage, use of synthetic fertilizers and pesticides, livestock management, burning of fossil fuel for agricultural operations, and burning of agricultural residues and land use change. When natural ecosystems such as forest / grasslands are converted to agricultural production, 20–40% of the soil organic carbon (SOC) is lost over time, following cultivation.

We thus need to develop management practices that can maintain/ increase SOC storage and reduce GHG emissions from agricultural ecosystems. Many agricultural practices can potentially mitigate greenhouse gas (GHG) emissions, the most prominent of which are improved cropland and grazing land management and restoration of degraded lands and cultivated organic soils.

The global technical mitigation potential by 2030 from agriculture (excluding fossil fuel offsets from biomass), considering all gases, is estimated to be approximately 5500–6000 Mt CO_2-eq. yr^{-1}, with economic potentials of approximately 1500–1600, 2500–2700 and 4000–4300 Mt CO_2-eq. yr^{-1} at carbon prices of up to 20, up to 50 and up to 100 US$ t CO_2-eq.$^{-1}$, respectively. In addition, GHG emissions could be reduced by substitution of fossil fuels for energy production by agricultural feedstocks (e.g. crop residues, dung and dedicated energy crops). The economic mitigation potential of biomass energy from agriculture is estimated to be 640, 2240 and 16 000 Mt CO_2-eq. yr^{-1} at 0–20, 0–50 and 0–100 US$ t CO_2-eq.$^{-1}$, respectively.

Calculation of Carbon Footprint : System boundaries of agricultural production system

Determination of the system boundary for carbon footprint calculation is the most important thing before initiating any calculation process as Knowing the carbon emission baseline of a region is a precondition for any mitigation effort, but the baselines are highly dependent on the system boundaries for which they are calculated. In our carbon footprint accounting system, we considered farm gate of agricultural production as system boundary. For crop production, the system boundary is the land boundary of studied cropland. However, the system boundary for livestock production is the farm gate of studied livestock such as dairy, goat, poultry etc. All agricultural inputs are traced back to production and raw material extraction and all major GHG emissions (CH_4, N_2O, and fossil CO_2) associated with inputs and farm management are accounted for.

GHG Emission / Mitigation sources in agricultural production system

Carbon Footprint of Agricultural Production System was generally assessed by taking into account all the GHG emissions caused by or associated with material used, and farm machine operated and irrigation and drainage power exhausted for crop production in a crop life cycle. In general, majority of agricultural GHG emissions occur at the primary production stage, and are generated through the production and use of agricultural inputs, farm machinery, soil disturbance, residue management and irrigation.

Most importantly activating plant functioning towards higher biomass production through intervention of any sustainable plant health management practice / technology and without any extra carbon spending is one of the most important way out towards GHG mitigation. Thus efficiency of higher biomass production without extra carbon spending through theses approaches should be accounted in Net Carbon Footprint calculation.

Direct and Indirect Emissions

Agricultural GHG emissions can be categorized into three types of sources: primary, secondary, and tertiary. Primary emissions are defined as GHG emissions coming directly from tillage, seeding, harvesting and transportation. Secondary emissions refer to GHG emissions from the production, packaging, and storage of fertilizers and pesticides. Tertiary emissions denote GHG emissions from the acquisition of raw materials, manufacture of agriculture equipment like agriculture machinery, and construction of agricultural buildings. According to the IPCC definition, primary emissions are direct emissions, and secondary and tertiary emissions are defined as embodied emissions and indirect emissions.

Measurement of different greenhouse gas (GHG)

In the context of global warming, composting is one of the best waste management options that can offset GHG gases on one hand, while also contributing towards sustainable agriculture through the utilization of end product (compost) for soil health management; which in turn can enable the reduction of chemical fertilizers *vis-a vis* GHG mitigation from source. However, implementation of a reliable technology to deal with these wastes is considered as a pillar for sustainable development of any nation. The amount of emitted gases under any composting process is highly influenced by the type of treated wastes and operational conditions, but most importantly the adopted composting technology, which would have a direct impact in reducing the rate of emissions, mainly N_2O and CH_4. At the same time apart from being environment friendly the technology needs to be cost- effective as well, in order to ensure large scale adoptability.

Emissions are formed due to inadequate aerobic conditions of composting. Generally, the creation of anaerobic zones in compost mixtures results in CH_4 emissions, whereas nitrogen transformation and loss (NH_3 and N_2O) are linked to ammonification, nitrification, and de-nitrification during the composting process. The rate of gaseous emissions generally vary as per the adopted composting method, but the emitted amount is still less than that recorded from the landfill sites and under waste-to-energy processes.

Global Warming Potential (GWP) values of Green House Gases

Global Warming Potential (GWP) has been developed as a metric to compare (relative to another gas) the ability of each greenhouse gas to trap heat in the atmosphere. Specifically, it is a measure of how much energy the emission of 1ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2) (EPA, 2022). CO_2 was chosen as the reference gas to be consistent with the guidelines of the Intergovernmental Panel on Climate Change (IPCC 2008). Because CO_2 has a very long residence time in the atmosphere, its emissions cause increase in atmospheric concentrations of CO_2 that will last thousands of years. The time period usually used for GWPs is 100 years. Nitrous Oxide (N_2O) has a GWP 273 times that of CO_2 for a 100-year timescale. N_2O emitted today remains in the atmosphere for more than 100 years, on an average (EPA, 2022). Now in case of methane, there is an emerging debate whether, GWP of methane will be taken on 100 year's basis (as IPCC recommended) or on a shorter scale. Because, GWP hides trade-offs between short- and long-term policy objectives inside a single time scale of 100 or 20 years (Plattner et al. 2009). The most common form, GWP100, focuses on the climate impact of a pulse emission over 100 years, diluting near-term effects and misleadingly implying that short-lived climate pollutants exert forcing in the long-term, long after they are removed from the atmosphere (Allen et al. 2016). Meanwhile, GWP20 ignores climate effects after 20 years (Ocko et al. 2017).

Now, the challenge is majorly related to methane, which is a powerful greenhouse gas with a 100-year global warming potential 28-34 times that of CO_2. But when measured over a 20-year period, that ratio grows 84-86 times. Despite methane's short residence time, the fact that it has a much higher warming potential than CO_2 and that its atmospheric volumes are continuously replenished make effective methane management a potentially important element in countries' climate change mitigation strategies (UNECE,2022) .

Now according to IPCC (2013) "No single metric can accurately compare all consequences of different emissions, and all have limitations and uncertainties". **Increasingly there are calls for the use of different time horizons (*e.g.* 20 years) or even different metrics that better reflect climate change or align with climate targets.** So though under UNFCCC, GWP_{100} remains the standard: according to the Paris "rulebook," but people can use other metrics to provide information; this comes with the requirement to provide supporting documentation (UNFCCC, 2018).

In this regard, Howarth (2011) suggested that the 20-year period is more appropriate for evaluation of GHG emissions since there is an urgent need to mitigate them in the next 15–35 years. Additionally, AR6, published in 2021, raised the GWP of methane to 29.8 over a 100-year horizon but seems to have reduced the 20-year horizon factor to 82.5.16 With the adoption of COP 21 (Paris), and particularly of net zero, targets for 2050 there is a convincing case for taking a 20–30-year, rather than a 100-year horizon (Steern, 2022).

According to Latest IPCC report (IPCC, 2021), it was clearly maintained that, **IPCC does not recommend any emissions metric because the appropriateness of the choice depends on the purposes for which gases or forcing agents are being compared**. Emissions metrics can facilitate the comparison of effects of emissions in support of policy goals. They do not define policy goals or targets but can support the evaluation and implementation of choices within multi-component policies (e.g., they can help prioritize which emissions to abate). The choice of metric will depend on which aspects of climate change are most important to a particular application or stakeholder and over which time horizons. Different international and national climate policy goals may lead to different conclusions about what is the most suitable emissions metric (Myhre et al., 2013b).

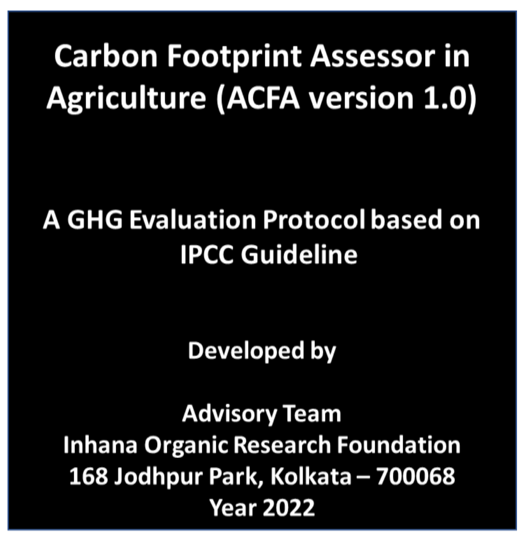
Now, according to Abernethy and Jackson (2022), to calculate the time horizon that aligns with scenarios achieving a specific temperature goal and to best align emission metrics with the Paris Agreement 1.5 °C goal, they recommend a 24 year time horizon, using 2045 as the endpoint time, with its associated $GWP_{1.50\,C}$ = 75.

In the study we used two different timescales for evaluating GHG emission in order to estimate the maximum impact of the GHG gases on environment. In case of N_2O, we considered the usual 100 years' time frame. But in the case of methane we took the 24 years' timeframe because CH_4 is short-lived in atmosphere, 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. Although there is significant history of using single-basket approaches, supported by emissions metrics such as GWP-100, in climate policies such as the Kyoto Protocol, multi-basket approaches also have many precedents in environmental management, including the Montreal Protocol (Daniel et al., 2012).

Carbon Footprint Calculation Methods – Development of Agricultural Carbon Footprint Assessor (ACFA – Version 1.0) under IBM-IORF Sustainability Project

Carbon footprint is an indicator that accounts for GHGs (greenhouse gases) emitted by human activity. Their concentration in the atmosphere traps solar radiation refracted on to the earth's surface. They are thus partly responsible for global warming. A carbon footprint is expressed in carbon dioxide equivalent (CO_2e). GHGs all have a different global warming potential (GWP). This indicator is therefore a way of standardizing the reading of these impacts since they are expressed as a volume of CO_2 retaining the same amount of solar radiation.

Carbon Footprint Calculation Method Agricultural Carbon Footprint Assessor (ACFA – Version 1.0) was developed based on The Intergovernmental Panel on Climate Change (IPCC) guideline specially IPCC 2006 Guideline and the 2019 Refinement to the 2006 IPCC Guidelines. Apart from that, work from several other scientists was also taken as reference.


Carbon Footprint Assessor in Agriculture (ACFA version 1.0)

A GHG Evaluation Protocol based on IPCC Guideline

Developed by

Advisory Team
Inhana Organic Research Foundation
168 Jodhpur Park, Kolkata – 700068
Year 2022

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 Guidelines) were produced at the invitation of the United Nations Framework Convention on Climate Change (UNFCCC) to update the Revised 1996 Guidelines and associated good practice guidance which provide internationally agreed methodologies intended for use by countries to estimate greenhouse gas inventories to report to the UNFCCC.

The 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories was adopted and accepted during the 49th Session of the IPCC in May 2019. It was prepared by the Task Force on National Greenhouse Gas Inventories (TFI) in accordance with the decision taken at the 44th Session of IPCC in Bangkok, Thailand, in October 2016.

The 2019 Refinement provides supplementary methodologies to estimate sources that produce emissions of greenhouse gases and sinks that absorb these gases. It also addresses gaps in the science that were identified, new technologies and production processes have emerged, or for sources and sinks that were not included in the 2006 IPCC Guidelines. It also provides updated values of some emission factors used to link the emission of a greenhouse gas for a particular source to the amount of activity causing the emission.

The updated IPCC methodology improves this transparency and reporting process by ensuring that the methodology used to determine these inventories is based on the latest science.

Components of Agricultural Operations for GHG Calculation

In respect of GHG emission/ mitigation associated with Agriculture, it is important to note that all the activities related to Conventional Agriculture lead to GHG emission. While under sustainable practice/ organic farming, there is scope for both GHG emission and mitigation. Accordingly the agricultural operations are listed below in broader class for Calculation.

Sl No	Farm Operations
1.	Compost Preparation / outsourcing
2.	Seed & Seed Treatment
3.	Land Preparation
4.	Nursery Management
5.	Nutrient management A. Fertilizer Application B. Compost Application C. Application of other inputs
6.	Irrigation
7.	Plant Management
8.	Plant Protection
9.	Weed Management
10.	Cultural Practice
11.	Other Inputs (if any)
12.	Harvesting

Data Source

Data of farm operations were collected from IBM-IORF Sustainability project 'Adoption of a Cluster of Villages for Agricultural Sustainability and Food Security through Clean Food Program' at Mandya, Karnataka, India during crop season 2022 – 23.

The farm operation related data base was collected both from Model Farm, developed under the project as well as from the project farmers.

Other National level database was collected from different authentic sites which was required for GHG calculation.

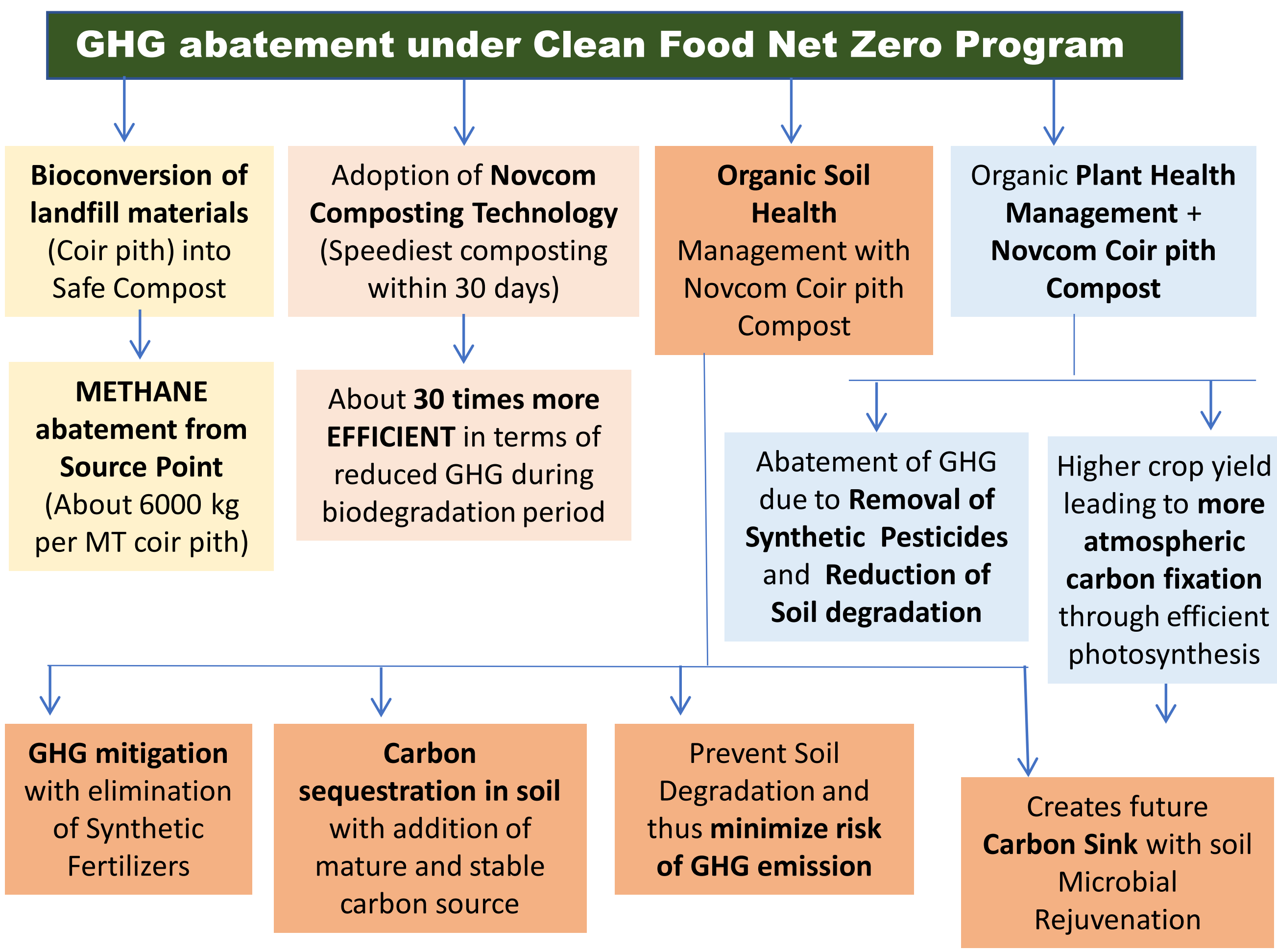
GHG emission from Novcom compost was calculated from data base generated through field experiment in the project site.

GHG data base was developed on 24 vegetables (Phase -1) under both conventional and Clean Food (with adoption of IRF technology) production.

Introduction of Clean Food Net Zero Program for GHG Mitigation

The Clean Food 'Net Zero' Program was initiated at Mandya, Karnataka under IBM-IORF Sustainability Project with the adoption of IRF Technology. Under this program bio- conversion of coir pith (a WASTE from coir industry which is dumped in open lands) 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 was taken up under IRF Technology, towards 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.



Estimation of GHG Mitigation through Agricultural Carbon Footprint Assessor (ACFA – Version 1.0)

GHG Emission from Conventional Farmers' Practice

A. GHG Emission from Seed and Seed Treatments

Only indirect CO_2 emission as per chemical treatment

0.002 kg Chemical used (generally Carbendazim 50%WP is used) for treatment of 1 kg seed

CO_2 equivalent = Seed requirement / ha x 0.001 (active ingredient) x 15.77 kg CO_2

=12.7 x 0.001 x 15.77 kg CO_2 = 0.20 kg CO_2

B. Seed Bed Preparation and Nursery Management

Embodied energy of farm equipment = 5 mandays x 8 hours x 0.314 MJ / hr

= 12.56 MJ x 0.09 kgCO_2 / MJ

=1.13 kgCO_2 equ

Chemical for seed bed management = 100 ml insecticides (1 round) + 100 ml fungicides (1 round) = 0.1 ltr x 0.25 (active ingredient) x 20.17 kg CO_2 / kg a.i. + 0.1 ltr x 0.50 (active ingredient) x 15.77 kg CO_2

=1.29 kg CO_2

Total for seed bed preparation = 2.42 kg CO_2

C. Main Land Preparation

No of field operation : 2 times ploughing followed by manual land setting

Tractor Weight : 2000 kg

Self life : 15 yrs (expected 5 hrs every day for 150 days) =Total 11250 hr

Tractor embodied energy = 12.8 **kg CO_2 / kg**

Diesel GHG /ltr = **2.6444 kg CO_2/lit**

Hrs required for 1 round ploughing = 150 min/ha

Total diesel required / ha (7.5 ltr/hr) = (7.5/60)*150 = 18.75 ltr

GHG emission for 1 ha ploughing = 18.75 x 2.6444 = **49.58 kg CO_2**

Tractor embodied CO_2 for 1 ha =[(12.8 x 2000)/(15year x150 day in a year x 5 hr)] x 2.5 hour for 1 ha = 5.69 kg CO_2

Total CO_2 emission with 1 ha ploughing 1 times = (49.58+5.69) = **55.27 kg CO_2**

So for main land preparation GHG emission = (For Vegetable cultivation usually 2 times plaguing is required) = 2 x **55.27 = 110.54 kg CO_2**

D. Transplanting in the main field

Embodied energy of farm equipment = 20 mandays x 4 hours x 0.314 MJ / hr

= 25.12 MJ x 0.09 kgCO_2 / MJ

=**2.26 kgCO_2**

Estimation of GHG Mitigation through Agricultural Carbon Footprint Assessor (ACFA – Version 1.0)

E. GHG Emission from Irrigation

Motor used for Irrigation : 2 HP ; pump electricity (kWh)/hour = 1.49; Energy kWh = 3.6 MJ

Weight of pump = 45 kg; Pump embodied CO_2 = 12.8 kg/kg

Self life = 15 years average working hour/year (15 year for 10 months 9 hour per day for 30 days) = 2700 x 15

Pump embodied CO_2 /hr = (12.8*45)/(2700x15) = 576/40500 = 0.014 kg CO_2

CO2 Baseline Database for the Indian Power Sector

0.81 ton CO_2 / MWh = 0.81 kg CO_2 / kWh

Electricity CO_2 for irrigation pump/hr = 1.49 x 0.81 = 1.21 kg CO_2

Pump efficiency 40 %

Nearly 20 percent of India's electricity generation is lost during its transmission

Pump electricity (kWh)/hour = 1.49 /[0.4 x (1-0.2)] =1.49 / 0.32 = 4.66 kWh = 3.78 kg CO_2

time for 1 round (min for 1 ha) irrigation= 60*7.5 min = 7.5 hr

Vegetables need 10 irrigation rounds

Total CO_2 = [(3.78 x 7.5 x 10)+(0.014 x 7.5 x 10)] =(283.5+1.05) **=** 284.55 kg CO_2

Now, As Sprinkler irrigation is about 50 % more efficient than flood irrigation, we considered that with sprinkler irrigation system, GHG emission will be 50 % of that flood irrigation

So, total GHG emission under sprinkler Irrigation : 284.55 kg CO_2 / 2 = 142.28 kg CO_2

F. Nutrient Management for Farmers' Practice

Average NPK required : 129, 212 and 156 kg / ha

That means 280 kg Urea, 1325 kg SSP and 260 kg MOP / ha

Inputs	Kg CO_2 / kg	Kg/ha	**Kg CO_2 Eq per ha**
Urea (46 %)	**7.079**	280	1982.1
SSP (16 % P_2O5 +11 % SO_4)	**0.09**	1325	119.3
MOP (K_2O 60 %)	**3.652**	260	949.5
Total in 1 ha		1865	**3050.9**

Estimation of GHG Mitigation through Agricultural Carbon Footprint Assessor (ACFA – Version 1.0)

G. Pesticide usage under Farmers Practice

Pesticides **used**	**Kg CO_2**
Total Insecticides	82.40
Total Fungicides	88.39
Total Pesticides used	**170.79**

H. Sprayers embodied CO_2 for Pest Management

Considering 100 min spent for 1 bigha spraying or 12.5 hr for 1 ha spraying

Embodied energy of sprayer : 0.502 MJ/hr

Total no of Spraying round : 29 rounds

Embodied energy of sprayers = (29 x 12.5 x0.502) = 182 MJ

To calculate the carbon dioxide emissions it was assumed that on average the manufacture of all components requires inputs of fossil fuel energy with an average emission factor of 0.07 kg CO_2/MJ.

Embodied CO2 = 182 x 0.07 (average emission factor) = 17.74 kg CO_2

I. GHG Emission due to Plant Management (Growth Promoters and others)

Average 3 round, 0.750 ltr/ ha per round

Energy equivalent of plant management chemical : 120 MJ/ltr

Total energy use in plant management chemical : (3 x0.750 x 120) = 122.25MJ/ha

For all agri-chemicals the carbon dioxide emission factor was taken to be 0.06 kgCO_2/MJ assuming that all energy used in production, packaging and distribution is derived from fossil fuels.

CO_2 emission for plant management chemicals : 122.25 x 0.06 (avg. emission factor) = 7.3 kg CO_2

J. Harvesting

As small and marginal farmers utilized human labour for harvesting, no CO_2 was emitted.

GHG Emission from Conventional Vegetable Cultivation

Sl No	Parameters	Kg CO_2	% CO_2 emission
1.	Seed	0.2	0.01
2.	Seed Bed Preparation and Nursery Management	2.42	0.07
3.	Main Land Preparation	110.54	3.15
4.	Transplanting in the main field	2.26	0.06
5.	Irrigation	142.28	4.06
6.	Nutrient management for farmers' practice	3050.9	87.06
7.	Pesticide usage under farmers' practice	170.79	4.87
8.	Sprayers embodied CO_2 for pest management	17.74	0.51
9.	Plant Management (Chemical)	7.3	0.21
10.	**Total GHG Emission / ha**	**3504.43**	**100**
Average Crop yield (kg/ha)		15180 kg	
Carbon Footprint of Conventionally grown Vegetables		**0.23 Kg CO_2 equivalent / kg**	

GHG Emission from Clean Food Net Zero

A. GHG Emission from Seed and Seed Treatments

Only indirect CO_2 emission as per chemical treatment

1.2 ltr Inhana Seed solution used

Energy of any Inhana solutions is 0.877 MJ/ ltr

For all Inhana solution the carbon dioxide emission factor was taken to be 0.06 kg CO_2/MJ assuming that all energy used in production, packaging and distribution is derived from fossil fuels

CO_2 equivalent =1.2 x 0.877 x 0.06 (average emission factor) = **0.06 kg CO_2**

B. Seed Bed Preparation and Nursery Management under IRF

Embodied energy of farm equipment = 5 mandays x 8 hours x 0.314[4] MJ / hr

=**1.13 kgCO_2** eq

IRF Organic solution for seed bed management = 3 x100 ml IRF solutions = 0.3 ltr x 0.877[33] x 0.06[5] =**0.016 kg CO_2**

Total GHG emission for seed bed preparation : 1.13+0.016 = **1.15 kg CO_2**

C. Main Land Preparation

No of field operation : 2 times ploughing followed by manual land setting

Tractor Weight : 2000 kg

Self life : 15 yrs (expected 5 hrs every day for 150 days) =Total 11250 hr

Tractor embodied energy = 12.8 **kg CO_2 / kg**

Diesel GHG /ltr = **2.6444 kg CO_2/lit**

Hrs required for 1 round ploughing = 150 min/ha

Total diesel required / ha (7.5 ltr/hr) = (7.5/60)*150 = 18.75 ltr

GHG emission for 1 ha ploughing = 18.75 x 2.6444 = **49.58 kg CO_2**

Tractor embodied CO_2 for 1 ha =[(12.8 x 2000)/(15year x150 day in a year x 5 hr)] x 2.5 hour for 1 ha = 5.69 kg CO_2

Total CO_2 emission with 1 ha ploughing 1 times = (49.58+5.69) = **55.27 kg CO_2**

So for main land preparation GHG emission = (For Vegetable cultivation usually 2 times plaguing is required) = 2 x **55.27 = 110.54 kg CO_2**

D. Transplanting in the main field

Embodied energy of farm equipment = 20 mandays x 4 hours x 0.314 MJ / hr

= 25.12 MJ x 0.09 kgCO_2 / MJ

=**2.26 kgCO_2**

Estimation of GHG Mitigation through Agricultural Carbon Footprint Assessor (ACFA – Version 1.0)

E. GHG Emission from Irrigation

Motor used for Irrigation : 2 HP ; pump electricity (kWh)/hour = 1.49; Energy kWh = 3.6 MJ
Weight of pump = 45 kg; Pump embodied CO_2 = 12.8 kg/kg
Self life = 15 years average working hour/year (15 year for 10 months 9 hour per day for 30 days) = 2700 x 15
Pump embodied CO_2 /hr = (12.8*45)/(2700x15) = 576/40500 = 0.014 kg CO_2
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0.81 ton CO_2 / MWh = 0.81 kg CO_2 / kWh
Electricity CO_2 for irrigation pump/ hr = 1.49 x 0.81 = 1.21 kg CO_2
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time for 1 round (min for 1 ha) irrigation= 60*7.5 min = 7.5 hr
Vegetables need 10 irrigation rounds
Total CO_2 = [(3.78 x 7.5 x 10)+(0.014 x 7.5 x 10)] =(283.5+1.05) **=** 284.55 kg CO_2
Now, As Sprinkler irrigation is about 50 % more efficient than flood irrigation, we considered that with sprinkler irrigation system, GHG emission will be 50 % of that flood irrigation
So, total GHG emission under sprinkler Irrigation : 284.55 kg CO_2 / 2 = 142.28 kg CO_2

F. GHG emission from Nutrient Management under Clean Food 'Net Zero' Program

Under Clean Food program, 40 ton Novcom coir pith compost was applied /ha

A. GHG emission from 40 ton Novcom composting from coir pith waste

= (-) 6000.79 CO_2 eq /1000 MT Novcom coir pith compost (Details workout in Chapter 2)
=(-)240.03 CO_2 eq /40 MT Novcom coir pith compost

B. GHG mitigation from Carbon sequestration with compost application in soil

Total Carbon sequestration : 40 ton (total compost applied) x (1-0.69) (dry matter %) x 0.29(Organic carbon) x 0.57 (sequestration factor) x 44/12
= 40 x 0.31 x 0.29 x 0.57 x 44/12 ton CO_2 equivalent /ha
=7.52 ton CO_2 equivalent /ha = (-) 7520 kg CO_2 equivalent /ha

C. Emission / Mitigation due to compost application

GHG Emission from 40 ton Novcom Coir pith Compost Application (in wet climate)

[Considering 1.17 % N and 69 % Moisture i.e. 3.63 kg N in 1 ton Novcom Compost]

$N_2O - N_{N\ inputs} = F_{ON} \times EF_1 + (F_{ON} \times Frac_{GASM}) \times EF_4 + (F_{ON} \times Frac_{LEACH-H}) \times EF_5$

$= (3.63 \times 0.006) + (3.63 \times 0.21 \times 0.014) + (3.63 \times 0.24 \times 0.011)$ kg

$= 0.042$ kg

$N_2O_{\ N\ inputs} = 0.042 \times (44 / 28)$ kg $= 0.066$ kg

Converting in CO_2 equivalent (as per ARC 6) = 0.066 x 277 kg $\mathbf{CO_2}$

= 18.28 kg $\mathbf{CO_2}$

GHG Emission from 40 ton = 18.28 x 40 = 731.2 **kg $\mathbf{CO_2}$**

GHG emission under Novcom compost application =731.2 – 7520 – 240030 kg $\mathbf{CO_2}$

= (-)246818.8 kg $\mathbf{CO_2}$

G. Pesticide usage under Clean Food Program

Total energy use in alternate pest/disease management : 98.8 MJ/ha

For all agro-inputs the carbon dioxide emission factor was taken to be 0.06 kgCO_2/MJ assuming that all energy used in production, packaging and distribution is derived from fossil fuels.

CO_2 for plant management chemicals : **98.8 x 0.06 = 5.93 kg $\mathbf{CO_2}$**

H. Sprayers embodied CO_2 for pest management (Avg. 13 round)

Embodied energy of sprayers = (13 round x (100 min/bigha x 7.5)/60)*0.502 (embodied energy MJ/hr) = 81.57 MJ

To calculate the carbon dioxide emissions it was assumed that on an average the manufacture of all components requires inputs of fossil fuel energy with an average emission factor of 0.07 kg CO_2/MJ.

Embodied CO2 = 81.57 x 0.07 = **5.71** kg CO_2

I. Plant Health Management (IRF Plant Health Management Solution)

Total energy use for plant management using IRF solution : 7.56 MJ/ha

CO_2 for plant management chemicals : 7.56 x 0.06 = 0.45 kg CO_2

Embodied energy of sprayers 12 round x(100 min/bigha x 7.5)/60)*0.502 (embodied energy MJ/hr) = 75.3 MJ

Embodied CO2 = 75.3 x 0.07 = 5.27 kg CO2

Total GHG for Plant management = 0.45+5.27 =**5.72 kg $\mathbf{CO_2}$**

Estimation of GHG Mitigation through Agricultural Carbon Footprint Assessor (ACFA – Version 1.0)

J. GHG emission from Harvesting

As small and marginal farmers utilized human labour for harvesting, no CO_2 was taken.

K. Impact on GHG Mitigation due to Management Change

Soil Organic carbon stock of Agro-climatic sub-region 8.2 = 0.153 Pg
Area of Agro-climatic sub-region 8.2 = 3.37 mha

Organic carbon stock 0.30 cm =$(0.153 \times 10^{12}) / (3.37 \times 10^{6})$
= 0.04540×10^{6} kg/ha = 45400 kg/ha

According to formula

$$\Delta C_{CC_{Mineral}} = [(SOC_0 - SOC_{(0-T)}) \bullet A] / T$$

$$SOC = SOC_{REF} \bullet F_{LU} \bullet F_{MG} \bullet F_I$$

Now

Now as per the IPCC database	Previous	Now
F_{LU} : Stock Change factor for land use	0.83	0.83
F_{MG} : Stock Change factor management regime	1.00	1.00
F_1 : Stock Change factor for input of organic matter	1.11	1.44
T; 20 Years (Default value)		

Soil Org. C Stock change / year = (45400 x 0.83x1.00x 1.44 - 45400 x 0.83x1.00x 1.11)/20 kg /ha
= (54262 – 41827)/20 kg /ha
= 12435/20 = 621.75 kg /ha

GHG Mitigation in terms of = 621.75 x 44/12 kg /ha
= (-) 2279.8 kg CO_2 equivalent **/ha**

GHG Emission / Mitigation from Clean Food Net Zero Vegetable cultivation Program

	Parameters	Kg CO_2
1	Seed	0.06
2	Seed Bed Preparation and Nursery Management	1.15
3	Main Land Preparation	110.54
4	Transplanting in the main field	2.26
5	Irrigation	142.28
6	Nutrient management for Clean Food Net Zero	(-) 246818.8
7	Pesticide usage under Clean Food Net Zero	5.93
8	Sprayers embodied CO_2 for Pest Management	5.71
9	Plant Health Management (IRF Technology)	5.72
10	GHG mitigation due to change of practice	(-)2279.8
11	**Total GHG Emission under Clean Food Net Zero**	**(-)248825**
Crop yield (kg/ha)		18360 kg
Carbon Footprint of Vegetables grown under Clean Food Net Zero Program		**(-)13.55 Kg CO_2 equivalent / kg**

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

GHG evaluation in respect of vegetable production under Clean Food Net Zero program (CFNZ), 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 13.78 kg CO_2 equivalent per kg vegetable produced. So a 100 ha CFNZ Program, can offset about 24,833 MT of CO_2 equivalent, enabling significant climate action while also creating opportunities for higher employment and income generation.

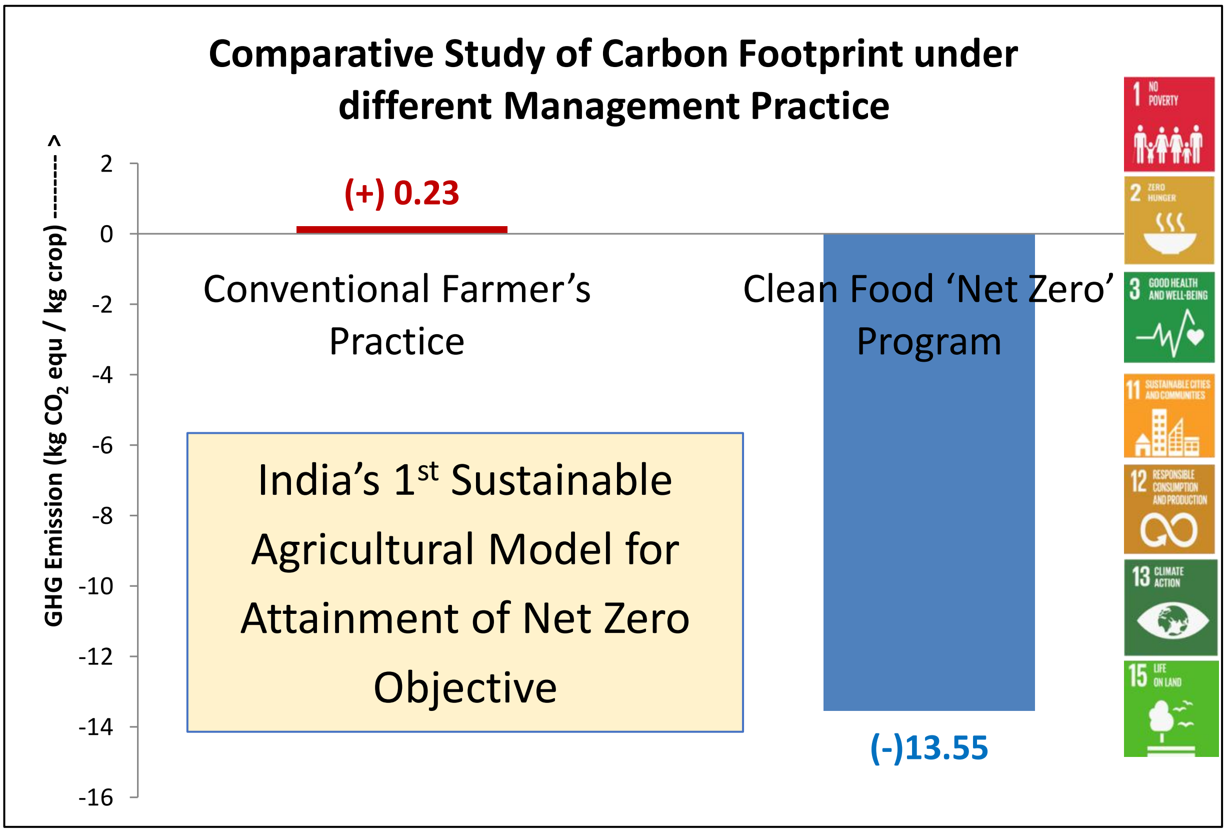

Fig. 1 : Comparative study of carbon footprint of vegetables grown under Conventional Farmers' Practice *vis-a-vis* CFNZ program, under IBM-IORF Sustainability Project.

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

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CHAPTER 8 : Energy Usage under Clean Food Net Zero Program

Summary

The advent of green revolution led to an increased use of energy in agriculture primarily due to increasing use of chemical fertilizers, pesticides, farm mechanization, etc. **The amount of energy used in agriculture has grown substantially, and currently, the agri-food chain accounts for 30 percent of the total energy used around the world.** The lack of energy efficiency in the agricultural and food sector causes significant Greenhouse Gas Emissions. **The IPCC has identified improved energy efficiency in the agricultural sector as a key intervention in this field** *(IPCC, 2007. Climate Change 2007: Mitigation. Contribution of Working).* **But the major Challenges for Energy Transition in agri-food systems is to decouple the use of fossil fuels in food-system transformation and related innovations without compromising food security.**

Energy transition towards Clean Food 'Net Zero' Program was investigated in all the major crops under IBM-IORF Sustainability Project at Mandya, Karnataka. Focus was imparted mainly on energy transition in respect of nutrient management as it covers more than 50 % of energy usage (if human energy is not considered). Two major energy indices viz. (i) Nutrient Energy Ratio (NER) and (ii) Nutrient Energy Productivity (NEP) was evaluated under the study. Clean Food 'Net Zero' Program was found to be 368 % more efficient in energy output /unit nutrient energy invested and 432 % more efficient in crop productivity/ unit nutrient energy invested. The results indicated Crop Sustenance, which is crucial considering that the Nutrient Energy Source was completely Organic. **ENERGY TRANSTITION and IMPROVEMENT OF ENERGY PRODUCTIVITY as enabled by the interventional IRF Technology demonstrates a benchmark criteria for SUSTAINABLE AGRICULTURE** and more importantly Climate Change Mitigation.

Introduction

In today's modern era, energy plays a strategic role in the economic development of any country. Energy is the most critical input in the agricultural crop production system, ultimately leading to the economic development of any society and country. However, agriculture is both a producer and consumer of energy. It uses large quantities of locally available non-commercial energy, such as seed, manure and animate energy, as well as commercial energies, directly and indirectly, in the form of diesel, electricity, fertilizer, plant protection, chemical, irrigation water, machinery etc. With time and the progress of agriculture, the amount of energy used in agricultural production has increased intensively because the traditional, low energy farming is being replaced by modern systems, which require more energy use.

Efficient use of these energies helps to achieve increased production and productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural living. Proper energy conservation measures, reasonable management, and minimization of energy losses at various steps have become highly influential in developing countries because of the ever-increasing population with substantial energy demands and depleting natural resources.

Energy input-output relation analysis is usually used to appraise the efficiency and environmental effects of the production systems. Moreover, it contributes to the economy, profitability and competitiveness of agricultural sustainability, since it provides financial savings, fossil resources preservation and air pollution reduction.

Specially energy evaluation under sustainable agricultural initiative is of special interest considering that adoption of sustainable initiative is supposed to reduce the energy requirement. But the precondition is that the crop yield is sustained.

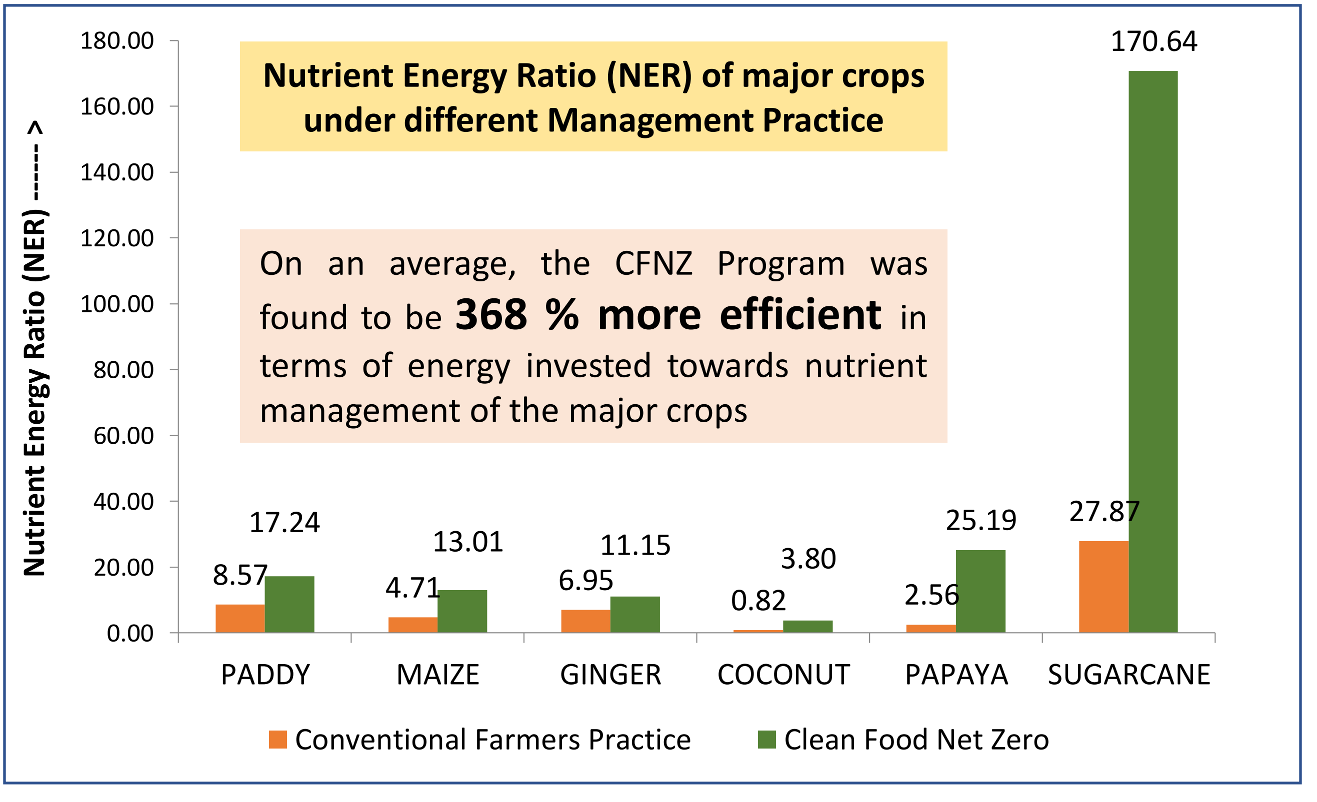
In agriculture, removal of chemical fertilizers is the key towards major energy saving, as fertilizer production especially N- fertilizer, uses large amounts of natural gas and coal, and can account for more than 50 per cent of total energy used in commercial agriculture. However, without sound technological support, even a slight reduction in dosage can entail crop loss, hence, complete elimination of this component forms the biggest challenge towards food security.

Pic.: Cultivation of Coconut based Net Zero Intercropping at Mandya, Karnataka

IRF Technology was adopted to drive the CFNZ Program under IBM-IORF Sustainability Project, towards offsetting synthetic fertilizers and pesticides without compromising crop productivity. For evaluation of energy transition main focus was imparted towards energy efficiency in respect of nutrient management, considering that the Phase-I Project evaluation indicated that under Conventional Farmers' Practice 60 % of the Total Energy was spent on nutrient management.

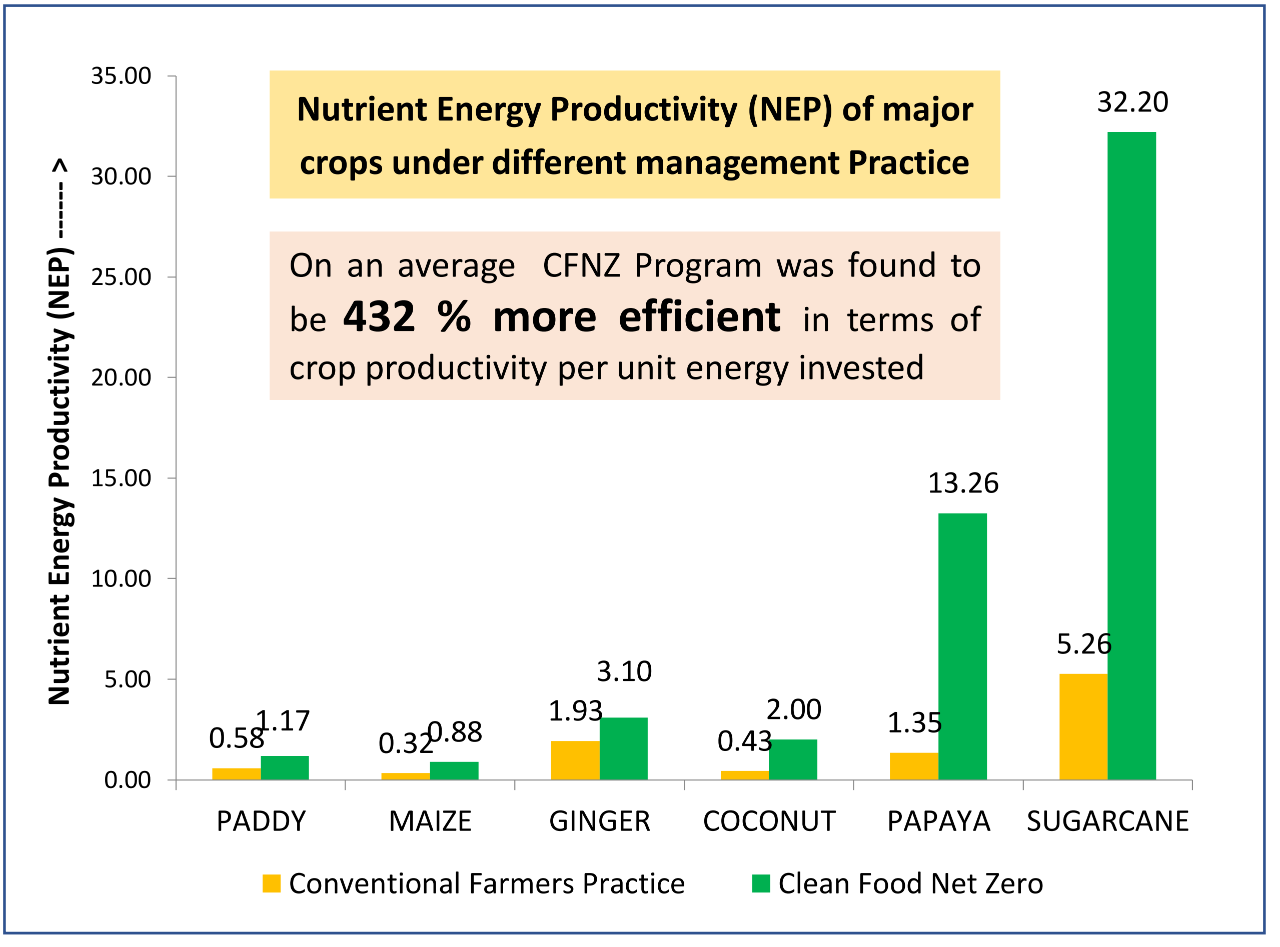
Hence the evaluation was done in respect of two major energy indices *viz*. (i) Nutrient Energy Ratio (NER) and (ii) Nutrient Energy Productivity (NEP). To evaluate these energy indices, the energy requirement for nutrient management under Conventional Farmers' Practice and CFNZ Program as well as energy output from harvestable crops, was calculated.

Comparative study of Nutrient Energy Ratio (NER) of major crops grown in the project area at Mandya, Karnataka



NUTRIENT ENERGY RATIO (NER), **which indicated the total energy output per unit energy invested (w.r.t. nutrient management)** showed a significantly higher value (Mean value 40.17) in case of all the crops under CFNZ Program, especially sugarcane. This was mobilized by the intervention of IRF Technology which enables energization of soil and plant system **towards efficient plant nutrient uptake and utilization from sustainable inputs**, leading to sustained/ enhanced crop yields even while completely eliminating synthetic fertilizers.

Comparative study of Nutrient Energy Productivity (NEP) of major crops grown in the project area at Mandya, Karnataka



NUTRIENT ENERGY PRODUCTIVITY (NEP) which indicated **crop yield obtained per unit of energy investment (w.r.t. nutrient management)** showed significantly higher value under CFNZ Program, in case of all the crops (Mean value- 8.77 Kg / MJ) especially sugarcane; *vis-a-vis* Conventional Farmers' Practice (Mean value- 1.65 Kg/ MJ).

Energy evaluation clearly indicated that **Clean Food 'Net Zero' program can be one of the most effective agricultural model towards ENERGY TRANSITION in Agriculture**. This model is mobilized by the interventional IRF Technology. On one hand bio-conversion of coir pith under Novcom Composting Technology and its utilization for Soil Health Management helped to **offset the high energy intensive chemical fertilizers**, and on the other hand Plant Health Management under IRF Technology ensured balanced crop nutrition from sustainable inputs to **eliminate the threat of crop loss following removal of chemical fertilizers**.

Detailed Project Report

Clean Food Program
Nadia, West Bengal

(2nd Year)

Continuation Project – District Nadia , State 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**.

Demography of the Project Area

The Project area lies in the Indo gangetic zone that forms the major food basket of India and therefore is a major contributor of food for meeting the increasing hunger. In this area, in order to maximize production the farmers have been using **HYV seeds, high dose of chemical fertilizers and are hugely dependent on the chemical pesticides**. But abundant use of the synthetic inputs over the years has **decreased the soil biological diversity, deteriorated the soil organic carbon and degraded the soils**.

Decreasing crop yields, increasing cost of unsustainable chemical inputs, and the threat of crop failure due to the increasing climatic adversities has made farming mostly unsustainable for the **marginal and resource poor farmers who comprise about 96% of the total farming population**. Land fragmentation is at a critical level with an **average land holding size as low as <0.26 hectare, which is about 32% Lower than the national average of 0.38 hectare and almost 1/10th of the Land Classification range for small farmers.** On the other hand the starkly contrasting cropping intensity of 2.49 on an average **indicate an extreme dependence of these farmers on land** and therefore a high vulnerability in respect of the existential climate change impact, that often threatens crop loss and thereby livelihood sustenance.

In spite of the rich legacy in agriculture, the resource reach-ness and richness both are small and due to this the farmers face an extreme compulsion to continue with the conventional farming practice. Finally farm gate price is mostly between 35% to 45% of the consumer price, **and most of the time even in case of escalation of the market price the farmers' share remains always insignificant**.

The Concept of 'CLEAN FOOD' ?

'Clean Food' means complete absence of Carcinogenic Chemicals, Heavy Metals and Growth Hormones. Safety of 'Clean Food' is authenticated by Actual Analysis using the 'Colorimetric Assay Test' – an effective, speedy yet an affordable solution for pesticide residue analysis, especially standardized for the marginal and small farmers during Phase-1 Project.

What is Clean Food?

NO

Carcinogenic Chemicals
Heavy Metals
&
Growth Hormones

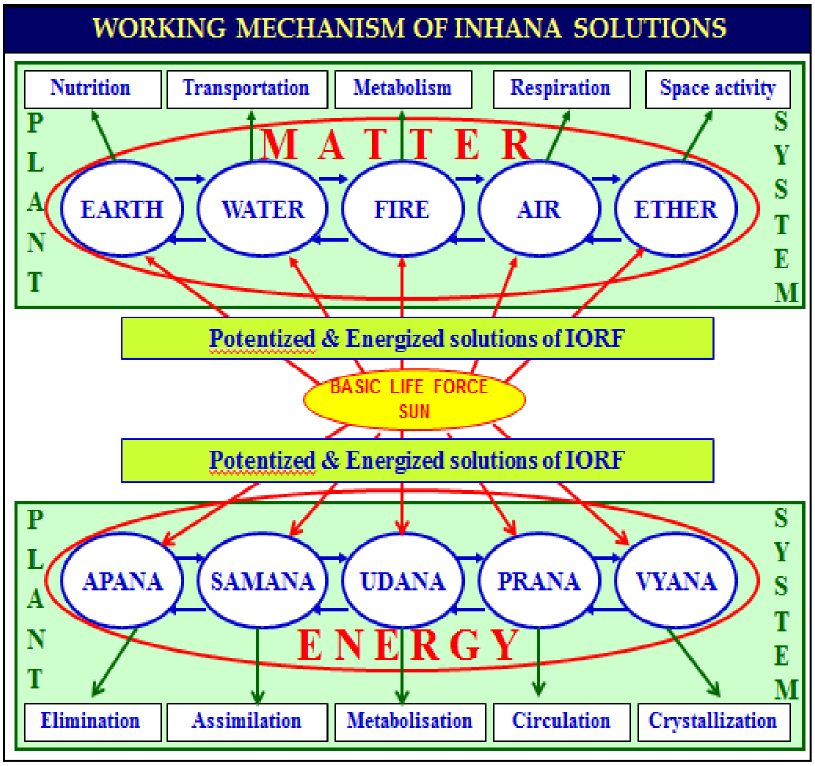
2 ZERO HUNGER

Clean Food Means : A 360 Degree Care for the Farming Community

- Transfer of Complete Road Map towards Safe & Sustainable Crop Production
- Reduction/Elimination of the Requirement of Unsustainable Inputs i.e., Chemical Fertilizer & Pesticides
- Reduction in the Cost of Unsustainable Inputs for Crop Production
- Comprehensive Guidelines for Crop Management from Seed Treatment to Seed Production
- Health Protection of Farmers & Family Members
- Protection of Land Productivity
- Crop Sustainability even under Biotic & Abiotic Stress Factors

IBM-IORF Sustainability Accelerator project

The Project is driven by **Inhana Rational Farming (IRF) Technology – a Comprehensive Organic Package of Practice developed by Indian Scientist and Founder Director of Inhana Organic Research Foundation (IORF), Dr. P. Das Biswas; that has been demonstrating ecologically and economically sustainable crop production, across different agro- ecological regions for over two decades now.**



The technology is based on the hypothesis 'The relationship between a Plant and Pest is Purely Nutritional'. IRF Technology has been inducted to drive this very objective considering that it is the only available Crop Technology so far, that undertakes the approach of **'PLANT HEALTH MANAGEMENT'** to activate Plants' Metabolism and 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 dependence on chemical pesticides.** Plant Health Management is the most ignored component in the Conventional System of Crop Production, but this component actually **holds the Key** to Crop Sustainability especially under the Changing Climatic Patterns.

Resource scarcity (*for compost production*) arising out of the critical land fragmentation is a **major challenge** in the project area towards taking any sustainable initiative. Hence, the **primary aim of 'Clean Food' Program is to showcase a RESOURCE INDEPENDENT Agricultural Model under IRF Technology**, **to the resource Poor Marginal and Small Farmers**, which was executed through the adoption of Inhana Plant Health Management (IPHM).

IRF Technology extends 70% Emphasis on this Component, which is primarily driven by **Inhana 'ENERGY SOLUTIONS'- developed under the Element Energy Activation (E.E.A.) Principle. Driven by Inhana 'Energy Solutions', IPHM is a 1st Ever approach in Indian Agriculture that works towards Activation of Plant Physiology.**

- Development of **Climate Resilient 'Net Zero' Paddy Seeds under Complete Organic management** in the farmers' field for self-reliance towards **Safe And Sustainable 'Clean Paddy' Production.**

- Development of **Climate Resilient 'Net Zero' Vegetable Seeds and Oilseed** in the farmers' field **under Complete Organic Management.**

- Study of **Energy Transition under different 'Clean Food' Models vs. Conventional Farmers' Practice,** for the major cropping sequences.

- Study of **GHG Footprint under different 'Clean Food' Models vs. Conventional Farmers' Practice,** for the major cropping sequences.

Pic.: 'Net Zero' Clean Vegetable Seed Development Program at Nadia, West Bengal, India under IBM-IORF Sustainability Project

Chapter 1 : Crop Performance under 'Clean Food' Program and their Safety Assessment

Summary

IORF conceived the 'Clean Food' initiative under IBM-IORF Sustainability Project towards the objective of providing an **ADOPTABLE ROAD MAP** to the Farmers (*especially the marginal and small land holders*) for **SAFE AND SUSTAINABLE CROP PRODUCTION** with induction of Inhana Rational Farming (IRF) Technology, that can help in shedding off their dependence on synthetic inputs, **Without the Threat of Crop Loss and Without Increasing the Cost of Production**, and ultimately produce **'CLEAN FOOD' - SAFE FOOD ENCAPSULATED IN SUSTAINABILITY.**

Crop Performance under Different Models of 'Clean Food' Program, *vs*. Conventional Farmers' Practice showed, on an average about 20% Higher Crop Yield .

The **COLORIMETRIC ASSAY TEST (CAT**) which was standardized under the IBM-IORF Sustainability Project, Phase-I to provide an EFFECTIVE, SPEEDY yet an ECONOMIC Solution for Food Safety Assessment especially to the Marginal and Small Farmers showed that **97% of the samples collected from the 'Clean Food' Project Area were free from pesticide residue**.

Clean Food Program

The 'Clean Food' program encompasses the major cropping sequences of the project area, and are as follows :

Tomato-cucumber-coriander, Potato-brinjal-cauliflower, Potato-Okra-cabbage, Brinjal-Frenchbean-Spinach, Pumpkin-okra-cabbage, Brinjal-Carrot, French Bean - okra-onion, Potato-chilli-carrot, Tomato-ridge gourd- spinach, Peas -Yam –cabbage and Pointed Gourd – Cauliflower.

Clean Food An Integrated program to achieve SUSTAINABILITY in terms of Food Production, Livelihood Development, Human Health, and Ecology & Biodiversity

How the Program is Attended ?

'Clean Food' is produced using **INHANA RATIONAL FARMING (IRF) TECHNOLOGY**, which is a Comprehensive Organic Package of Practice **developed by Dr. P. Das Biswas (*Founder Director, IORF*). Clean Food is actually developed following** a **RESOURCE INDEPENDENT Agricultural Model under IRF Technology,** executed through the adoption of **Inhana Plant Health Management (IPHM)**.

Development 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.

So 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 that works towards **Activation of Plant Physiology for enhanced plant metabolism and biochemical secretions.** This approach on one hand enhances the agronomic efficiency of the plants and on the other hand cuts down the formation and accumulation of free amino acids and free sugar pools in the plant cell sap, thereby reducing the ready food source for the pest. Hence, Activation of Plant Physiology ensures the **Dual Premise of Crop Sustainability and Higher Plant Immunity towards Pest & Disease** leading to **Elimination of Chemical Pesticides**.

Plant Health Management under IRF Technology is attended through the scheduled application of 'INHANA ENERGY SOLUTIONS'. These solutions are the potentized and energized botanical extracts developed under Element-Energy-Activation (E.E.A) Principle.

Pic.: Clean Food Production at Nadia, West Bengal, India

The Inhana Plant Health Management (IPHM) Schedule of the project Area was as follows :

- Seed is the basic component of the Crop Cycle and to promote a healthy Crop Cycle the IPHM Schedule started with Organic Seed Treatment.
- Post seed germination and once the Saplings attained a 3-4 leaf stage the Inhana Nursery Solutions (AG-1, AG-2 & AG-3) were applied in a synchronized manner to enable Higher survival and a healthy growth phase thereafter.

IPHM Schedule in the Main Field :

1. IB-13 @ 1.5 ltr./ ha
2. P5 Concoction @ 150 ml/ spraying tank. (after 7 days of 1st Spray)
3. IB-3 + IB-7 @ 750 ml/ ha (each) – after 7 days of 2nd Spray.
4. P5 Concoction @ 150 ml/ spraying tank. (after 7 days of 3rd Spray)
5. IB-11 + IB-12 @ 750 ml/ ha (each) – after 7 days of 4th Spray.
6. P5 Concoction @ 150 ml/ spraying tank. (after 7 days of 5th Spray)
7. IB-1 + IB-7 @ 750 ml/ ha (each) – after 7 days of 6th Spray.
8. P5 Concoction @ 150 ml/ spraying tank. (after 7 days of 7th Spray)

NOTE : Plant Tonic (CDS Concoction) was applied @ 375 ltr./ ha at the time of irrigation (twice in a month)

Pic.: Application of Novcom compost in the model farm for Clean Vegetable Production under IBM-IORF Sustainability project

Assessment of crop performance was taken up in respect of **Eleven Major Cropping Sequences**, followed in the area. Soil Health Management towards reduction / elimination of N- Fertilizer in the entire 100 ha was a formidable task, considering the **acute resource scarcity for compost production.** Hence, IORF selected **MODEL FARM for demonstration of Inhana Soil Health Management (ISHM) towards Reduction/ Elimination of N- fertilizer** under these cropping sequences.

Therefore Crop Performance was estimated under **different 'Clean Food' Models *vis-à-vis* Conventional Farmers' Practice**

1. **Clean Food Model - 1 (100 % Reduction of Chemical Pesticide)**
2. **Clean Food Model - 2 (Reduction of 50% N +100 % Chemical Pesticide) – Model Farm**
3. **Clean Food Model - 3 (Reduction of 100% N+100 % Chemical Pesticide) – Model Farm**

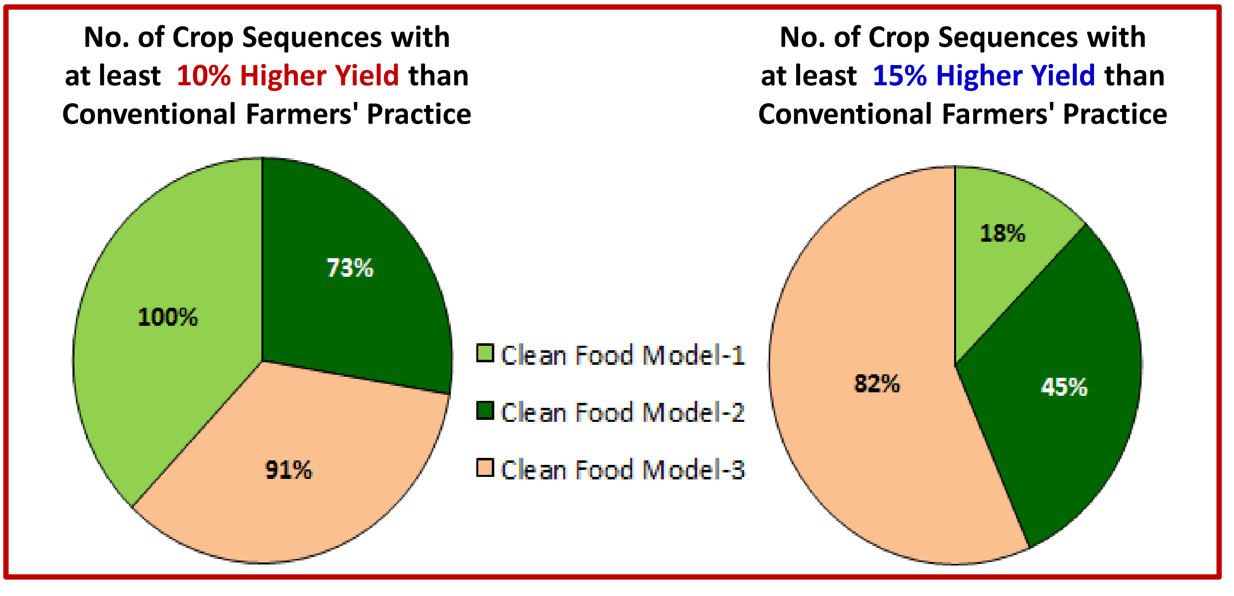
Crop Performance under Different Models of 'Clean Food' Program, *vs*. Conventional Farmers' Practice

Sl.	Cropping Sequence	Conventional Farmers' Practice	Clean Food Model – 1 (100 % Reduction of Chemical Pesticide)	Clean Food Model – 2 (Reduction of 50% N + 100 % Chemical Pesticide)	Clean Food Model – 3 (Reduction of 100% N + 100 % 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
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**

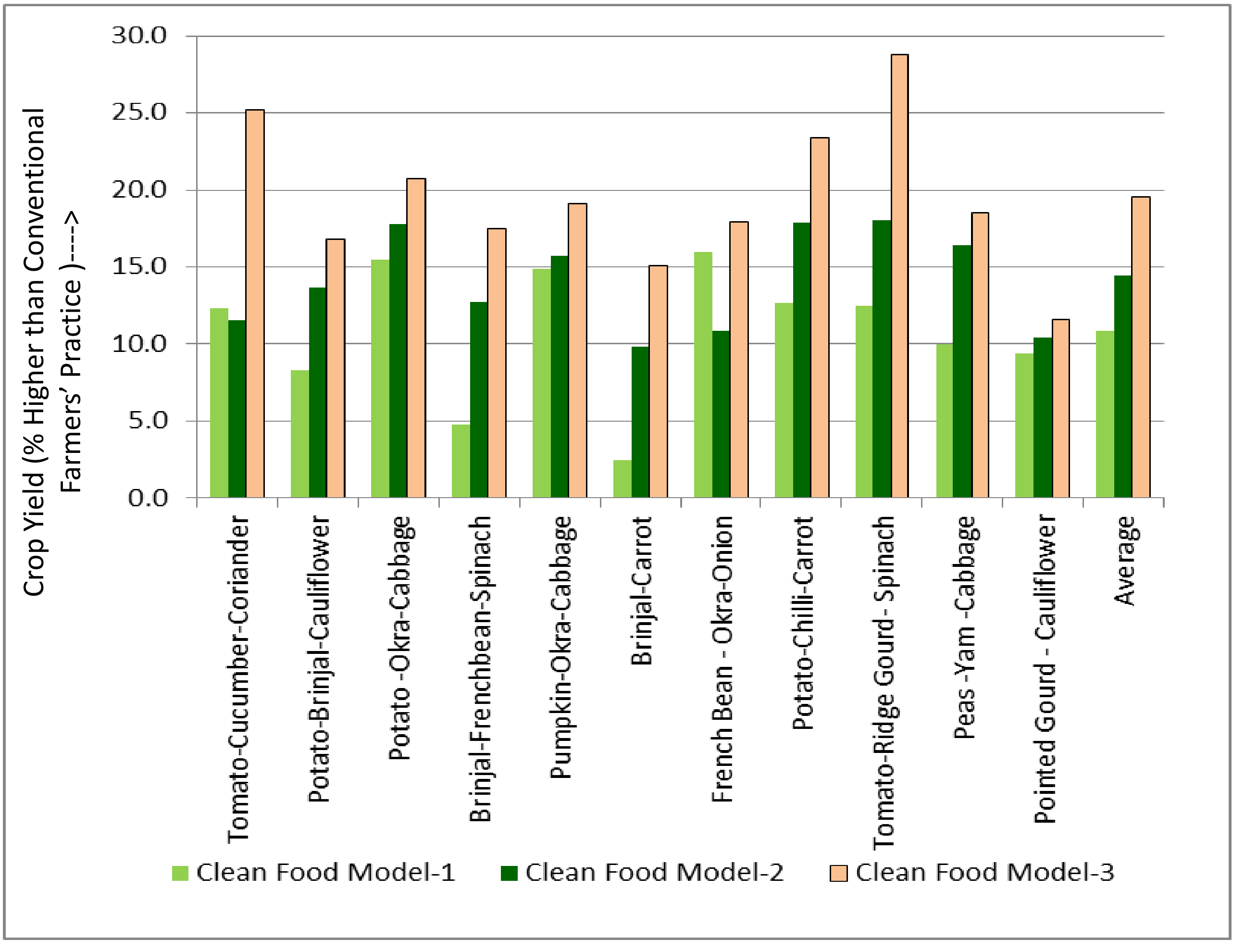
Evaluation of crop performance indicated an overall better crop yields under the 'Clean Food' Models. In the case of Clean Food Model–1, >12 to 16 percent higher yield was obtained w.r.t the Conventional Farming Practice, under the various cropping sequences.

Moreover, under 'Clean Food' Model-3; where apart from pesticide elimination, a 100% reduction of N-Fertilizer was undertaken through application of Novcom Compost, **on an average about 20% Higher Crop Yield** was recorded as compared to conventional farmers' practice, with the **highest (28.7%)** recorded under Tomato- Ridge Gourd- Spinach Cropping Sequence.

Pic.: 'Net Zero' Clean Food Production at Nadia, West Bengal, India



Percent Increase in Crop Yield under Different 'Clean Food' Models, *vs.* Conventional Farmers' Practice



The higher Crop yield under complete elimination of both Chemical Pesticides and N- fertilizer is noteworthy considering the huge threat of crop loss associated with reduction of chemical inputs, and the primary bottleneck towards large scale organic conversion. The finding conclusively indicates the relevance of interventional IRF Technology and the innovative approach of 'Plant Health Management' towards Safe Crop production without any crop loss and at the same cost of production.

Lack of access to technology is a primary limiting factor towards sustainable progression in Indian agriculture, especially considering that more than 80% farmers are marginal to small land holders. The 'Clean Food' Model brings forth an adoptable solution for these land dependent resource farmers whose livelihoods are being constantly threatened by the changing climatic patterns and are therefore in dire need of adoptable climate resilient agricultural practice/s.

Safety Assessment of Clean Food

Food Safety, Where Do We Stand ?

Report published by Food Safety and Standards Authority of India (FSSAI) has revealed that essential edibles such as vegetables, fruits, grains and spices are laced with pesticides. In most cases, the items were said to contain pesticides which are not approved (The times of India, 2019).

Findings of Consumer Voice study in 2010 showed that the amount of **pesticides used by Indian farmers is 750 times higher than the European Limits**. **Vegetables majorly found to be contaminated were; okra, brinjal, lettuce, cucumber and tomato**, while others like chilli, radish, potato etc., were showing lesser amount of residues. Major pesticide residues in most of the vegetable samples were found to be Chlorpyrifos, Monocrotophos, Endosulfan, DDT and Lindane etc., which are **classified under hazardous category and some of them are even banned for the use in vegetable farming**. Still, their residues were found in the samples of different vegetables (Nishant & Upadhyay, 2016). Studies conducted by the Kerala Agricultural University indicated **pesticide residues in 25% of the food products available in organic shops** (Time of India, 2019). According to the FSSAI report 2019 (Mittal, 2019), among the vegetable samples studied brinjal showed the maximum number of pesticide residues; followed by the samples of tomato, okra, cabbage, cauliflower and cucumber.

Climate Change Impact on Pesticide Usage

Climate factors have been found to influence both pest incidence (pathogens, weeds, fungi, and insects) and the effectiveness of chemical treatments. Climate change has been found to alter pest incidence, abundance, and damages. A number of studies have investigated climate influences on pests, pesticide costs and cost variability.

All review evidence, mainly on insect abundance, show that climate change enhances populations. Scientists examined the effects of climate change on pesticide expenditures and found that pesticide expenditures rise with increased temperatures and precipitation for the majority of crops. The climate also influences herbicide, insecticide, and fungicide use through changes in their effectiveness and persistence.

Scientists also found that increase in temperature and changes in rainfall pattern can decrease persistence and, in turn, increase the required number of applications. Climate change impact can also increase the incidence of crop susceptibility to disease with changing temperature, precipitation, and humidity. Additionally, increased atmospheric CO_2 can enhance weed growth and increase weed tolerance to herbicides.

The Guiding Principles for Food Safety in India

In India, Food Safety is based on the guiding principle of risk analysis of the Codex Alimentarius Commission (CAC). The Codex Alimentarius Commission (CAC) was created in 1961/62 by Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), to develop food standards, guidelines and related texts and it is a collection of internationally adopted food standards and related texts presented in a uniform manner.

The Food Safety and Standards Authority of India (FSSAI) under the administration of Ministry of Health and Family Welfare has been designated as the nodal point for liaison with the Codex, known as "National Codex Contact Point of India" (NCCP).

According to Food Safety and Standards (Contaminants, Toxins And Residues) Regulations, 2011; developed by Food Safety and Standards Authority of India, lowest limits of pesticide residue in vegetables is 0.1 ppm except very few cases. This is in accordance with Codex Alimentarius Maximum Residual Limit of 0.1 ppm in respect of vegetables.

Limitations of Standard Chromatographic Techniques towards Safety Monitoring of Food especially for Multiple Harvest Crops Like Vegetables

Gas chromatography is the most widely adopted technique in pesticide residue analysis. But the chromatographic methods coupled to MS detectors are **time-consuming, laborious, and expensive.** These methods require highly skilled personnel and sophisticated modern instruments which can not be provided every where.

Due to the high cost of analysis, this method is economically unviable. Also being a time consuming process, it is not useful especially for batch wise safety compliance of multiple harvest crops like vegetables, which have a very short time gap between harvest and consumption.

Thus we need alternative solutions that can provide authentic results in a speedy and economical manner. According to the Decision 2002/657/EC (European Commission, 2002), "screening methods are used to detect the presence of a substance or class of substances at the level of interest" and alternative screening methods should aim to achieve rapid, selective, cost-efficient, and sensitive screening in the food safety field.

Clean Food Safety Facts.

Clean Food means Safety authentication not but Audit but by Actual Analysis. As the Clean Food developed under his project comprised short duration, multiple harvest- Vegetable Crops, hence; batch wise residue assessment was essential. But the costly, time-taking Chromatographic Method was an economically unviable proposition for the above. Moreover, as this project strived to induce sustainability in every aspect of food production, hence; the need arose to work out an adoptable solution, especially for the marginal and small land holders; considering that these resource poor farmers are actually the major contributors to the Indian food basket.

The COLORIMETRIC ASSAY TEST (CAT) was standardized under the IBM-IORF Sustainability Project, Phase-I to provide an EFFECTIVE, SPEEDY yet an ECONOMIC Solution for Food Safety Assessment especially to the Marginal and Small Farmers

For the 1st time in the history of Indian Agriculture, this newly standardized test method was utilized to adjudge the safety aspect of 'Clean Food' developed under Phase-I, and in Phase-II this method was reutilized for batch wise SAFETY authentication of Clean Vegetables in order to validate its effectiveness in respect of identifying the presence/ absence of pesticide residues in a comprehensive manner.

Background Behind Standardization of Protocol for Pesticide Residue Monitoring in Vegetables using the Colorimetric Assay Test .

In India, as per the last five years pesticide use trend, more than 25000 MT pesticides (technical grade) was consumed and a total of 750 formulations were registered for use in India (as per Insecticides / Pesticides Registered under section 9(3) of the Insecticides Act, 1968 for use in the Country (As on 30.11.2020)-)**.** However, five major groups of chemicals *viz*. Organochlorine, Organophosphate, Carbamate, Synthetic Pyrethroids and Neonicotinoids cover more than 90% of the synthetic pesticides consumed in India.

So, **COLORIMETRIC ASSAY TEST** of five major groups *viz*. Organochlorine, Organophosphate, Carbamate, Synthetic Pyrethroids and Neonicotinoids will serve to authenticate the non-presence of every single variant out of **more than 650 pesticides formulations** covering major Insecticides, Fungicides and Herbicides.

Pic.: Comparative residue analysis using Colorimetric Assay Test in IORF laboratory.

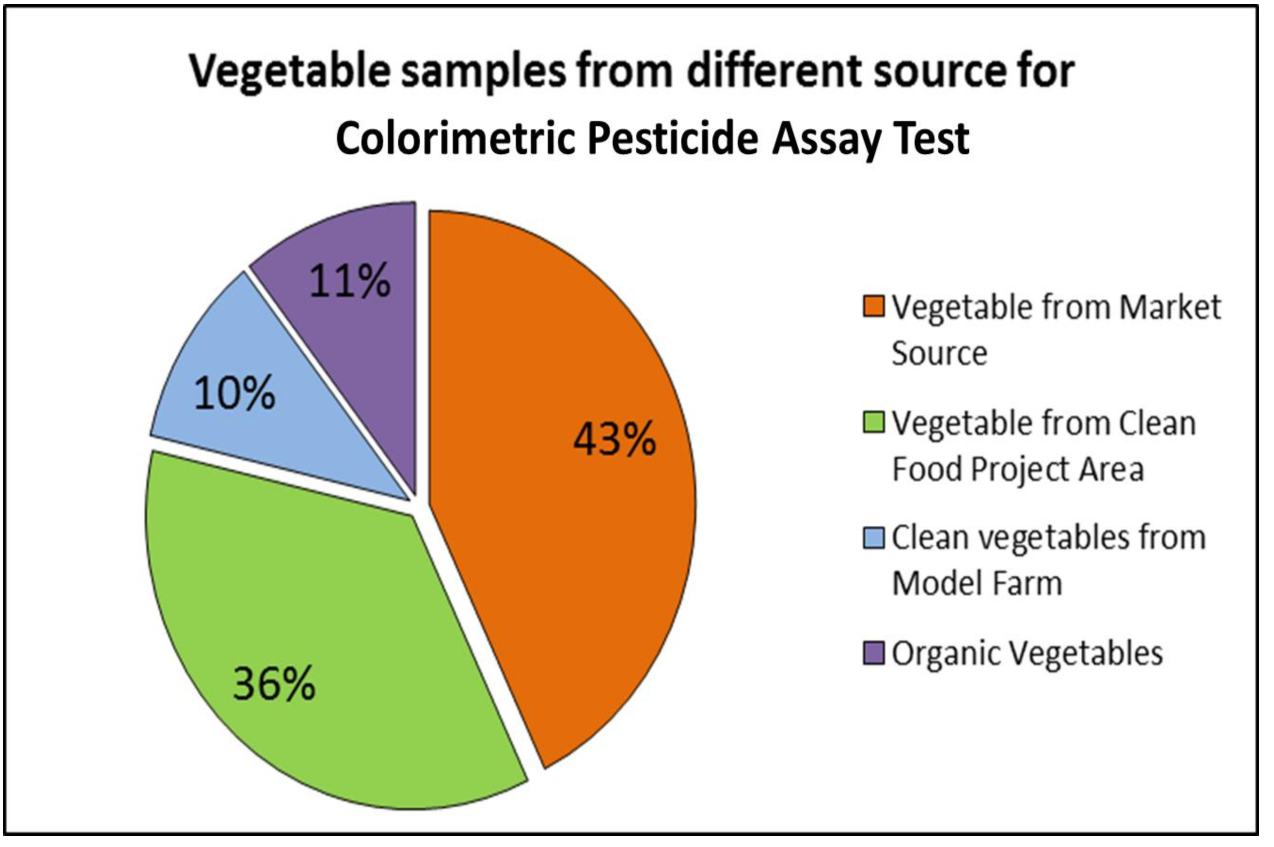
Not only the pesticide, but also the presence/ absence of harmful heavy metals *viz*. Hg^{2+}, Cd^{2+}, Cu^{2+} and Pb^{2+} can also be done using the colorimetric qualitative test. Apart from that; Triazines, Paraquat and many other known and unknown toxic substances which inhibit our central and peripheral nervous system; if present in food product; can also be brought under the scanner under the Colorimetric Assay Test.

The study confirms **Absence of 650 different types of Pesticides** and their combinations in Clean Vegetables*

Table 1 : Samples Analyzed utilizing the Colorimetric Pesticide Assay Test

Sl No	Crop	Vegetable from Market Source	Vegetable from Clean Food Project Area	Clean vegetables from Model Farm	Organic Vegetables	Total Samples
1	Brinjal (Solanum melongena L.)	12	10	3	3	28
2	Chilli (Capsicum annuum)	10	8	3	3	24
3	Tomato (Solanum lycopersicum)	8	8	3	3	22
4	Potato (Solanum tuberosum)	8	12	3	3	26
5	Cabbage (Brassica oleracea var. capitata)	6	10	3	3	22
6	Cauliflower (Brassica oleracea var. botrytis)	6	10	3	3	22
7	Yam (Dioscorea)	4	4	2	2	12
9	Pointed Gourd (Trichosanthes dioica Roxb.)	10	12	3	3	28
10	Cucumber (Cucumis sativus)	6	6	3	3	18
11	Pumkin (Cucurbita pepo L.)	6	8	3	3	20
12	Okra (Abelmoschus esculentus)	8	8	3	3	22
13	French Bean (Phaseolus vulgaris)	6	6	3	3	18
14	Spinach (Spinacia oleracea)	4	6	3	3	16
15	Onion (Allium cepa)	6	6	2	2	16
16	Carrot (Daucus carota subsp. Sativus)	8	8	3	3	22
17	Peas (Pisum sativum)	4	8	3	3	18
10	Ridge Gourd (Luffa acutangula (L.) Roxb.)	4	4	2	2	12
19	Corriender (Coriandrum sativum)	4	6	2	2	14
	Total	120	140	50	50	360

Total 360 vegetable samples were taken for **Colorimetric Pesticide Assay Test,** among which 120 sample were sourced from nearby vegetable markets, 140 samples were collected from clean food project area, 50 samples from clean food model farm and another 50 samples were sourced from certified organic selling points. Among different vegetables, highest samples were from brinjal and pointed gourd followed by potato and chilli.



Pic.: Residue analysis of vegetables using the Colorimetric Assay Test

Sample Pesticide Residue Analysis Reports for 'Clean Vegetables'

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Sample Collected by : Dr. K. Mukherjee, Nadia KVK

No : CATPR/ IL/2023/C102 Date : 8.03.2021

Name of Applicant : IORF Clean Food Project Team

Address : Ground Floor, 168 Jodhpur park, Kolkata - 700068

Description of sample : Vegetables (18 different types)

Mark on Sample : Approximately 500g each in sealed packed separately and signed by Dr. K. Mukherjee

Sample Received on : 9.1.23 – 20.2.23

Analysis Started on : 10.2.23

Analysis Completed on : 27.2.21

Colorometric Assay test of Pesticide Residues / 1

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm)		Result	
			Visual	Spectro-photometer	Visual	Spectro-photometer
Sample 1: Brinjal						
1.	Organochlorine	Paulini & Rurbaud, 1957	0.05	0.01	BDL	BDL
2.	Organophosphate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
3.	Carbamate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
4.	Neonicotinoid	Nwanisobi & Egbana, 2015	0.05	0.01	BDL	BDL
5.	Synthetic Pyrethroid	Suate et al, 2020, Mahaed E et al 2014	0.05	0.01	BDL	BDL
6.	Phenylpyrazole	Mahaed E et al 2014	0.05	0.01	BDL	BDL
7.	Triazine, Paraquat	Mahaed E et al 2014 Lionetto , 2013	0.05	0.01	BDL	BDL
8.	Heavy metals (Cu, Zn. Hg. As, Cd, Pb)	Mahaed E et al 2014 Frasco et al. 2005	0.05	0.01	BDL	BDL

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Colorometric Assay test of Pesticide Residues / 4

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm)		Result	
			Visual	Spectro-photometer	Visual	Spectro-photometer
Sample 6 : Tomato						
1.	Organochlorine	Paulini & Rurbaud, 1957	0.05	0.01	BDL	BDL
2.	Organophosphate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
3.	Carbamate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
4.	Neonicotinoid	Nwanisobi & Egbana, 2015	0.05	0.01	BDL	BDL
5.	Synthetic Pyrethroid	Suate et al, 2020, Mahaed E et al 2014	0.05	0.01	BDL	BDL
6.	Phenylpyrazole	Mahaed E et al 2014	0.05	0.01	BDL	BDL
7.	Triazine, Paraquat	Mahaed E et al 2014 Lionetto , 2013	0.05	0.01	BDL	BDL
8.	Heavy metals (Cu, Zn. Hg. As, Cd, Pb)	Mahaed E et al 2014 Frasco et al. 2005	0.05	0.01	BDL	BDL
Sample 7: Cucumber						
1.	Organochlorine	Paulini & Rurbaud, 1957	0.05	0.01	BDL	BDL
2.	Organophosphate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
3.	Carbamate	Mahaed E et al 2014	0.05	0.01	BDL	BDL
4.	Neonicotinoid	Nwanisobi & Egbana, 2015	0.05	0.01	BDL	BDL
5.	Synthetic Pyrethroid	Suate et al, 2020, Mahaed E et al 2014	0.05	0.01	BDL	BDL
6.	Phenylpyrazole	Mahaed E et al 2014	0.05	0.01	BDL	BDL
7.	Triazine, Paraquat	Mahaed E et al 2014 Lionetto , 2013	0.05	0.01	BDL	BDL
8.	Heavy metals (Cu, Zn. Hg. As, Cd, Pb)	Mahaed E et al 2014 Frasco et al. 2005	0.05	0.01	BDL	BDL

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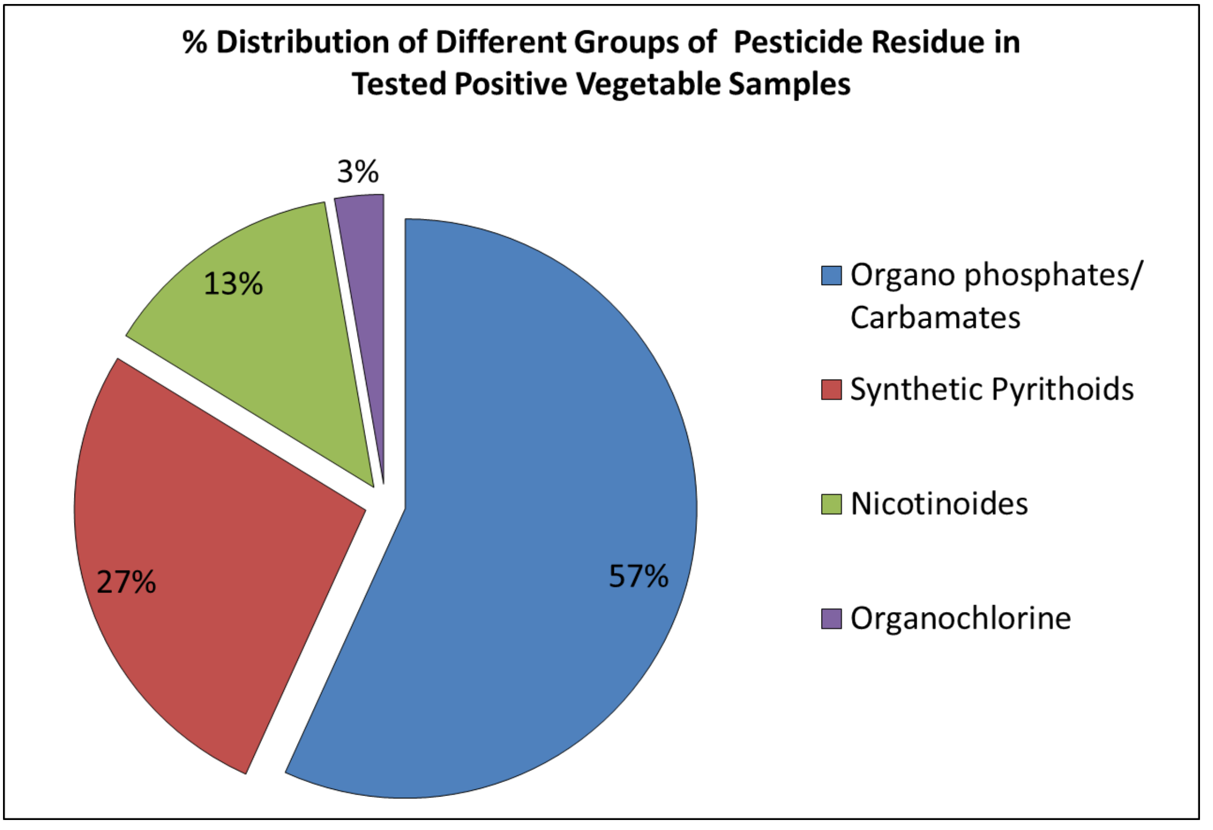
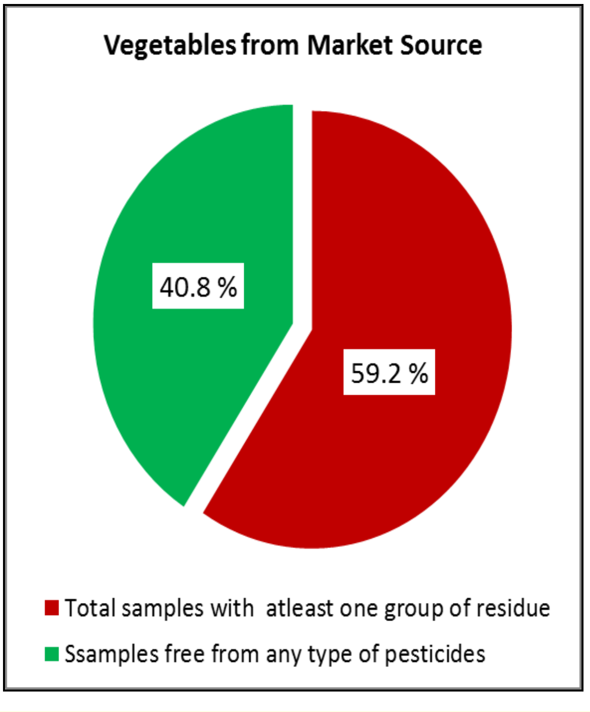


Fig. 1: Comparative presence of different pesticides groups in the vegetables tested positive for pesticide residue



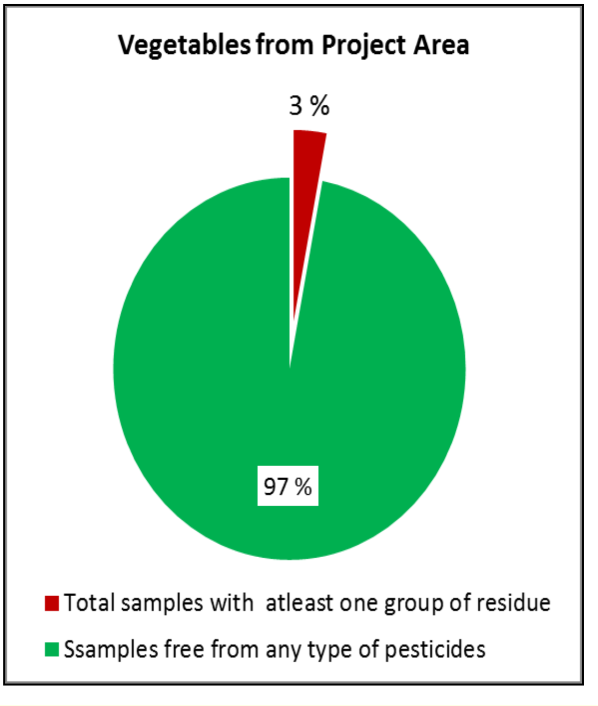


Fig. 2: Percent Vegetable Samples that exceeded Maximum Residue Limit (MRL) w.r.t. at least one pesticide group, as per CODEX ALIMENTARIUS FAO-WHO & FSSAI (> 0.10 ppm) Standards

Colorometric Pesticide Assay Test

Pesticide Residue in Vegetable Samples

92.6 % Reduction in Contamination Risk

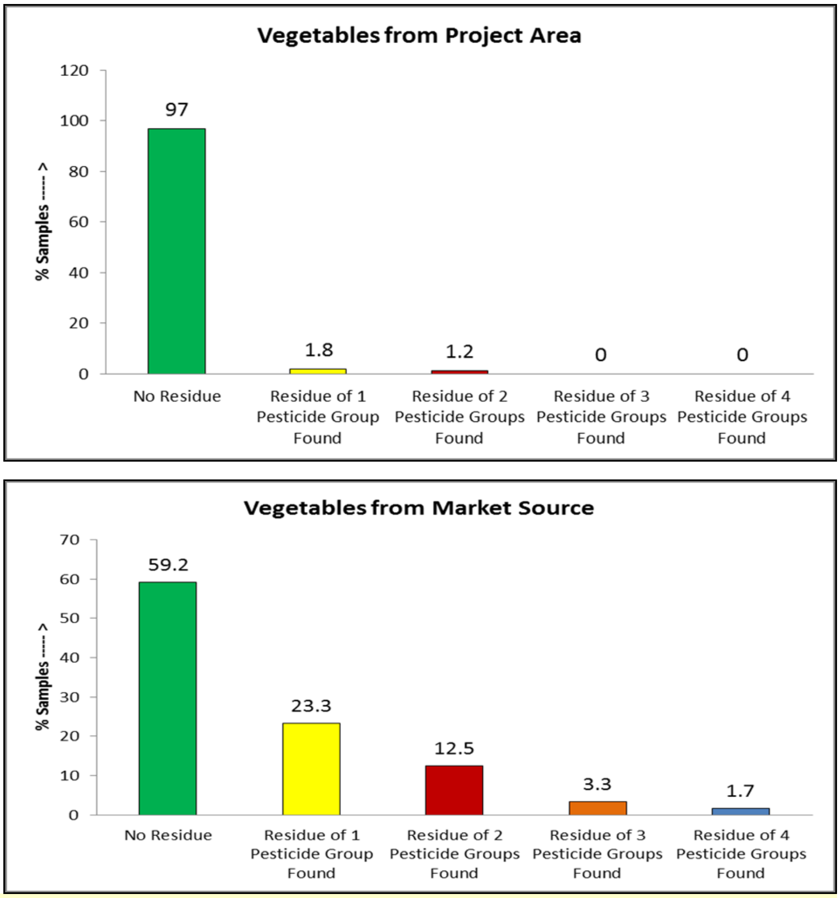


Fig. 3: Comparative study of pesticide residue in conventional vegetables vis-a-vis vegetables grown in the project area.

Pic.: Pesticide Residue Analysis in IORF laboratory.

Conclusion :

In a country like India, the marginal and small farmers with critically fragmented land structure represent >80% of the Agricultural Scenario. In the Project Area these farmers comprise >96% of the total farming community, with a critical land holding size even <0.26 hec. The contrasting high Cropping Intensity, Critical Dependence on Land, and the Constant Threat of Crop Loss especially under the Existential Climate Change; leads to abundant use of agrochemicals, especially where field cops like vegetables are concerned.

This is clearly indicated by the presence of pesticide residue in >40% of the conventional grown vegetables, analyzed using the COLORIMETRIC ASSAY TEST. Pesticide Residue analysis of more than 140 vegetable samples representing 18 different varieties of vegetables, indicated Residue Free Status in 97% of the samples collected from the ‘Clean Food’ Project Area.

Another crucial finding was made in case of crops like **brinjal and pointed gourd**, which have a higher pesticide load **because of long duration (7-8 months) in field**. Under ‘Clean Food’ Program with adoption of IRF Technology, a **considerable reduction of pest pressure was observed even in case of these crops**, **which naturally lowered the requirement for pesticide application.** This was corroborated by the Pesticide Residue Analysis, which revealed **>92.6% Reduction in the Risk of Pesticide Contamination in Food under ‘Clean Food’ Program. The finding conclusively defined the role intensive Plant Health Management under IRF Technology, towards Elimination of the Pesticide Load in agriculture**.

Pic.: ‘Net Zero’ Clean Food Production under IBM-IORF Sustainability Project at Nadia, West Bengal, India

Chapter 2 : Development of Climate Resilient 'NET ZERO' Clean Paddy Seeds in Farmers' Field

Summary

Climate change is threatening food security round the globes, where a large proportion of food is produced by vulnerable smallholder farmers. Looking at climate change impact, relevance of climate resilient seeds enhanced many fold as seed quality plays significant role in success / faliour of any cropping system. In this background, an initiative was taken up to develop climate resilient, **'NET ZERO' Clean Paddy Seed** using Inhana Rational Farming (IRF) Technology through farmers' participatory program during 2022-23 under IBM-IORF Sustainability Project at the Nadia district of West Bengal (India).

The study indicated higher **'NET ZERO' Clean Paddy Seed production (**4021 kg/ ha) in comparison to convention paddy seed production (2850 kg/ ha). Climate resilience of the seeds was evaluated through study of germination under water stress (G_{WS} %), salt stress (G_{SS} %), accelerated ageing (G_{AA}%) and Electrolyte leakage (EC) and significantly higher value was obtained for **'NET ZERO' Clean Paddy Seed.**

Climate Resilience Index (CRI)" which was developed majorly as a function of seed germination under abiotic stress, showed 35.5 % higher value as compared to conventional paddy seeds.

The Need and Relevance of Climate Resilient Seed

Farmers need a genetically diverse portfolio of improved crop seeds varieties suited to a range of agro-ecosystems and farming practices, to improve crop resilience to climatic change impact . Moreover Limited availability of good quality certified seed is a major constraint towards sustainable crop production in India as seed is the basic and most critical input for sustainable agriculture.

Out of the total seeds used by the Indian farmers only 30% are certified/quality seeds. And the present production meets only 20% of the total demand. Apart from climatic adversity, poor quality seed is a prominent cause of crop failure and low productivity in India. At the same time our own seed bank and seed diversity has been greatly affected under chemical agriculture.

Climate smart agriculture as a part of climate change mitigation strategy starts with quality- resilient seeds. The seeds developed under conventional farming are generally high fertilizer responsive hence; they lack the quality traits *viz*. higher nutrient use efficiency, disease resistance and resilience against biotic and abiotic stress, that are required for sustaining crop yields irrespective of the changing climatic patterns. In this context seed produced under organic environment could help out in infusing such quality traits that can enable Better Adaptability against Climate Change and Support Sustainable Agriculture.

It is estimated that the direct contribution of quality seed alone to the total production is about 15–20% depending upon the crop, and it can be further raised up to 45% with efficient management of other inputs. Hence, quality organic seeds can yield plants that are more adaptive of the changing climate and thrive well under organic conditions or in other words ensure sustained crop production irrespective. But the availability of Organic Seed is practically NIL, considering the fact that the farmers usually incur from 30 to 70% Crop Loss during Organic Seed Production.

The paddy crop or rice is one of the chief grains of India and shares a prominent portion of the Indian food bowl. Also, India has the largest area under rice cultivation. At the same time being a C_3 plant, rice is not only 1/3rd Less Photosynthesis Efficient than C_4 plants like maize, wheat etc., the crop performance is severely impacted under minor fluctuations in the weather conditions.

But the most important reason why this crop was selected for 'NET ZERO' Clean Seed production is because it is also one of the most CHALLENGING crops w.r.t. climate change mitigation considering the HIGH WATER and NITROGEN USAGE and HIGH GHG EMISSION POTENTIAL.

Rice is both a victim and a Cause of Climate Change

- ❑ Rice cultivation uses a lot of water, uses 34-43% of the world's irrigation water for production
- ❑ Rice is responsible for up to 10% of global methane emissions
- ❑ Rice fields represent 15% of the world's wetlands
- ❑ Rice farmers are among the world's most vulnerable to climate change impacts such as salinity, temperature rise, drought, erratic rainfall and flooding etc.

In West Bengal almost half of the arable land is under rice cultivation. Moreover, the major rice is grown during the Kharif (rainy) season and is majorly affected by weather fluctuations.

Hence, the crop faces many CHALLENGES such as declining or stagnant yields, lack of water availability, contamination of natural resources due to excessive use of agrochemicals, biodiversity losses, greenhouse gas emissions and losses due to extreme climatic events.

Initiative towards development of 'NET ZERO' CLEAN PADDY SEED

Grown under Complete Organic Management under Inhana Rational Farming Technology *(through Inhana Plant Health Management and utilization of Waste bio-converted Novcom Compost for Inhana Soil Health Management)*

This Better Rice Initiative for Safe & Sustainable Rice Production, was undertaken with the following Objectives

- ❑ **Higher Nutrient Utilization Efficiency** leading to better response under lower dose of synthetic inputs.
- ❑ Can **perform well under low input** as well as organic agriculture.
- ❑ **Higher climate resilience** and therefore better immunity against pests – one of the most important criteria for Safe & Sustainable Rice Cultivation.
- ❑ Most effective pathway to **Prevent Seed Borne Disease problems**.
- ❑ Prerequisite for **Yield Sustainability** under All Type of Growing Conditions.
- ❑ To initiate the concept of community seed development, especially towards **empowerment of the marginal and small farmers.**

Pic. :Application of Novcom compost during final land preparation for cultivation of Climate Resilient 'NET ZERO' Clean Paddy Seeds under IBM-IORF Sustainability Project

Pic.: Seedling treatment before transplantation under IRF Technology for cultivation of Climate Resilient 'NET ZERO' Clean Paddy Seeds under IBM-IORF Sustainability Project

The Phase-I IBM-IORF Sustainability Project, demonstrated the pathway for Safe and Sustainable 'Clean Food' production. Due to lack of authentic organic seeds and complete lack of any seeds in the sustainable category, the same conventional seeds were used for this Safe and Sustainable Program.

But it was recognized that self- sufficiency in SUSTAINABLE SEEDS of diversified crops will be essential to enable Large Scale, Safe and Sustainable Agriculture Progression as well as for Empowerment of Economically Vulnerable, Resource Poor Marginal and Small Farmers.

In this background, a Program was undertaken by Inhana Organic Research Foundation (IORF), in Phase- II Project to develop **'NET ZERO' Clean Paddy Seeds '*Grown under Complete Organic Management under Inhana Rational Farming (IRF) Technology*** **(***through Inhana Plant Health Management and utilization of Waste bio-converted Novcom Compost for Inhana Soil Health Management)*

The program is driven by Inhana Rational Farming (IRF) Technology – a comprehensive Crop Technology for Safe & Sustainable Crop Production that undertakes the dual approach of Plant Health and Soil Health Management. However, since conventional seeds were used for this program hence; a rigorous schedule of 'Plant Health Management' was undertaken to restore the inherent self- nourishment capability of the plant system.

Pic.: Cultivation of Climate Resilient 'NET ZERO' Clean Paddy Seeds under IBM-IORF Sustainability Project at Nadia, West Bengal, India.

The program was initiated with Soil Health Analysis of the Model Farm. **Soil quality was analyzed before main field preparation.**

Table 1 : Evaluation of Soil Quality

Sl. No.	Parameters	Pre	Post
1.	Moisture%	23.22	19.55
2.	pH	6.34	6.03
3.	EC (1:5)	0.05	0.07
4.	Av NO_3	28.36	31.99
5.	Org. C%	0.86	0.82
6.	Av-N	339.00	321.44
7.	Av P_2O_5	180.35	59.60
8.	Av. K_2O	444.51	479.16
9.	Av- SO_4	42.54	8.69
10.	MBC (microgram C/ gm dry soil)	282.18	175.29
11.	RESPIRATION (BR) (mg CO_2 / gm dry soil/ day)	0.13	0.13
12.	FDA (µg/ gm dry soil)	68.10	21.94
13.	SIR (microgram CO_2 / gm dry	7.04	6.68

The soils were mostly Silty clay loam to silt loam in texture. The physical index (PI) value indicated that in terms of soil physical quality, it was good for agricultural crops. Soil pH of the area varied from slightly acidic to neutral (Avg. 6.3), where as soil EC value (0.04) indicated there was no problem of soil salinity. However soil organic carbon is less than 1.0 % indicating poor to very poor status. Status of available- N,P,K,S values indicated moderate available-N, high phosphate and potash and poor sulphate availability. Thus as per Soil Fertility Index (FI), the soils have moderate to moderately high nutrient availability. But evaluation of the microbiologic properties revealed low activity of the soil microflora.

ORGANIC SEED BED PREPARATION: The Seed bed was prepared in 0.01 ha area. After 2 manual harrowing, 300 kgs. Novcom Compost was applied in the seed bed. The land was kept for 7 days and after 3rd harrowing the bed was finally prepared.

MAIN FIELD PREPARATION: During the preparation of main field Novcom Compost @ 5 tons/bigha was applied at the time of 2nd ploughing and Seedling transplantation done about two weeks post compost application. CDS concoction was also applied @ 150 lit/ ha after 1st puddling and final puddling.

The different Stage of Operations towards Development of NET ZERO' Clean Paddy Seeds

Stage 1: Complete Inhana Package for Seed Treatment to Seed Bed Management

DETAILS OF THE INITIAL SEEDS TAKEN FOR THE PROJECT:

Seed variety Satabdi Miniket (IET-4786), also a popular variety in West Bengal was used for the program. Product Purity= 98% (Min), Moisture= 13% (Max), Germination= 80%(Min), Inert Matter= 2% (Max) and Weed Seed=20 no./kg.

SEED TREATMENT: The sourced seeds were treated under IRF Technology. The sourced seeds were kept under Sun for 1.5 hrs. and washed twice thoroughly to remove unproductive seeds. The seeds were soaked in water for 24 hrs. and then for 45 minutes in the water mixed with Inhana Seed Treatment Solution (@ 1.5 ltr solutions for the seeds of 1 ha). After 45 mins. all the seeds were put in a jute bag, the bag mouth was sealed and the bag was stored for 48 hours in a warm place.

Pic.: Roots of the seedlings were emersed in IRF seedling treatment solution before transplanting - Climate Resilient 'NET ZERO' Clean Paddy Seeds Production Program.

Objectives of Seed Treatment

- ✓ Faster Germination.
- ✓ Higher Germination.
- ✓ Higher Energy Reserve.
- ✓ Higher Resource Utilization Potential.
- ✓ Higher Resilience.
- ✓ Higher Response to Lesser or No Synthetic Inputs.
- ✓ Replacement of farmers' seed with improved Quality Seed.

Stage 2: Seedlings Treatment before Transplantation in the main field under IRF Technology

TRANSPLANTATION : The Uprooted **Seedling from Seed Bed was treated** with Inhana Seedling Treatment solutions. Approx. 450 ml. Inhana Seedling Treatment Solution was used for treatment before main field transplanting.

OBJECTIVES OF SEEDLING TREATMENT

- ✓ Enhance root growth for speedy establishment.
- ✓ Higher seedling vigor for speedy growth & higher tiller emergence.
- ✓ Withstand transplanting shock and climatic stress.

PLANT HEALTH MANAGEMENT IN MAIN FIELD

Different Inhana 'Energy' Solutions was applied on the paddy plants post Seedling Transplantation in the main field. Spraying was done at the different plant growth stages, in a scheduled manner.

Inhana Plant Health Management : Spraying done in the main field
IB(AG)1 - 7 days after transplantation
IB(AG)3+IB(AG)5 - 14 days after transplantation
IB(AG)5 - 21 days after transplantation
IB(AG)2 -40 days after transplantation
IB(AG)4+IB(AG)5 - 47 days after transplantation
IB(AG)3 - 57 days after transplantation
IB(AG)2 - 65 days after transplantation
IB(AG)1 - 75 days after transplantation
P5 Concoction was applied before Flowering initiation.

OBJECTIVES

- ✓ Enhancement of Nutrient Utilization Efficiency to enable better response from organic nutritional source.
- ✓ Better photosynthetic efficiency irrespective of any climatic fluctuations.
- ✓ Development of better host- defense mechanism of the plants against disease causing pathogens..

Pic.: Transplanting of paddy seedlings under Climate Resilient ‘NET ZERO’ Clean Paddy Seeds Production Program at Nadia, West Bengal, India.

Pic.: Spraying of Inhana Plant Health Management Solutions under Climate Resilient ‘NET ZERO’ Clean Paddy Seeds Production Program at Nadia, West Bengal, India.

THE DRIVING TECHNOLOGY

The Project is driven by Inhana Rational Farming (IRF) Technology and is based on the hypothesis 'The relationship between a Plant and Pest is Purely Nutritional'. IRF technology has been inducted to drive this very objective considering that it is the only available Crop Technology so far, that undertakes the approach of **'PLANT HEALTH MANAGEMENT'** to activate Plants' Metabolism and Photosynthetic Efficiency in order to curtail the accumulation of ready food source for the pests in the plants' cell sap, **so as to curtail pest infestation and thereby the dependency on chemical pesticides.**

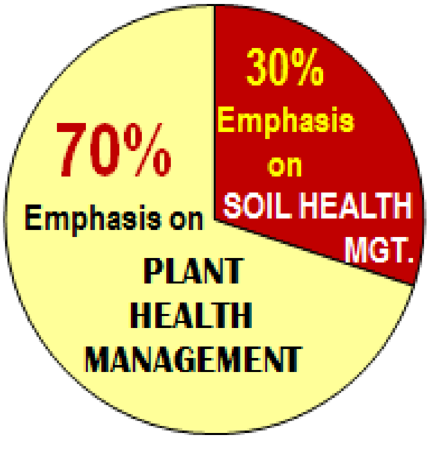
Plant Health Management is the most ignored component in the Conventional System of Crop Production, but this component **ACTUALLY HOLDS THE KEY to Crop Sustainability especially under the Changing Climatic Patterns.**

Hence IRF Technology extends 70% Emphasis on this Component, which is primarily driven by **Inhana 'ENERGY SOLUTIONS'- developed under the Element Energy Activation (E.E.A.) Principle.**

IRF TECHNOLOGY puts MAXIMUM EMPHASIS on PLANT HEALTH MANAGEMENT

PLANT HEALTH MANAGEMENT aims at Activation of Plant Physiology towards Higher Nutrient Utilization Efficiency . . . **FOR YIELD SUSTENANCE**

Higher Nutrient Utilization Efficiency also means formation of Complete Proteins and Complex Carbohydrate . . .i.e., Lesser Pools of Free Amino Acids & Reducing Sugars . . . **IMMUNITY FROM PEST ATTACK**



Activation of Plant Physiology also means enhanced Biochemical Secretions . . .i.e. **BETTER STRUCTURAL & BIOCHEMICAL RESISTANCE against Disease**

Effective Nutrient Management & Pest Management Through Plant Health Management

YIELD PARAMETERS OF PADDY CROP UNDER DIFFERENT MANAGEMENT

The Phase-I, IBM-IORF Sustainability Project had demonstrated the Safe and Sustainable 'Clean Vegetable' production through the intervention of IRF Technology.

Hence, in Phase-II a very detailed Model Farm experiment was laid out to evaluate the impact of **individual role of Inhana Plant Health Management (IPHM) and Inhana Soil Health Management (ISHM) towards Yield Attributes of Paddy Crop, when undertaken at different stages i.e., Seed Bed and/ or Main Field.**

The Different Treatments are as follows :

Control 1 : Inhana Soil Health Management (ISHM) with Inhana Plant Health Management (IPHM) in Seed Bed, ISHM with Conventional crop management in Main field.

Control 2 : ISHM + IPHM in Seedbed and Conventional Soil and Crop management in main field.

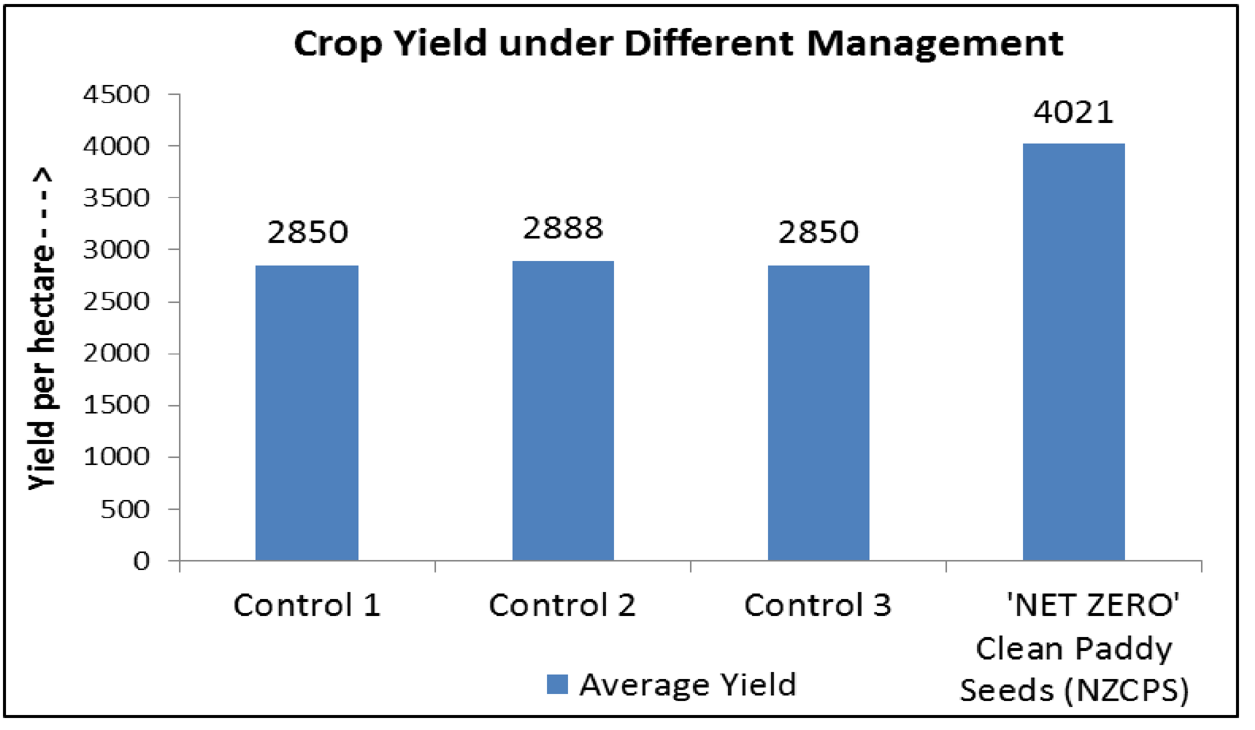
Control 3 : 100% Conventional Management (Fertilizer and Pesticide)

organic soil management which was done through application of on- farm produced waste bio-converted Novcom Compost. **In case of the Control Plots (1, 2 and 3) a similar trend of yield was observed and hovered around 2800-2900 kg/ ha.** The finding gave a very strong indication considering that the commonality amidst all the Control Plots was that they did not receive any IPHM in the Main Field.

Considering that the same HYV *(high fertilizer responsive seeds)* were used for the 'NZ' Clean Paddy Seed Program, better response under Organic management i.e., 100% Fertilizer Reduction and Elimination of Chemical Pesticides **highlights the importance of Plant Health Management towards elevating the nutrient utilization efficiency of the plants to achieve better response under**

Pic.: Agronomic Data generation from field under Climate Resilient 'NET ZERO' Clean Paddy Seeds Production Program.

Yield of Paddy Crop under Different Management



In stark contrast, the average yield of 4021 kg/ ha obtained under **'NZ' Clean Paddy Seed program** exclusively demonstrated the relevance of **Inhana Plant Health Management** towards not only yield sustenance, rather yield improvement, especially significant, because this was obtained overcoming the extreme climatic events that occurred during the tillering and seed setting phase.

Pic.: Cultivation of Climate Resilient 'NET ZERO' Clean Paddy Seeds under IBM-IORF Sustainability Project at Nadia, West Bengal, India.

Quality Analysis of 'NET ZERO' (NZ) Clean Paddy Seeds

Availability of quality seeds at affordable prices and appropriate to different agro-climatic conditions is a prime requirement for **large scale safe and sustainable crop production**. Quality evaluation of the paddy seeds developed under IBM-IORF Sustainability project (Phase-II) was undertaken to assess the impact of IRF Technology towards the Seed Quality attributes.

Table 2: Evaluation of 'NZ' Clean Paddy Seeds as per Indian Seed Certification Standards

SEED QUALITY	Indian Seed Certification Standards for each Class		'Net Zero' Clean Paddy Seed developed under IRF Technology
	Foundation	Certified	Miniket (IET- 4786)
Pure seed (min.)	98.0%	98.0%	**99.85 %**
Inert matter (max.)	2.0%	2.0%	**0.15 %**
Huskless seeds (max.)	2.0%	2.0%	**No**
Other crop seeds (max.)	10/kg	20/kg	**No**
Total Weed seeds (max.)	10/kg	20/kg	**No**
Germination (min.)	80%	80%	**92 %**
Moisture (max.)	13.0%	13.0%	**9.32**

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

Germination capacity of a seed lot refers to the capacity of the seeds in that lot to germinate normally and produce all parts of a healthy seedling and growth thereafter. Sowing good quality seeds leads to lower seed rate, better emergence (>70%), more uniformity, less replanting, and vigorous early growth; which helps to increase resistance to insects and diseases, and decrease weeds. As a result, yield can increase by 5–20%. **The germination rate of the developed seeds was found to be 92% on an average, indicating a high seed viability.**

It is necessary to maintain correct moisture content of the seeds because those with high moisture content lose their germination vigour and viability within a short period of time. it may be noted that **1% decrease in seed moisture content doubles the storage life of the seed**.

Moisture maintenance is also essential to protect the seeds from pest infestation and attack by diseases. A slower rate of seed respiration results in a slower rate of deterioration. Hence, proper drying of the seed is critical for minimizing deterioration during storage. **Moisture percent in the developed paddy seeds was found to be within the safe moisture level as per standard reference for Foundation as well as Certified seeds**

Table 3 : 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
Control (Average)	90	95	11.76	687.6	0.29	70.00	85.00	86.70	0.034
Conventional Paddy Seeds (Farmers' Practice)	85	86.70	11.96	656.2	0.28	75.00	83.50	95	0.033
'NZ' Clean Paddy Seeds	93	98.35	13.56	729.12	0.31	80.00	90.00	98.35	0.030

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*

SEED VIABILITY was tested through Tetrazolium test to study the degree of activity of the dehydrogenase enzyme system closely related to seed respiration and viability (Sharma, 2018). Seed viability test value for 'NZ' Clean Paddy Seeds was highest (98.4 average) indicating their high quality as compared to the control and conventional counterpart.

SEED VIGOUR (SV-I & SV-II): Seed Vigour is best described by the German word "Triebkraft" meaning "Driving Force", which determines post germination seedling survival and performance. The term is defined by ISTA as 'the sum total of those properties of the seed which determine the level of activity and performance of the seed of seed lot during germination and seedling emergence'.

Pic.: Harvesting of paddy seedlings under Climate Resilient ‘NET ZERO’ Clean Paddy Seeds Production Program at Nadia, West Bengal, India.

Development of Climate Resilient ‘NET ZERO’ Clean Paddy Seeds (Varity : Satabdi Miniket IET-4786), under IBM-IORF Sustainability Project at Nadia, West Bengal, India.

As the germination test is conducted in an optimum condition specific to different species, it is not always possible to get an idea of the performance of a seed lot in the field on the basis of germination test in the laboratory. It is mainly because of the reason that field conditions are seldom optimum and the emerging seedling suffers from one or the other kind of stress. Hence, in many cases seed lots having similar laboratory germinations may give widely differing field emergence values.

Seeds which perform well are termed 'high vigour' seeds (Perry, 1978). SV-I is calculated by determining the germination percentage and seedling length of the same seed lot while SV-II is calculated by determining the germination percentage and dry weight of the seedling of the same seed lot . The test values both in terms of SV-I and SV-II were higher in the case of **'NZ' Clean Paddy Seeds, which confirmed them as 'high Vigour' seeds.**

GERMINATION UNDER WATER STRESS (Gws%) AND SALT STRESS (G_{SS} %) : Another major constraint to seed germination and seedling establishment is waster stress (both in case of excessive moisture or moisture stress) and soil salinity, which are the critical limiting factors in crop production. In case of all the seed lots, germination potential was found to reduce considerably under water stress and salt stress, but the reduction was significantly lower for **'NZ' Clean paddy Seeds which indicated their higher resilience to un-favourable conditions as compared to conventional seeds**.

Table 4: G_{WS} or Germination under Water Stress (under different induced osmotic potential)

Manitol (Water Stress)	Control	Percent Reduction in Germination Potential with increase in Osmotic Potential	Conventional Farmers' practice	Percent Reduction in Germination Potential with increase in Osmotic Potential	'NZ' Clean Paddy Seeds	Percent Reduction in Germination Potential with increase in Osmotic Potential
Control	90	-	95	-	100	-
$0.3\Psi_0$	85.00	5.56	70.00	26.32	88.00	12.00
$0.6\Psi_0$	80.00	5.88	70.00	0.00	75.00	14.77
$1.2\Psi_0$	10.00	87.50	45.00	35.71	45.00	40.00

GERMINATION UNDER ACCELERATED AGEING (G_{AA}%) : This test is used to determine the storage and seedling field emergence potential of seed lots. The germination potential of seeds naturally decrease with increase in seed age. However, this decrease will be definitely slower in the case of robust seeds.

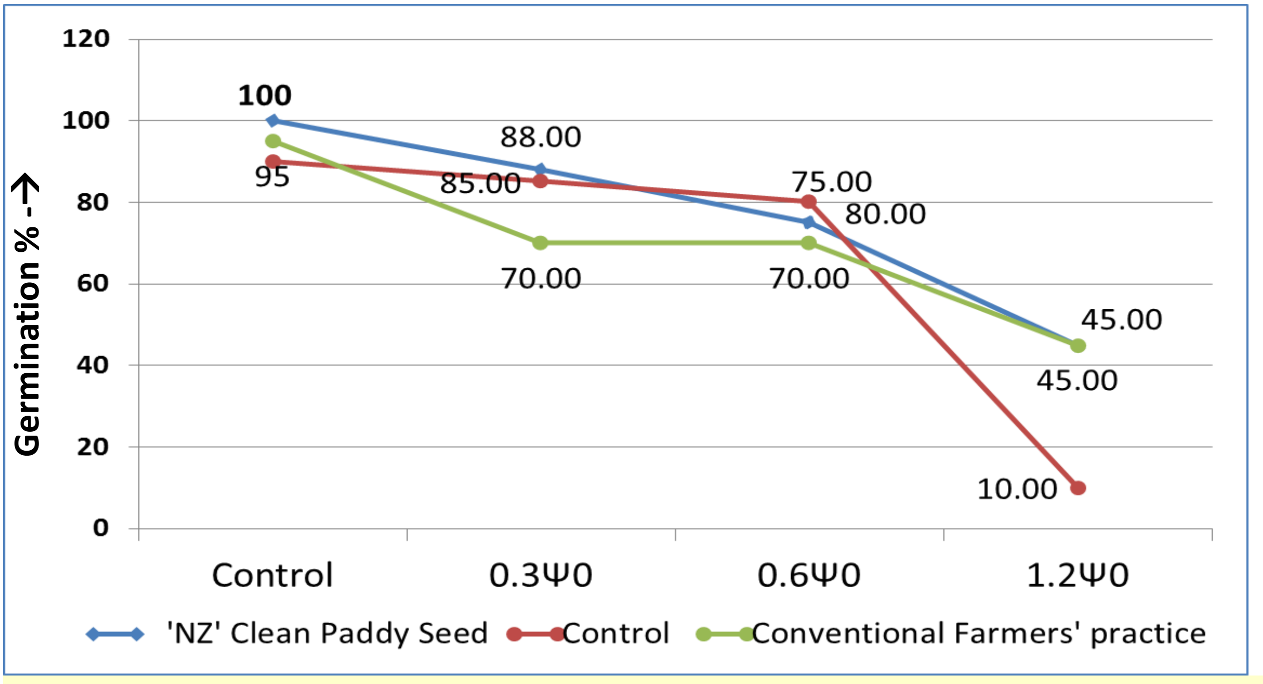


Fig. 1: Comparative germination potential of Net Zero Clean Paddy Seeds under different levels of water stress

Under accelerated ageing, germination potential decreased in the case of both 'NZ' Clean Paddy Seeds, Control and Conventional seeds, though the extent of reduction was not as high as that documented under water stress and salt stress tests. **However, following a trend similar to previous tests; the 'NZ' Clean Paddy Seeds showed superior performance as compared to the conventional seeds.**

Some studies indicate that membrane lipid peroxidation is one of the major causes of seed ageing under accelerated ageing conditions. However , **healthy plants contain numerous antioxidant compounds, both enzymatic and non-enzymatic, which act to prevent oxidative damage by the scavenging free radicals** before they attack membranes or other seed components. **The G_{AA} test values confirmed that the 'NZ' Clean Paddy Seeds embodied the potentials of a 'Healthy Plant'.**

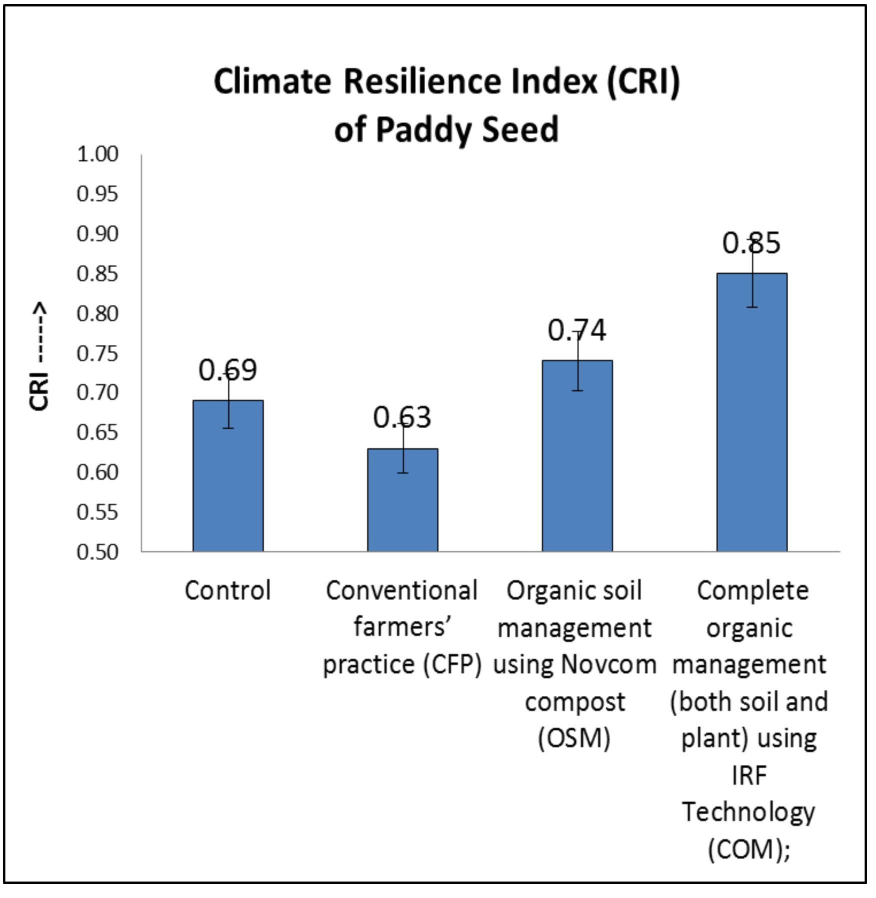
Electrical Conductivity (EC): The principle of the EC test is that, less vigorous or more deteriorated seeds show a lower speed of cell membrane repair during seed water uptake for germination and therefore release greater amounts of solutes to the external environment. The loss of leachate includes sugars, amino acids, fatty acids, proteins, enzymes, and inorganic ions (K^{+2}, Ca^{+2}, Mg^{+2} , Na^{+2}, Mn^{+2}). Hence, the EC test evaluates the amount of ion leakage.

The study showed significantly higher value (up to 31.3 %) in the case of conventional seeds as compared to 'NZ' Clean Paddy Seeds which indicated higher potential of the latter to fight against adverse field conditions.

QUALITY (RESILIENT) SEEDS are the primary requirement for **SAFE & SUSTAINABLE AGRICULTURE.** In this respect the Seed Vigour Test that defines seed ability to germinate and establish seedlings rapidly, uniformly, and robustly across diverse environmental conditions; forms a crucial indicator.

The test results conclusively indicate **'NZ' Clean Paddy Seeds** (*developed under IRF technology*), **as 'High Vigour' seeds, which indicates their potential to enhance the critical and yield-defining stage of crop establishment** - the primary objective of Safe & Sustainable Agriculture

"CLIMATE RESILIENCE INDEX (CRI)"



"Climate Resilience Index (CRI)" which was developed majorly as a function of seed germination under abiotic stress, showed 35.5 % and 14.6 % higher value in case of the 'NZ' Clean Paddy seeds (COM) as compared to CFP and OSM respectively. The overall better performance of 'NZ' Clean Paddy seeds critically indicates that **the concept of "feed the soil" for sustainable organic farming does not hold true till focus is generated towards "PLANT HEALTH MANAGEMENT".**

ATTRIBUTES OF 'NET ZERO' CLEAN PADDY SEEDS

- ✓ **Climate Resilient Seed**
- ✓ **ZERO CO_2 Footprint Seed**
- ✓ **Zero Pesticide Foot print Seed**
- ✓ **Seed with Zero Seed borne Diseases**
- ✓ **Seed with Higher Germination Potential**
- ✓ **Biotic & Abiotic Stress Resistant Seed**
- ✓ **Seed with Higher Nutrient Utilization Potential**
- ✓ **Seed with 25% Lower Requirement than conventional seeds**

The **'NET ZERO' Clean Paddy Seeds developed under West Bengal Project w**as provided to the **Project Farmers of Phase-II, IBM-IORF Sustainability Project at Mandya (Karnataka)** and it is for the **First Time in the Indian Agricultural Scenario that Safe & Sustainable 'Climate Resilient' Seeds has been used for Safe and Sustainable 'NET ZERO' Clean Paddy production** (winter crop) at Mandya (Karnataka)**, through the utilization of Novcom Coir-pith Compost.**

Farmers program conducted under IBM-IORF sustainability Project towards distribution of Net Zero Clean Paddy Seeds among the project farmers at Nadia, West Bengal, India.

Chapter 3 : Development of Climate Resilient 'NET ZERO' Clean Vegetable Seeds & Oilseed under Complete Organic Management

Summary

Climate-resilient crops and crop varieties have been recommended as a way for farmers to cope with or adapt to climate change, but availability of climate resilient vegetable seeds are rare in India if not totally unavailable. In the present study under IBM-IORF Sustainable project, we initiated a program towards development of climate resilient vegetable seeds in farmers' field with adoption of Inhana Rational Farming (IRF) Technology. We selected 12 different open pollinated vegetable varieties *viz.* Brinjal, Chilli, Okra, Tomato, Green peas, Cauliflower, Carrot, Red amaranth, Cabbage, French bean, Spinach, Potato and one oilseed variety – Mustard; in the 1st phase of the seed developmental program.

Till the time of report, we have completed documentation of the seed yield data of eight vegetables *viz.* Okra (1278 kg/ha), Tomato (214 kg/ha), Green peas (272 kg/ha), Red amaranth (1620 kg/ha), Spinach (3618 kg/ha), Bean (5255 kg/ha) and potato (29.49 ton) and oilseed - mustard (528 kg). Seed quality in terms of germination, seed vigour and climate resilience are in the process which will be documented in the 3rd year activity report.

The Need of climate resilient seed

Organic or sustainable crop production is the need of the day for agricultural sustainability as well as to mitigate the increasing risk of food chain contamination due to synthetic pesticides. The risk increases under the climate change impact and conventional farming has practically no answer towards meeting the safe and sustainable objectives. However shifting over from the conventional farming practice to nature friendly, sustainable crop production is not easy. It needs a great effort starting from suitable technological intervention to efficient resource utilization along with market support. However, the most important thing to start with is 'Quality Seeds' which can perform under low input environment and show resilience towards biotic and abiotic stress factors. Furthermore, adaptation is the key for achieving resilience in our food and agricultural system. Adapting seed to changing climates, resource availability, and environmental conditions is one way to mitigate risks for farmers and the food supply they serve.

It is estimated that more than 95% of organic/ low input agriculture is dependent on seeds varieties that were bred for the conventional high input sector. Recent findings have sown that such varieties lack important traits required under organic and low –input production system, which have major importance towards climate change mitigation strategies (van Bueren, 2011). A range of breeding goal desired for the climate resilient agriculture such as reduce reliance on inorganic N-inputs, higher nutrient use efficiency, greater resistance against diseases as well as other biotic and abiotic stress; are severely compromised under the conventional high input dependent seed development program (Lueck, 2006). Especially the vegetable crops are highly sensitive to climatic vagaries, where sudden rise in temperature or irregular precipitation at any phase of crop cycle can affect growth, flowering, pollination and fruit development, which may subsequently lower the crop yield (Afroza *et al.*, 2010). To mitigate the adverse impact of climate change on the productivity and quality of vegetable crops there is need to develop sound adaptation strategies (Spaldon, 2015).

At the same time, organic seed development can reduce agriculture's reliance on a seed industry based on proprietary control and chemical-intensive farms leading to . Organic seed systems – when viewed as an alternative to the dominant seed system – can help address bigger problems in agriculture. Expanding organic seed systems can also increase economic opportunities for farmers who successfully produce organic seed on their farm. The economic benefits include selling organic seed commercially, becoming more seed self-sufficient and reducing input costs, and reducing financial risks by having seed that's better adapted to their farm. Farmer involvement decentralizes how organic seed is bred, produced, and distributed, and expands the diversity of seed grown and available (Hubbard and Zystro 2016).).

Development of Net Zero Okra Seeds at Model Plot, Nadia, West Bengal under IBM-IORF Sustainability Project

VEGETABLE SEEDS – The Indian Scenario

Limited availability of good quality certified seed is a major constraint towards sustainable crop production in India. Out of the total seeds used by the Indian Farmers only 30% are certified/ quality seeds. **In respect of vegetable seeds, only 50% of the national demand is met by domestic production (Shrestha and Dhakal, 2020).**

Although vegetable production in India has increased (187.47 mt) with time but shrinking land resources (10.43 mha) and increasing environmental challenges have made the development and use of quality seeds more important to meet the increasing demand of vegetables by Indian populace (NHB 2018-19, 1st advance estimate).

Quality seed alone can enhance the total production about 15–20% and it can be raised up to 45% with effective management of other inputs (seednet.gov.in and Ali 2016). **But the irony is that the vegetable growers of India do not get quality vegetable seeds at proper time in spite of readiness to spend considerable money.**

OILSEEDS – The Indian Scenario

India is the 4th largest oilseeds producer in the world. It has 20.8% of the total area under cultivation globally, accounting for 10% of global production. The country produces groundnut, soybean, sunflower, sesamum, niger seed, mustard and safflower oilseeds. The self-sufficiency in oilseeds attained through "Yellow Revolution" during early 1990's, could not be sustained beyond a short period.

This is because, nearly 72% of the oilseeds area is restricted to rain fed farming, and is mostly grown by the small and marginal land holders, which makes it difficult for them to adopt modern farming techniques for improving productivity. Moreover, as oilseed productivity is greatly dependent on the environmental factors, hence; the existential climate change has been also adversely affecting oilseed production.

The present scenario calls for a Sustainable Pathway for oilseed Production, that can deliver; climate resilient seeds with higher nutrient utilization efficiency for ensuring higher productivity especially under low input system.

Initiative towards development of 'NET ZERO' CLEAN VEGETABLE SEED & OILSEED

In this background, an initiative was undertaken to develop climate resilient, 'Net Zero' Clean Vegetable Seeds and Oilseed under IBM-IORF Sustainability Project (2022-23) in the Nadia district of West Bengal (India), through '**Complete Elimination of Pesticides and 100% Reduction of N-fertilizers**' under complete Organic Management (through Inhana Plant Health Management and utilization of Waste bio-converted Novcom Compost for Inhana Soil Health Management).

The **objective was to evaluate the crop yield vis-à-vis seed yield under organic management with the adoption of "Inhana Rational Farming (IRF) Technology**".

"Inhana Rational Farming (IRF) Technology" is a complete organic package of practice that ensures ecologically and economically sustainable crop production through its unique approaches of Soil and Plant Health Management. The technology (*developed by Dr. P. Das Biswas, scientist and pioneer of sustainable organic tea cultivation in India*), which is based on the "Element Energy Activation (EEA)" Principle, strives to regenerate the soil and reactivate the plant physiology. The Inhana 'Energy Solutions' are the primary drivers of the dual approaches under this technology.

Twelve different types of vegetables and mustard were selected for the seed development program.

Table 1 : Crop wise Seed Variety taken under the Program

Crop		Seed Variety
BRINJAL	:	Tara BWX, DEB - 721
CHILLI	:	Bullet, DEB - 1301
OKRA	:	Deb Swarna, DEB - 411
TOMATO	:	Kashi Aman, DEB- 2929
GREEN PEAS	:	Local (farmer's own seeds)
CAULIFLOWER	:	Sakama -60, DEB 1113
CARROT	:	Deb kunda, imported, DEB - 1001
RED AMARANTH	:	Lal Kanaka, DEB - 2603
CABBAGE	:	Golden Acre, DEB - 802
BEANS	:	Arjun PG, DEB-207
SPINACH	:	Pusa Bharati, DEB - 1905
Onion	:	Leader, DEB - 1807
Mustard	:	Farmers' own seed

Pic.: Development of Net Zero Tomato and Chilli Seeds at Model Plot, Nadia, West Bengal under IBM-IORF Sustainability Project

Pic.: Development of Net Zero cauliflower Seeds at Model Plot, Nadia, West Bengal under IBM-IORF Sustainability Project

SEED SOWING DETAILS

Direct Sowing in field

i. Spinach
ii. Red Amaranth
iii. Green peas
iv. Onion
v. Mustard

Sowing in Raised Bed

i. Cauliflower
ii. Cabbage
iii. Tomato
iv. Brinjal
v. Chilli
vi. Beans
vii. Okra
viii. Carrot

About 300 kg Novcom Compost was applied in the raised seed bed (about 0.007 ha).

Table 2 : Productivity of Vegetables & Oilseed under CF 'NET ZERO' Program

Crop		Clean Food 'NET ZERO' Yield (Tonne/ ha)	'NET ZERO' Clean Seed Yield (Tonne/ ha)
BRINJAL	:	29.12	Process Ongoing
CHILLI	:	18.28	Process Ongoing
OKRA	:	17.90	1.278
TOMATO	:	32.09	0.214
GREEN PEAS	:	10.52	0.272
CAULIFLOWER	:	30.24	Process Ongoing
CARROT	:	12.96	Process Ongoing
RED AMARANTH	:	16.20	1.62
CABBAGE	:	22.22	Process Ongoing
BEANS	:	16.42	5.255
SPINACH	:	36.18	3.618
ONION	:	9.80	Process Ongoing
MUSTARD	:	0.528	0.528

EVALUATION OF CROP YIELD ATTRIBUTES

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 CFNZ program was higher than the average productivity of the same under conventional farmers' practice. **The yield increase under CFNZ varied from 10-15% on an average. But the result is stupendous** considering the fact these crops were grown under complete organic management utilizing IRF Technology. The results are also exemplary considering that these were short duration vegetable crops, where balanced nutrition is a primary requirement under specific growth phases ; and any mismatch at any stage can lead to severe yield reduction.

The findings completely nullifies the general myth of crop loss under sustainable/ organic crop production systems especially in the initial years and **indicates the relevance of an effective and sustainable crop technology in this respect.**

This initiative could be a benchmark for sustainable/ organic management of the vegetables and the technological advancement under this project gains special relevance especially for the vegetable growing zones of our country, which are usually one of the high agrochemical using zones, that face enhanced risk of soil deterioration and ecological disruptions.

EVALUATION OF SEED YIELD

Seed productivity, is the single most important criteria for economic viability. But seed Development Program is a complicated exercise considering the longer residence time of the crop in the field, which increases the challenges in respect of any sudden climatic disruptions as well as chances of pest and disease infestation, **both of which can cause extensive crop loss**. **This is primarily the reason why only a small percentage of the vegetable growers actually undertake seed production.**

The fact that the 'Net Zero' Clean Seeds were developed under Complete organic Management i.e., without using any Chemical fertilizer and chemical pesticides; and in the farmers' field, without any specific seclusion from the surrounding fields, with sustained yield; clearly points out the relevance of 'Plant Health Management'.

The program conclusively highlights the relevance of a Science based, Effective and Sustainable Crop Technology, and Effective Organic Soil Management towards mitigation of all the challenges and etches out a Pathway for production of Climate Resilient, Safe and Quality Seeds that are prerequisite for scaling up Safe and Sustainable/ Organic Crop Production.

Pic.: Development of Net Zero Red Amaranthus and Green Pea Seeds at Model Plot, Nadia, West Bengal under IBM-IORF Sustainability Project

Pic.: Development of Net Zero Mustard Seeds at Model Plot, Nadia, West Bengal under IBM-IORF Sustainability Project

Development of Climate Resilient 'NET ZERO' Clean POTATO Seeds under Complete Organic Management

THE NEED of Climate Resilient Potato Seeds.

Potato is one of the most important food crop in West Bengal, ranked 2nd position after U.P. The state contributes About 28 % of the national production. But there has been an increasing susceptibility of this crop towards climate change even leading to crop failure.

Potato suffers from many fungal diseases, among them early blight, is a major problem in India especially in West Bengal. As a result, the full potential of this crop is far from being exploited due to several biotic and abiotic stresses. Hence, there is a huge scope of improving the productivity and utilization of non – productive area. Moreover qualitative enhancement can significantly increase the cost benefit ratio.

But to ensure the desired objectives a Safe and Sustainable pathway for potato production will be crucial and in this respect quality- climate resilient and disease free potato seeds are the prime requirement.

Pic.: Development of Net Zero Potato Seeds at Model Plot, Nadia, West Bengal under IBM-IORF Sustainability Project

Initiative towards development of 'NET ZERO' CLEAN POTATO SEED

In this background, an initiative was undertaken to develop climate resilient, 'Net Zero' Clean Potato Seeds under IBM-IORF Sustainability Project (2022-23) in about 0.13 ha area in the Nadia district of West Bengal (India), through '**Complete Elimination of Pesticides and 100% Reduction of N-fertilizers**'. Complete Organic Management was adopted for this program through Inhana Plant Health Management and utilization of Waste bio-converted Novcom Compost for Inhana Soil Health Management.

Evaluation of Potato Crop Yield & Seed Yield

Both Potato Crop & Seed Potato Yield was recorded from the Project Plot. The Comparative evaluation of Potato Crop Yield has been done for Potato developed under Clean Food 'NET ZERO' Program vs. Conventional Farmers' Practice.

Attributes		Seed Production under Conventional Farmers' Practice	Potato under Clean Food 'NET ZERO' Program
Crop Yield (ton/ ha)	:	23.54	33.33
Percent Higher Yield over Conventional Farmers' Practice	:	-	**42.0**
Seed Potato Yield (ton/ ha)	:	-	**16.99**

Some Potato Seed Facts from the Project Area

- Though under Conventional Farmers' Practice potato yield is recorded as 23.54 ton/ ha, the effective yield was 20.23 tons/ha. (balance was rejected/wastage). The farmers under conventional practice experienced higher percentage of wastage which is about 14% of total production.
- The farmers were expecting a higher crop production this year considering that there was insignificant incidence of pest and disease. But in actuals, there was higher percent of wastage, probably due to higher temperature during the final growth phase of the tuber.
- Under IRF Technology the waste was much less , about 11% that also due to a very high standard followed for seed selection .
- **About 42% Higher Yield was obtained under 'Net Zero' Clean Potato Program, as compared to Conventional Farmers' Practice.**
- In case of the potatoes produced under Clean Food 'Net Zero' program i.e. under Complete Organic Management following Inhana Rational Farming (IRF) Technology; a very high standard was maintained for seed selection, so much so that the potatoes rejected (*during the seed selection process*) still complied the general set standards and could be sold as table potato, with a 50% return value.

Chapter 4 : Soil- Site Suitability Evaluation of Major Crops

Summary

The primary objectives of soil site suitability evaluation is to predict the potential and limitation of land for crop production. It is essential to select crops for cultivation according to the soil suitability, so that maximum profit may be achieved while maintaining the ecological sustainability. Under IBM-IORF Sustainability Project, soil site suitability of 12 major vegetable and horticulture crops were evaluated.

Percent area under highly to moderate suitable for different crops were as follows: Paddy (34 % area), Potato (23 % area), Tomato (39 % area), Bean (40 % area), Chilli (100 % area), Carrot (40 % area), Green peas (40 % area), Onion (37 % area), Cabbage (100 % area), Banana (34 % area), Guava (18 % area) and Papaya (20 % area), However with enhancement of soil fertility , soil site suitability can be enhanced to a significant extent.

Introduction

Productivity of a particular crop depends on land resources and the climate of the area. The inherent ability of soils to supply nutrients for crop growth and maintenance of soil physical conditions to optimize crop yields is the most important component of soil fertility that virtually determines the productivity of agricultural system (Jayasree, 2022). So, identification of crop requirements and matching them with the resource available to optimize the productivity in a sustainable manner assumes a greater importance as the present level of productivity of most of the crops has either reached the plateau or has started declining.

Also, crop response to a specific soil property may vary widely with respect to individual crop type and therefore requires crop-wise soil-site suitability evaluation, to adjudge suitable cropping options for an area (Reza et al, 2021). This in turn guides the administrators and policy makers for formulating timely decision for movement of agricultural inputs and prediction of crop production (Naidu et al, 2006).

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Hence, Soil - site suitability evaluation is the pre-requisite for land use planning (Sys et al., 1993), besides this evaluation also determines the potentialities of soils for alternative uses. Also as soil- site suitability evaluation clearly indicates the nature of constraints that hamper optimal production, scope remains for taking up proper reclamation and management of natural resources within the selected land use framework (Varheye, 1993).

Hence, from agricultural point of view, it helps in identifying the suitability of soils to produce different crops on a sustainable basis without degradation of the land. This might prove to be extremely useful in cases where land occupation and or land tenure problems might become a conflicting issue or where environmental rules might seriously restrict land use opportunities.

Clean Potato Cultivation under IBM-IORF Sustainability Project at Nadia, West Bengal, India

The importance of soil- site suitability evaluation has grown multifold considering the continuous depletion of soil as a resource under conventional agricultural practice. Hence, farm level evaluation has become crucial in order to assess the role of present soil quality towards supporting the on- going cropping pattern especially under the present climate change impact.

Soil- site suitability of major crops was undertaken in the IBM-IORF sustainability Project (Phase– II), to assess whether the presently grown crops are appropriate for the area, and to ensure that the land use plan adopted by the farmers provides better economic returns and livelihood sustenance, under the existential climate change impact.

Soil site suitability evaluation was carried out following the criteria outlined by FAO [4], Sys et al (1993) and Naidu et al. (2005). The FAO framework involves formulation of climatic and soil-site criteria to meet the requirement of crops and rating of these parameters for **highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable (N) classes**. These were matched with existing land qualities to arrive at a specific suitability class.

Soil-site suitability of major crops viz., wet season paddy, potato, cabbage, chilli, tomato, carrot, beans, onion, green peas, banana, guava and papaya were evaluated in the study area on a 10 ha grid basis. The potential land suitability sub-classes were also determined after considering the improvement measures to correct these limitations (Sys et al. 1991). The following Subclasses have been defined as : climate limitation (c), topography limitation (t), wetness limitation (w), salinity limitation (n), soil fertility limitation (f) and physical soil limitation (influencing soil/water relationship, (s))

Clean Cabbage Cultivation under IBM-IORF Sustainability Project at Nadia, West Bengal, India

Soil- site Suitability Evaluation of Paddy

In West Bengal agrarian scenario, cropping pattern is dominated by paddy (Rahim et al., 2011). Rice is one of the major crops of this state, and it contributes highest proportion to the rice production of India (about 14 %). Paddy covered almost 55.63 per cent of the total cropped area of the state (Das and Kumar, 2018) and wet Season Paddy production in 2020-21 crop year was recorded about 13.3 million ton.

In the study area in the monsoon season wetland paddy is cultivated in almost all the area under lowland and midland and about 40 % area of upland. As per the soil site suitability study about 62 % area is marginally suitable (S3) for this crop followed by moderate suitability (S2) in about 36 % area while only 2 percent area is under highly suitable (S1) category. However the major limitation was fertility or more precisely soil organic carbon and with correction of this single factor, more than 98 % area can be brought under highly (S1) to moderately (S2) suitable category.

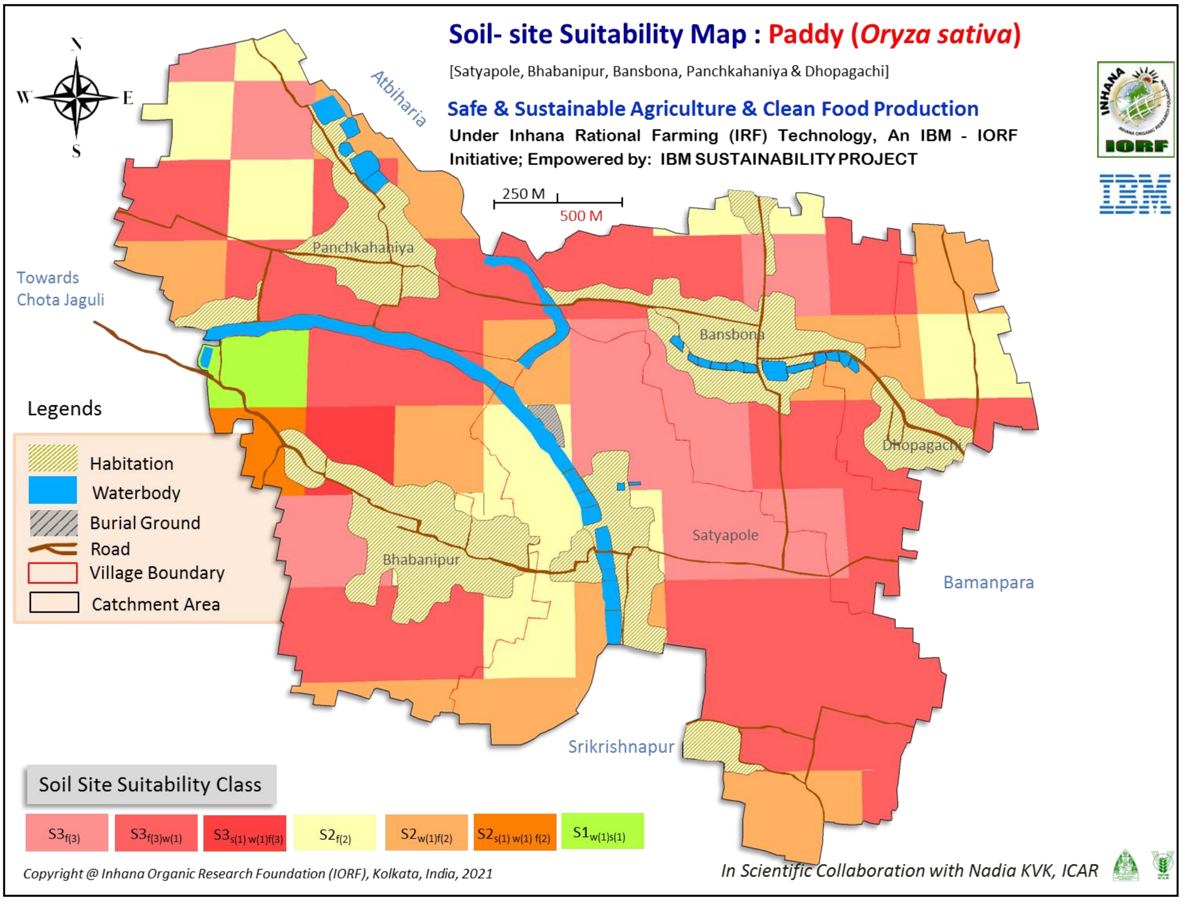
Soil- site Suitability Evaluation of Potato

Potato (Solanum tuberosum L.) has emerged as the fourth most important food crop in India after rice, wheat and maize (Ojha & Saha, 2014); sharing 20.32 million ha area with an average production of 46.61 million metric tons.

In West Bengal, potato is the most popular crop after paddy due to its high production and high return potential. Area under potato in West Bengal is 4.2 lakh hectares and production is 127 lakh tonnes. It is the second largest potato producing state in the country after Uttar Pradesh.

In the study area, potato is one of the important cash crop and a significant area is sown with potato every year. As per the soil- site suitability study about 77 % area was marginally suitable (S3) for this crop followed by about 17 % area under moderately suitable (S2) category and only 6 percent area under highly suitable (S1) category.

However with correction of soil fertility, about 34% area can be upgraded to the highly suitable (S1) category while about 66 % area can be brought under moderately suitable (S2) class.



Soil- site Suitability Map : Paddy (Oryza sativa)
[Satyapole, Bhabanipur, Bansbona, Panchkahaniya & Dhopagachi]
Safe & Sustainable Agriculture & Clean Food Production
Under Inhana Rational Farming (IRF) Technology, An IBM - IORF Initiative; Empowered by: IBM SUSTAINABILITY PROJECT
N
W
E
S
Atbiharia
250 M
500 M
Panchkahaniya
Towards Chota Jaguli
Bansbona
Dhopagachi
Satyapole
Bhabanipur
Bamanpara
Srikrishnapur
Legends
Habitation
Waterbody
Burial Ground
Road
Village Boundary
Catchment Area
Soil Site Suitability Class
$S3_{f(3)}$
$S3_{f(3)w(1)}$
$S3_{s(1)\,w(1)f(3)}$
$S2_{f(2)}$
$S2_{w(1)f(2)}$
$S2_{s(1)\,w(1)\,f(2)}$
$S1_{w(1)s(1)}$
Copyright @ Inhana Organic Research Foundation (IORF), Kolkata, India, 2021
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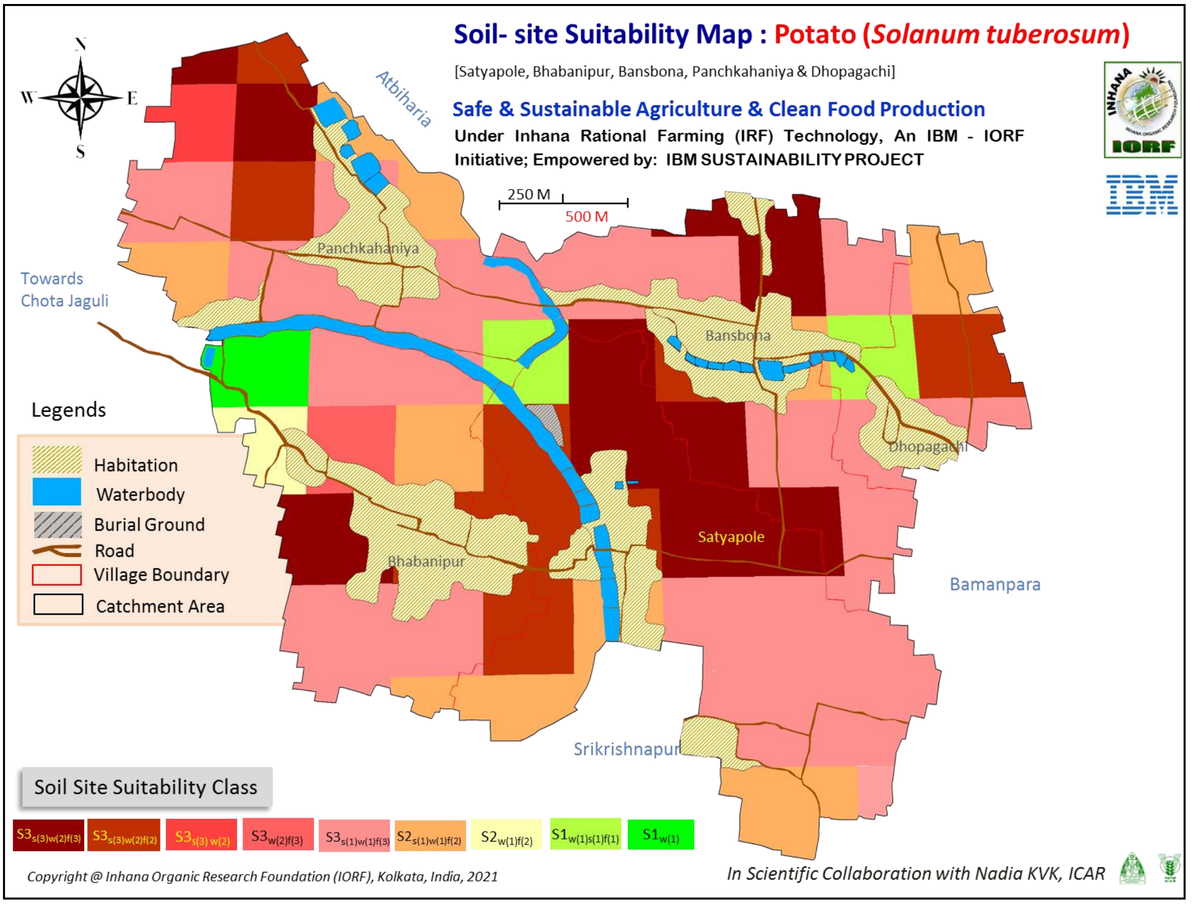

Soil- site Suitability Map : Potato (Solanum tuberosum)
[Satyapole, Bhabanipur, Bansbona, Panchkahaniya & Dhopagachi]
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Soil- site Suitability Evaluation of Tomato

Tomato is a day neutral plant and can be grown throughout the year depending on the climate. Tomato can be grown in almost all types of soils. However, it cannot withstand water logging. Hence well drained sandy loam soil rich in organic matter is preferred.

In India, it is grown in an area of 7.89 lakh hectare with production of 197.59 lakh tonnes. West Bengal occupies an area of 0.57 lakh hectare with production of 12.65 lakh tonnes and productivity of 22.01 t/ha, respectively.

In the study area, tomato cultivation is primarily done in the winter season.

As per the soil- site suitability study about 61 % area is marginally suitable (S3) followed by about 33 % area under moderately suitable (S2) category and only 6 percent area under highly suitable (S1) category. Correction of soil fertility, can promote about 67 % area to the highly suitable (S1) category and 33 % area under moderately suitable (S2) category.

Soil- site Suitability Evaluation of Bean

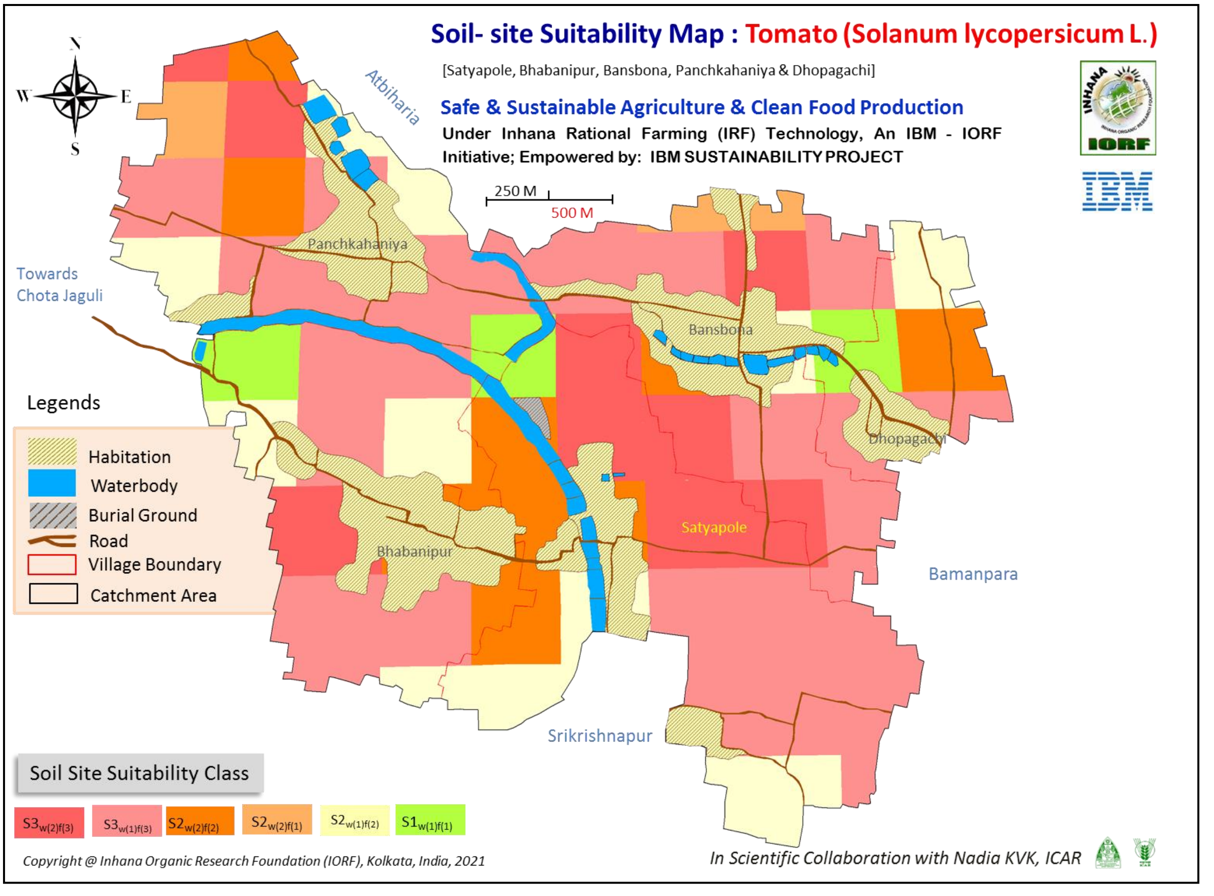
Bean (*Phaseolus vulgaris* L.) is an important grain legume for food and cash of the smallholder farmers worldwide. It is considered as a nutritious vegetable as it contains high amount of vegetable proteins, besides carbohydrates and vitamins.

In bean production West Bengal is in 7th position and produced about 142 thousand tones in the cropping season 2021 -22, contributing about 5.6 % of India's total bean production.

Beans grow well in nutrition-rich soil with good drainage. Sandy and silty loamy soils are best for Green Beans, although they can grow in almost any soil variety other than heavy soil.

In the study area basically 3 types of bean i.e. French Bean, Yardlong Bean and Broad beans are cultivated singly or as a mixed crop in winter season. But as per the soil site suitability study about 60 % of the project area is only marginally suitable (S3) and the rest 40 % area comes under moderately suitable (S2) category.

However with correction of soil fertility, about 63 % area can be upgraded to the highly suitable (S1) category followed by moderate suitability (S2) in the rest 37 % area.


Soil- site Suitability Map : Tomato (Solanum lycopersicum L.)
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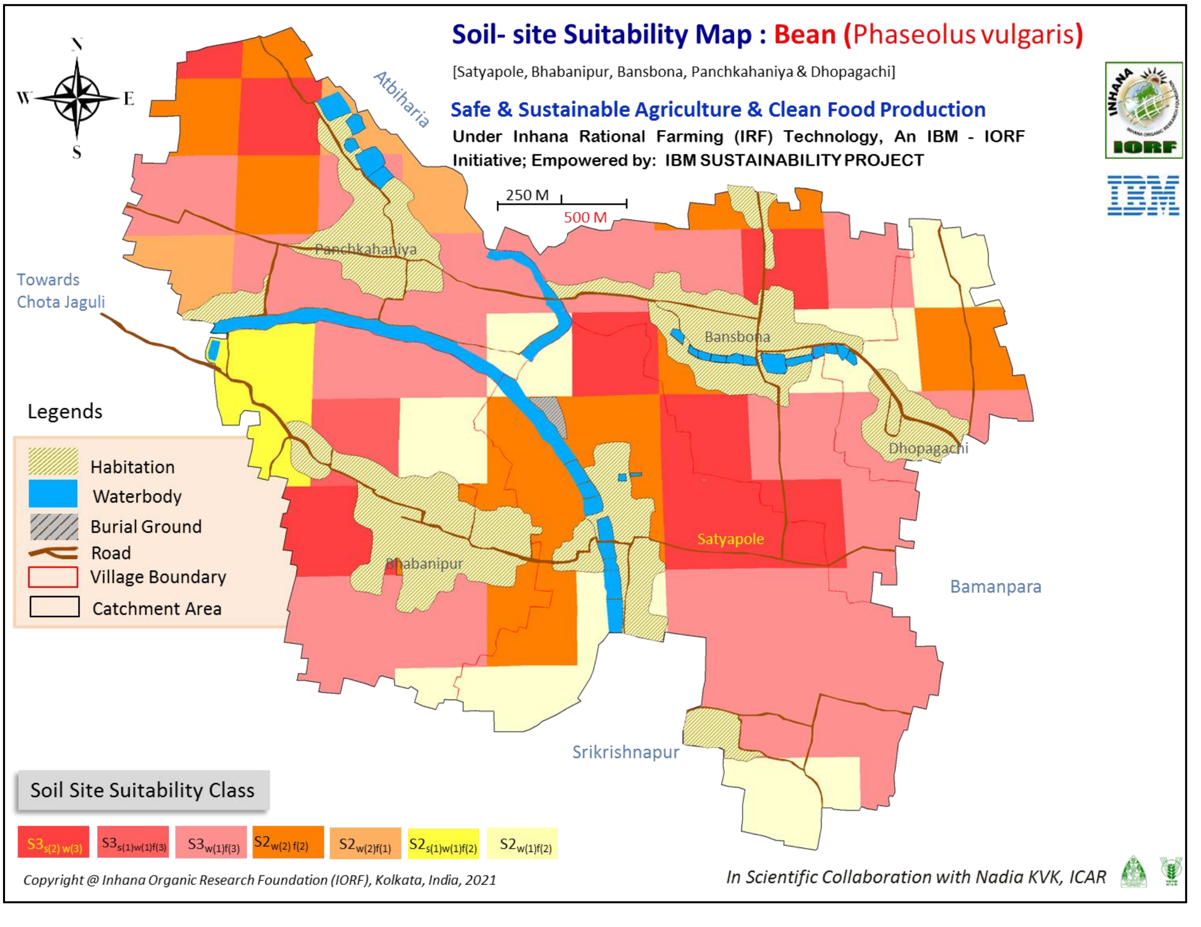
Soil- site Suitability Map : Bean (Phaseolus vulgaris)
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Soil- site Suitability Evaluation of Chilli

Chilli belongs to the genus Capsicum under Solanaceae family.

In India, Andhra Pradesh is the leading state in Chilli production followed by Karnataka, West Bengal and Odisha. In Chilli production, West Bengal is in 16th position and produced about 8.23 thousand tonnes in the cropping season 2021 -22, contributing about 0.44 % of India's total production where as Andhra Pradesh was highest with 700 thousand tonnes and 37 % total production share.

Chilli can be grown in all type of soils, but the sandy - loam, clay loam and loamy soils with pH of 5.5 to 7.0 are best suited for chilli. The soil must be well drained and well aerated. Acidic soils are not suitable for chilli cultivation.

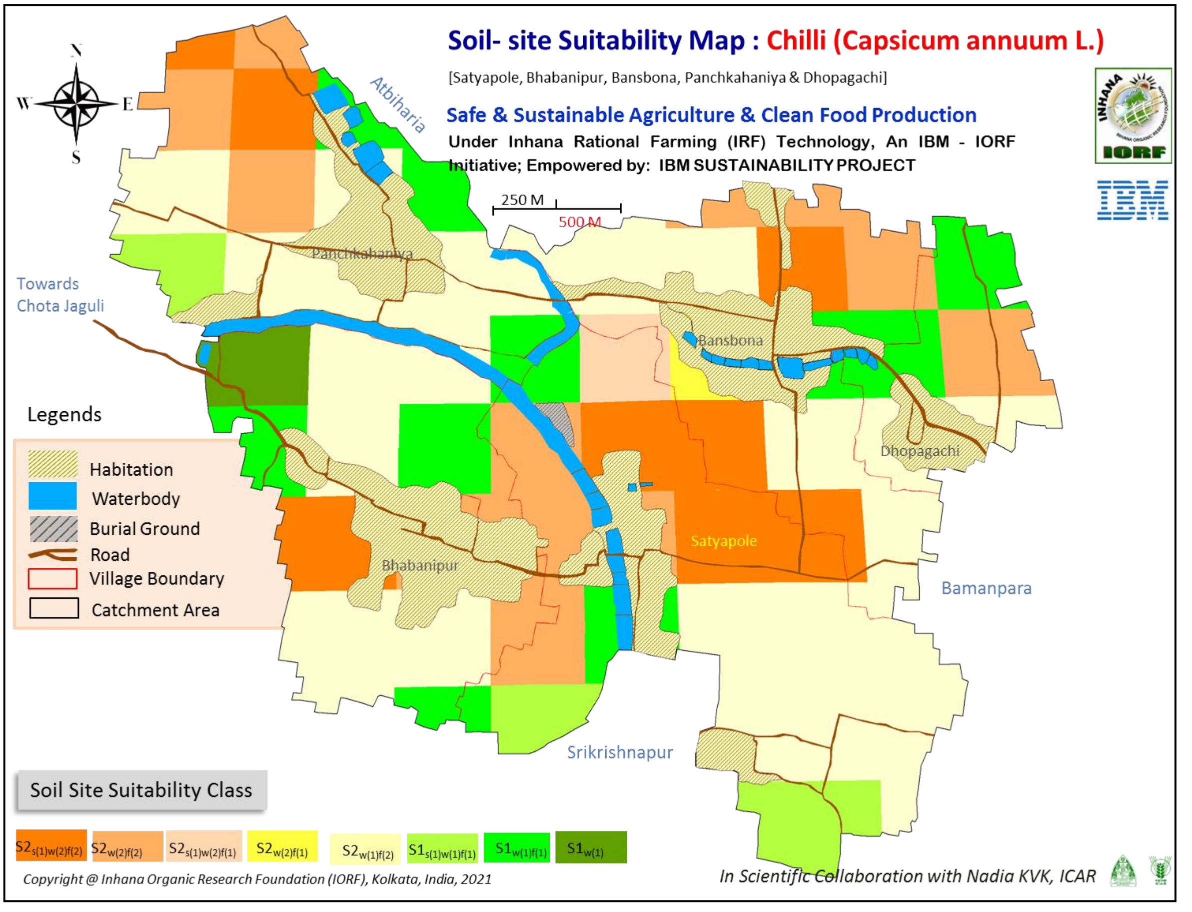
As per soil- site suitability study about 77 % of the project area is moderately suitable (S2) while the rest 33 % area is under highly suitable (S1) category. Moreover, with correction of soil fertility, about 65 % area can be brought under the highly suitable (S1) category.

Soil- site Suitability Evaluation of Carrot

In India, carrot is grown across the country. In terms of utility, it is an important root vegetable crop. Haryana is the leading producer, followed by West Bengal, Andhra Pradesh, Punjab, Bihar, Tamil Nadu, Karnataka and Assam.

In the crop year 2021-22, West Bengal produced about 235 thousand tones of carrot, contributing about 12.32 % of total carrot production in India. The crop needs deep loose loamy soil. It requires a pH ranging from 6.0 to 7.0 for higher production.

In the study area, the farmers grow carrot mainly in the upland in the winter season. As per the soil- site suitability study about 60 % area is marginally suitable (S3) followed by moderately suitable (S2) in about 36 % area, while only 4 percent area is highly suitable (S1) for this crop. Soil fertility again forms the limiting factor here, and with correction about 67 % of the project area can be promoted to the highly suitable (S1) category, with moderate suitability in the rest 33 % area.


Soil- site Suitability Map : Chilli (Capsicum annuum L.)
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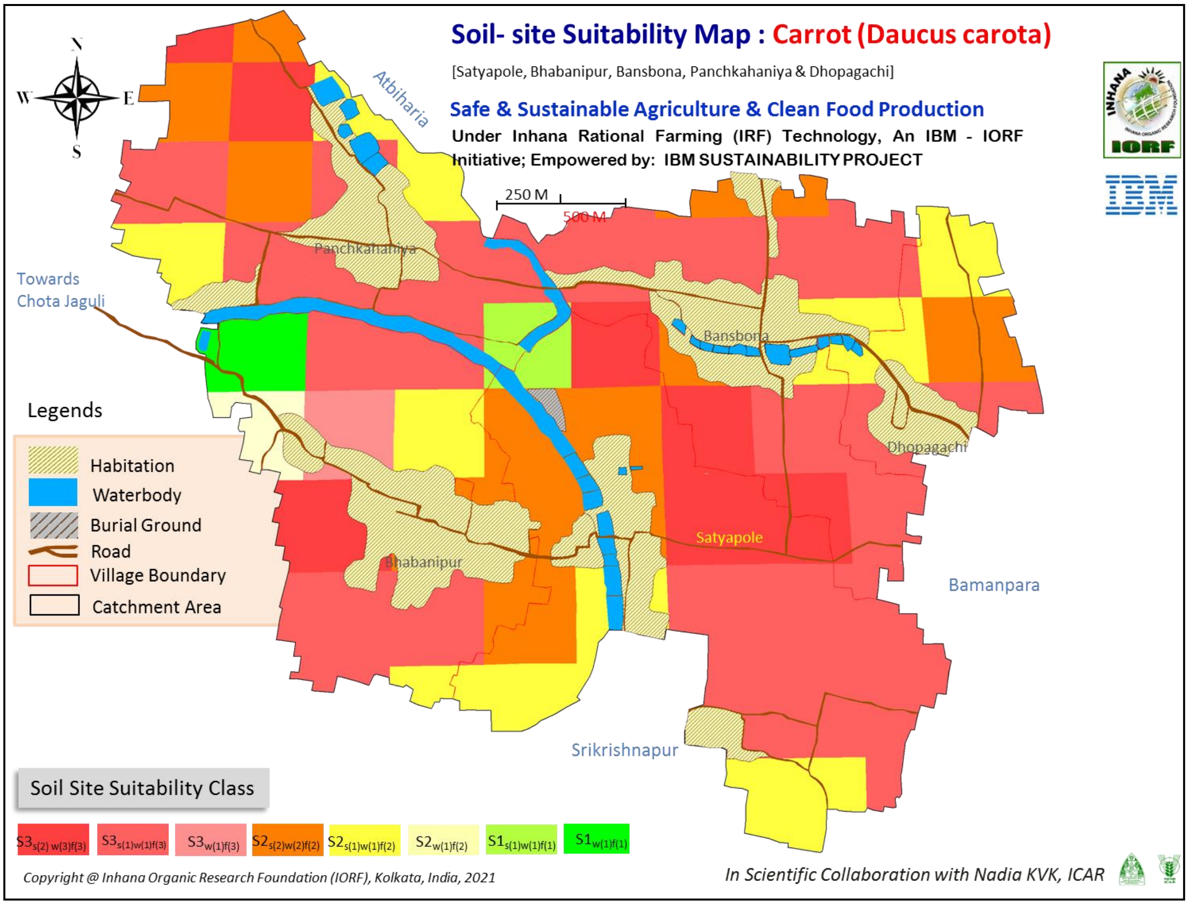
Soil- site Suitability Map : Carrot (Daucus carota)
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Soil- site Suitability Evaluation of Green Peas

Pea (Pisum sativum L.) is one of the world's oldest vegetable crops and belongs to the Leguminosae family. It is cultivated for its tender and immature seeds for use as vegetable and mature dry seeds for use as a pulse. Peas are a source of vitamins and minerals namely magnesium, thiamine, phosphorus etc.

Pea is cultivated all around the world and in India, it can be found in the state of Himachal Pradesh, Madhya Pradesh, Rajasthan, West Bengal, Orissa and many more. Major pea growing states are Bihar, Haryana, Punjab, H.P. Odisha, and Karnataka. According to the latest information, in the year 2021-22, total 6076 thousand tonnes of peas was produced in India in about 582 thousand ha area. West Bengal is in 6th position with about 144 thousand ton production and about 2.7 % production share.

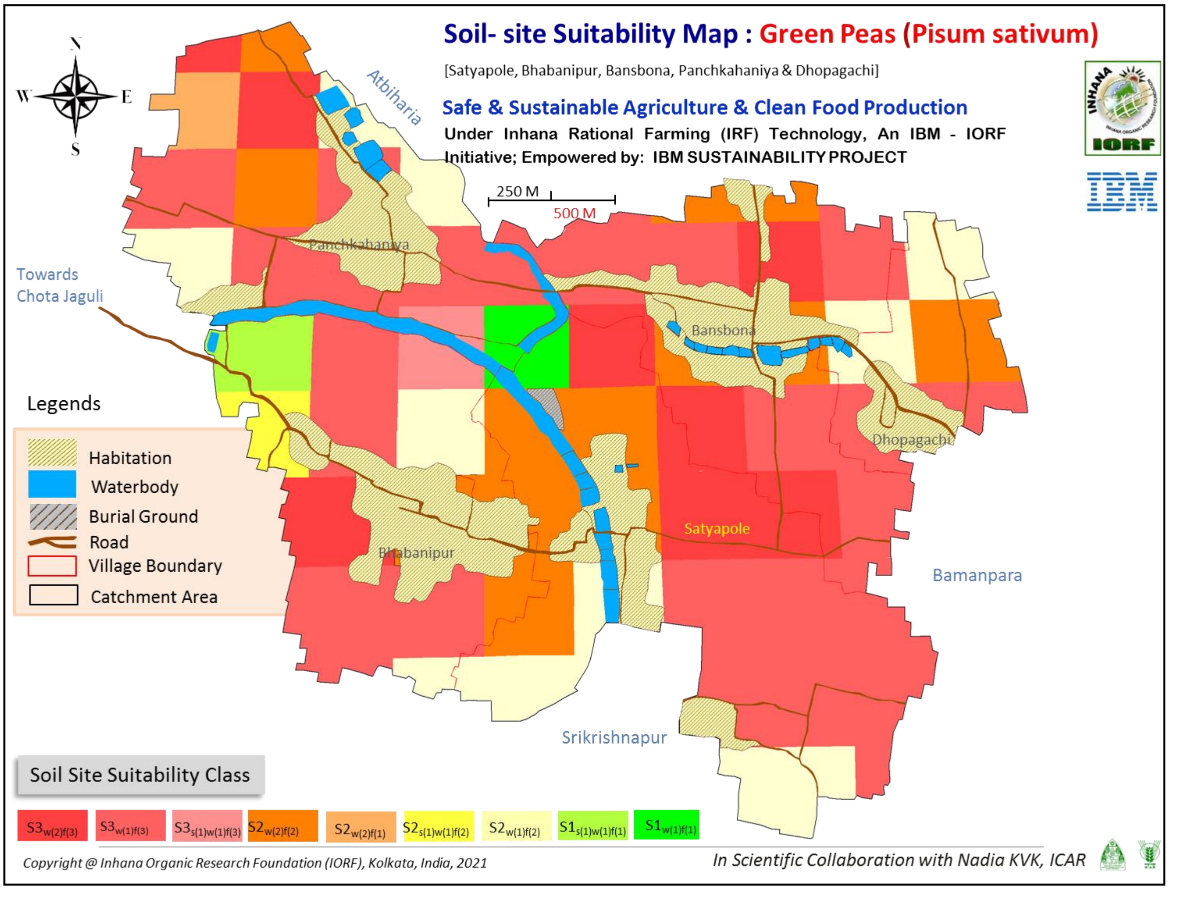
Peas can be cultivated in a variety of soil types. However well drained, loose, friable and heavy soils with a pH range of 6.0-7.5 are considered as ideal. Light soils are preferred for cultivating early cultivars. Soils rich in organic matter promote excessive vegetative growth and poor pod development. As per the soil- site suitability study about 60 % of the project area is only marginally suitable (S3) for this crop followed by moderately suitable (S2) in about 36 % area and only 4 percent area is under highly suitable (S1) class. However with correction of soil fertility, about 66 % area can be brought under highly suitable (S1) category and rest 34 % area under moderately suitable (S2) category.

Soil- site Suitability Evaluation of Onion

Onion is cultivated by farmers in almost all states of India as both Kharif and Rabi crop synched with geographical location and weather based. In onion production also, West Bengal is in 7th position and produced about 861 thousand tones in the cropping season 2021 -22, contributing about 2.8 % of India's total onion production where as Maharastra was highest with 13302 thousand tones and 43 % total production share.

Onion can be grown in all types of soils such as sandy loam, clay loam, silt loam and heavy soils. However, the best soil for successful onion cultivation is deep, friable Loam and alluvial soils with good drainage, moisture holding capacity and sufficient organic matter. In the study area onion is mostly cultivated as a mixed crop.

As per the soil- site suitability study about 63 % of the project area is only marginally suitable (S3), moderately suitable (S2) in about 33 % area while only 4 percent area is under highly suitable (S1) category. But here again, the correction of soil fertility can upgrade about 67 % of the project area to the highly suitable (S1) class, with the rest 33 % area under moderately suitable (S2) category.


Soil- site Suitability Map : Green Peas (Pisum sativum)
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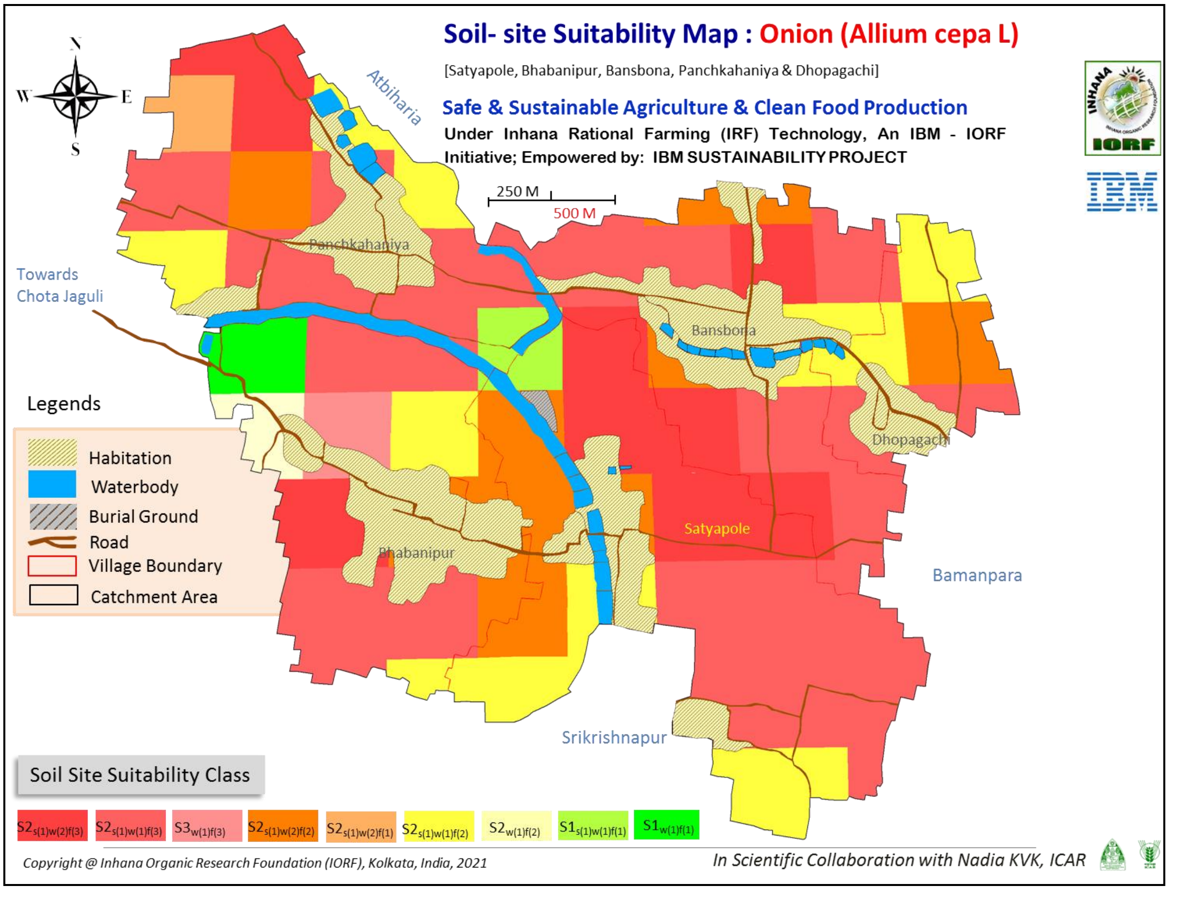
Soil- site Suitability Map : Onion (Allium cepa L)
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Soil- site Suitability Evaluation of Cabbage

Cabbage (Brassica oleracea var. capitata) is one of the most important winter vegetables grown in India and has a high nutritive value. Due to its wide adaptively, resistance to disease and stress, high yield and good transportation potential, it is cultivated worldwide.

The Area and production of cabbage in West Bengal is 0.79 lakh hectare and 22.88 lakh tonnes, respectively and contribute highest (24.4 %) among the states. In the study area, the farmers grow cabbage in significant area in the early winter to pre-summer season.

Well drained loam to sandy loam soil with high organic matter and pH of 6.0-6.5 is ideal for cabbage production. In heavy soils, growth and development of the plants is slow but the developed heads have better keeping quality. Light soils tend to produce early with loose heads.

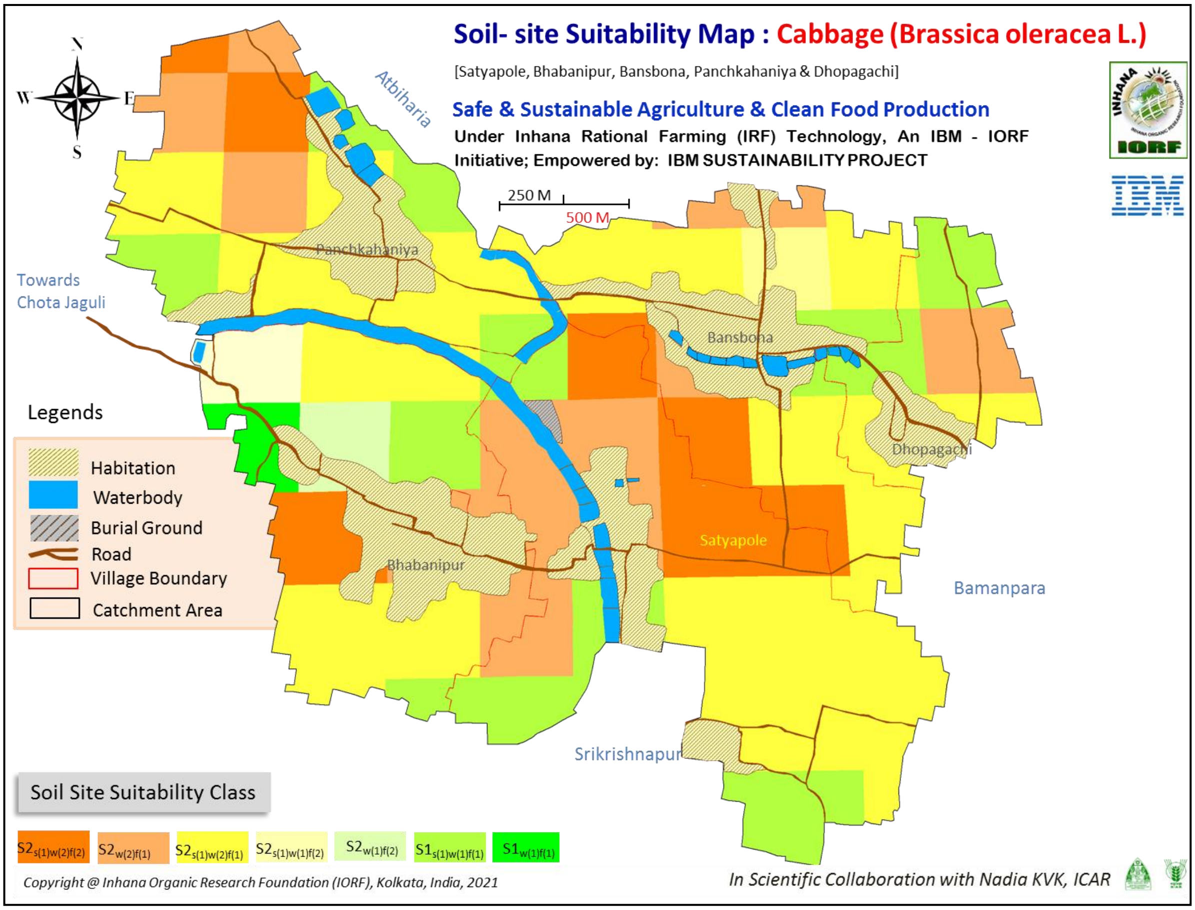
As per the soil- site suitability study, about 79 % of the project belong to the moderately suitable (S2) category, while the rest 21 percent area is highly suitable (S1) for the crop. Correction of soil fertility can promote about 65 % of the area to highly suitable (S1) category.

Soil- site Suitability Evaluation of Banana

Banana contributes 37% to the total fruit production in India and occupies 20% of the total cropped area in India.

Maharashtra ranks second in respect of area and first in terms of productivity in India. West Bengal ranks 8th and produced 1148 thousand tones in the cropping season 2021-22 contributing about 3.54 % of India's total banana production where as Andhra Pradesh was highest with 5839 thousand tonnes and 18 % of total production share.

The soil suitable for banana should be 0.5 - 1m in depth, rich, well drained, fertile, moisture retentive, containing plenty of organic matter. The range of pH should be 6.5-7.5. Alluvial and volcanic soils are the best for banana cultivation. As per the soil- site suitability study. about 42 % area is marginally suitable (S3) followed by moderately suitable (S2) 34 % area and most critically 24 % under non- suitable (N1) category. However, with correction of soil fertility, about 56 % area can be brought under the highly suitable (S1) category.



Soil- site Suitability Map : Cabbage (Brassica oleracea L.)
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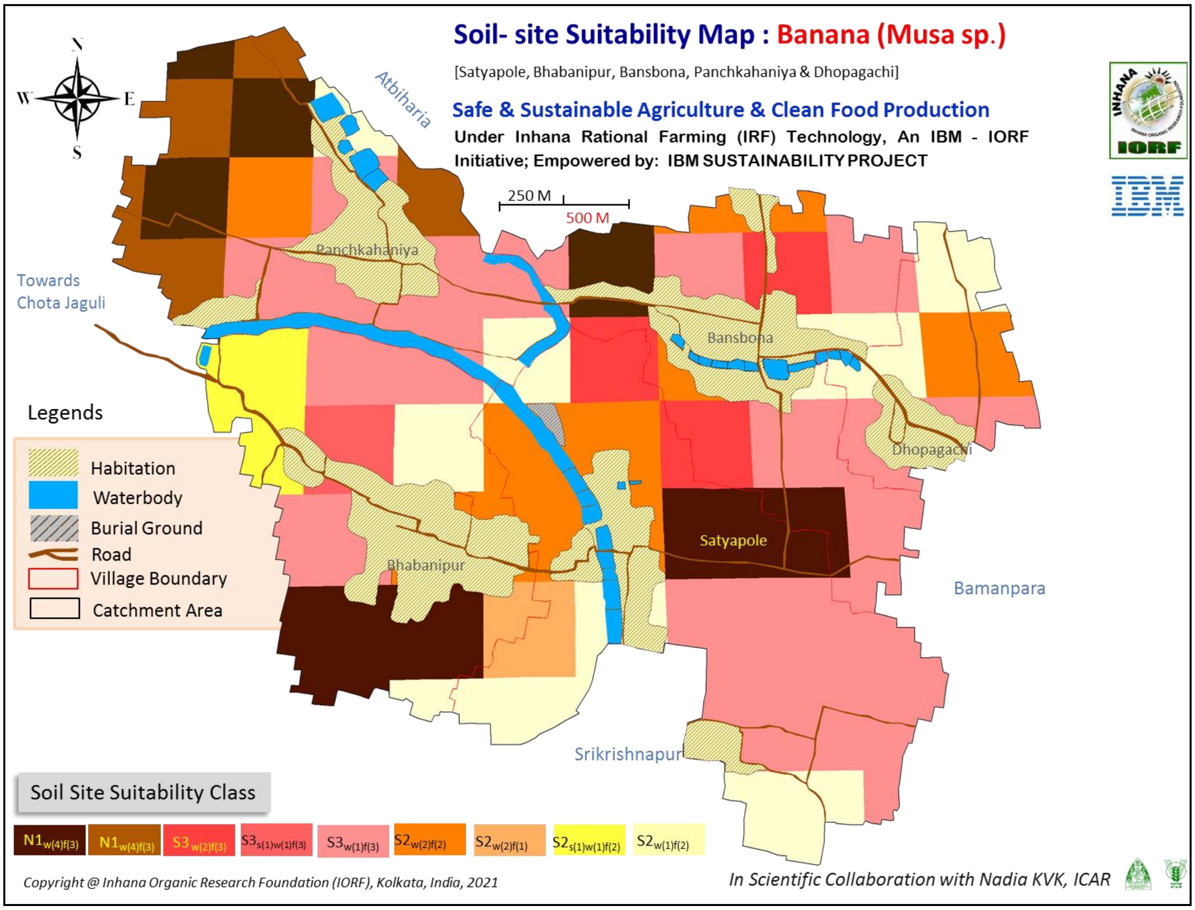

Soil- site Suitability Map : Banana (Musa sp.)
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Soil- site Suitability Evaluation of Guava

Guava (*Psidium guajava*) is one of the important commercial fruits in India. It is the fourth most important fruit after mango, banana and citrus. West Bengal ranks 7th and produced 204 thousand tonnes in the cropping season 2021 -22 contributing about 4.51 % of India's total guava production where as Uttar Pradesh was highest with 984 thousand tones and 22 % total production share.

Guava is a hardy plant, which can be grown on wide varieties of soils including shallow, medium black and alkaline soil. However, it grows successfully on well-drained soils with at least 0.5 to 1m in depth.

A soil pH ranging from 6.5 to 8.5 is considered as ideal for higher production but alkaline soil are not suitable for higher fruit production. As per the soil- site suitability study about 58 % area was marginally suitable (S3) followed by about 18 % area under moderately suitable (S2) category while 24 % area again under non- suitable (N1) category. However with correction of soil fertility, about 54 % area can be brought under the moderately suitable (S2) category.

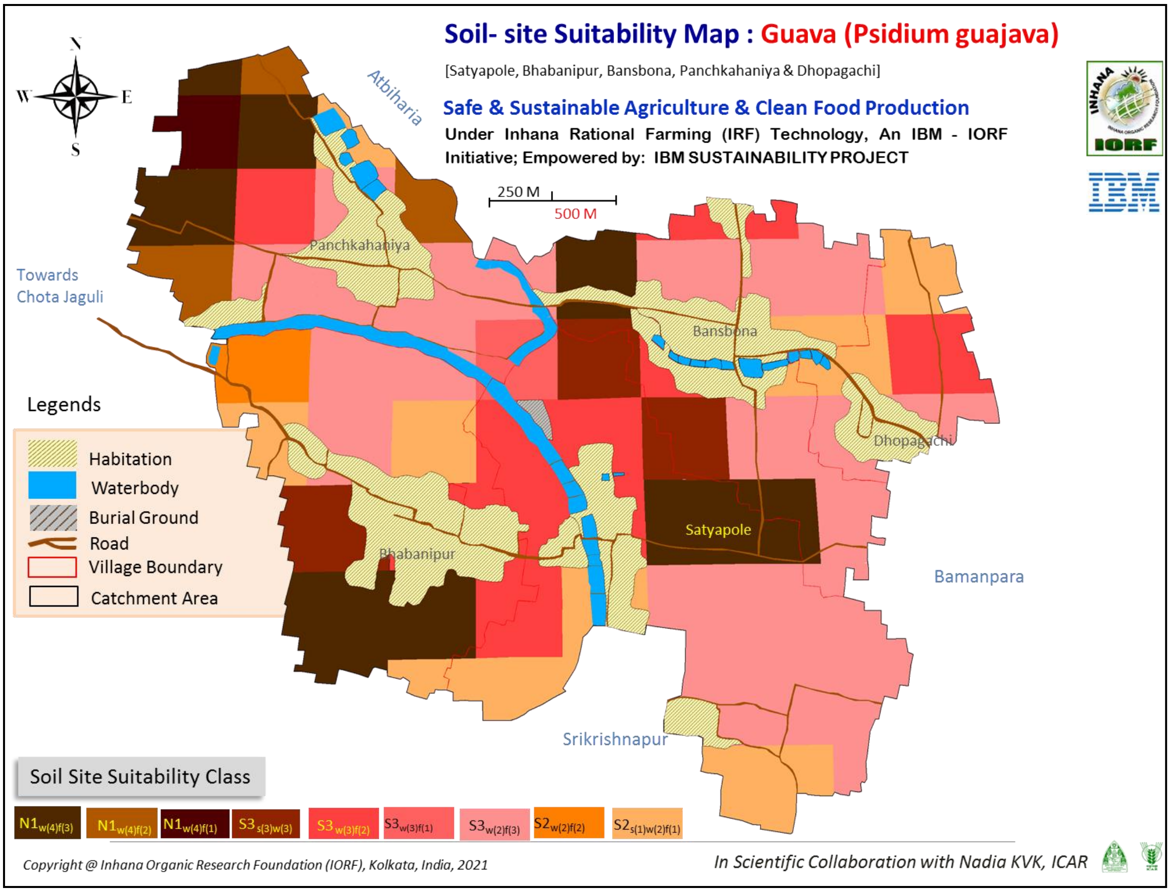
Soil- site Suitability Evaluation of Papaya

India is the largest producer of papaya (about 5.7 million tonnes), contributing 42% of world production from 30% of the global area under papaya cultivation. The area under papaya cultivation is 1.9% of the total area under fruit cultivation and its production is 6.6% of India's total fruit crops.

West Bengal ranked 7th and produced 300 thousand tonnes in the cropping season 2021 -22 contributing about 5.22 % of India's total papaya production where as Andhra Pradesh was highest with 1503 thousand tonnes and 26 % total production share.

A high fertile soil with good drainage is most desirable for successful papaya cultivation. The plant grows well in sandy loam soil having pH between 6.5 to 7.0. Papaya grows well in sunny, warm and humid climate.

The plant can be grown upto an elevation of 1000 m above the sea level but can't withstand frost. As per the soil site suitability study about 56 % of the project area is marginally suitable (S3) followed by moderate suitability (S2) in about 20 % area with rest 24 % area under non suitable (N1) category. However, here again correction of soil fertility, can upgrade about 68 % of the project area to the moderately suitable (S2) class.


Soil- site Suitability Map : Guava (Psidium guajava)
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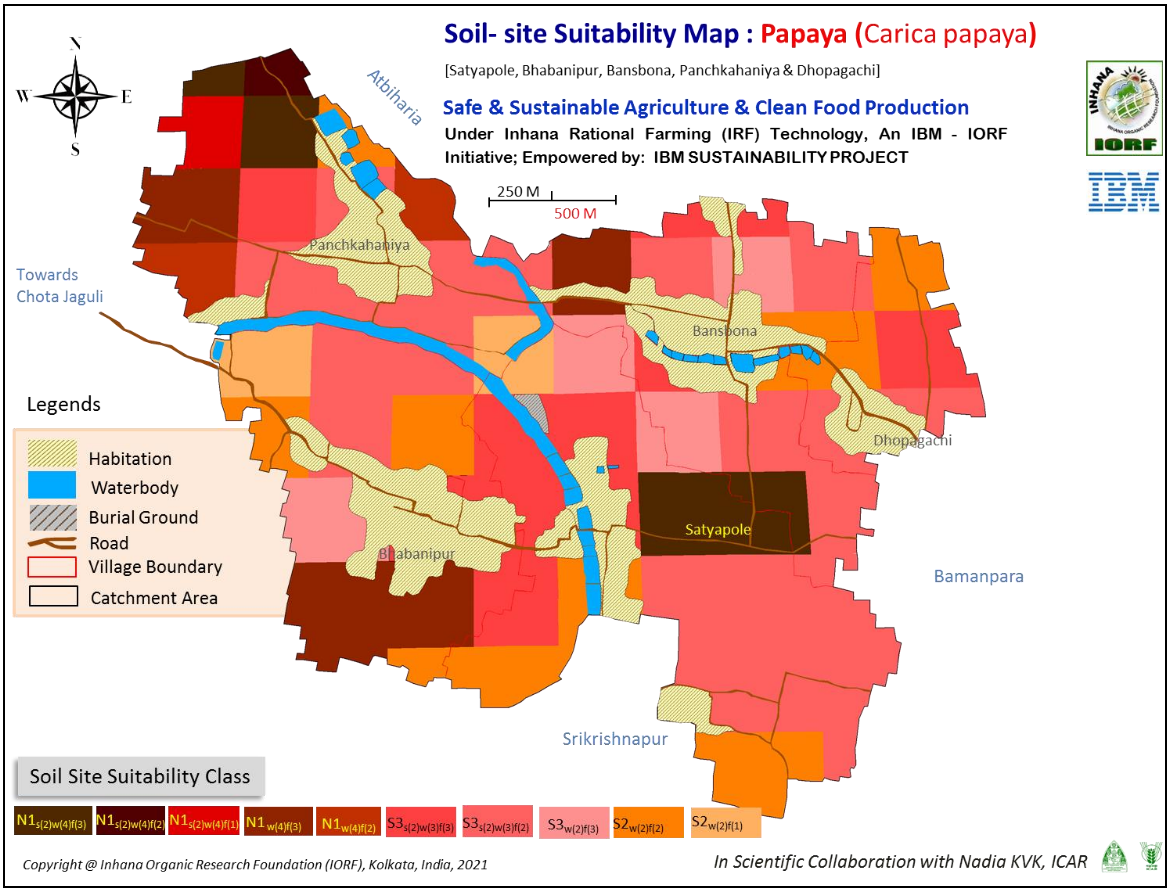
Soil- site Suitability Map : Papaya (Carica papaya)
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Clean Green Pea Cultivation under IBM-IORF Sustainability Project at Nadia, West Bengal, India

Clean Guava Cultivation under IBM-IORF Sustainability Project at Nadia, West Bengal, India

Chapter 5 : Study of Energy Transition under the different Clean Food Models in major cropping sequences.

Summary

In India, traditionally, the relationship between agriculture and energy has been unidirectional, with agriculture using energy as input in crop production. The growth in energy use in the agricultural sector is powered through mechanization and use of energy-intensive inputs . But the major Challenges for Energy Transition in agri-food systems is to reduce the non renewable energy inputs like synthetic fertilizers and pesticides with renewable energy sources **without compromising food security.**

Assessment of energy requirements of different crop sequences were done in Model Farm under different 'Clean Food' Models in IBM-IORF Sustainability Project. The Evaluation was done w.r.t. Eleven different Cropping Sequences followed in the project area and the study showed that Clean Food with 100% Reduction of N- fertilizer & Chemical pesticides Model can reduce about 24 % input energy without compromising crop yield. Rather crop productivity in terms of energy output enhanced by 22 % and thud the energy use efficiency increased by 61 %.

Under Clean Food Model energy transition was primarily in soil nutrient management and plant protection which showed that the energy investment was reduced **by a remarkable 94% when both chemical pesticides and N- fertilizers were completely eliminated.**

Introduction

India is an agriculture-based country, where the agriculture sector provides livelihood to two-thirds of the total working population and contributes to 15% of the Gross Domestic Product (GDP). Since the adoption of Green Revolution in the 1960s, there has been a 45% increase in per person food production in the country. **However, the rise in agriculture output is not directly related to the rise in farm households' income.** This is because the advent of green revolution led to an increased use of energy in agriculture primarily due to increasing use of chemical fertilizers, pesticides, farm mechanization, etc. The amount of energy used in agriculture has grown substantially, and currently, the agri-food chain accounts for 30 percent of the total energy used around the world. **In India, about 18% of the Total Energy is consumed in the agricultural and food sector. Agriculture Energy Consumption in 2020 was 19,6,913 GWH** and is expected to increase further in order to meet the production target of the country during next 20 years. **Also as per National Sample Survey Office, one-fifth of rural households primarily engaged in agriculture have income less than the poverty lines.**

On the flip side, the rise in energy use is imbibed with adverse effects on climate due to burning of fast depleting fossil fuels with far greater emission of greenhouse gases (NAAS 2018). Intensive Use of Energy in turn has led to environmental problems such as those associated with soil, water pollution and CO_2 and N_2O emissions that contribute to global warming. But, the agriculture sector has the potential to act as a key renewable energy source for the country (Praven *et al*, 2021). **Hence, efficient use of energy in agriculture is crucial for minimization of the environmental problems**, **to prevent destruction of natural resources and promote sustainable agriculture as economical production system**.

But the major Challenges for Energy Transition in agri-food systems is to decouple the use of fossil fuels in food-system transformation and related innovations **WITHOUT COMPROMISING FOOD SECURITY.** With the growing demand for energy and food, the transformation of both systems is necessary to align them more closely with global climate and sustainability goals.

In particular, the energy transition can directly affect and be affected by changes in food systems – and vice versa *(Source: Renewable energy for agri-food systems, 2021 by IRENA and the FAO, UN).* In this aspect, Energy Analysis of agricultural ecosystems is a concrete approach to investigate and **assess Energy Use Efficiency, and evaluate the SUSTAINABILITY QUOTIENT Of any Crop Production System**.

Assessment of energy requirements of different crop sequences were done in Model Farm under different 'Clean Food' Models which are as given below :

i) 'Clean Food' Program with **100% Reduction of Chemical Pesticides** (CF).

ii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **50% Reduction of N- fertilizer** (CF_{50})**.**

iii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **100% Reduction of N- fertilizer** (CF_{5100})**.**

The data obtained was compared with the energy use under Conventional Farming Practice (CFP).

The Evaluation was done w.r.t. Eleven different Cropping Sequences followed in the project area *viz*., Tomato-Cucumber-Coriander, Potato-Brinjal-Cauliflower, Potato-Okra-Cabbage, Brinjal-Frenchbean-Spinach, Pumpkin-Okra-Cabbage, Brinjal-Carrot, French bean-Okra- Onion, Potato- Chilli- Carrot, Tomato-Ridge gourd- Spinach, Peas -Yam –Cabbage and Pointed Gourd – Cauliflower.

Energy Analysis of Cropping Sequences under Conventional Practice & different 'Clean Food' Models – 1

Crop Sequence	CFP	CF	CF_{50}	CF_{100}
Total Energy Input (MJ/ha)				
Tomato-cucumber-coriander	72941	61659	57599	57871
Potato-brinjal-cauliflower	99431	84708	75910	70886
Potato -Okra-cabbage	96996	86393	76727	71403
Brinjal-Frenchbean-Spinach	68860	56462	53573	53367
Pumpkin-okra-cabbage	84406	73388	66376	63588
Brinjal-Carrot	58268	45155	41011	39100
Frenchbean - okra-onion	80021	70494	63385	60222
Potato-chilli-carrot	87719	76300	68242	63498
Tomato-ridge gourd- spinach	70213	63042	59092	59180
Peas -Yam -cabbage	113060	106487	97697	93646
Pointed Gourd - Cauliflower	71666	56188	51622	49716
Average	**82144**	**70934**	**64658**	**62043**
Energy Productivity (Kg/MJ)				
Tomato-cucumber-coriander	0.59	0.79	0.84	0.93
Potato-brinjal-cauliflower	0.80	1.02	1.19	1.31
Potato -Okra-cabbage	0.70	0.91	1.04	1.15
Brinjal-Frenchbean-Spinach	0.66	0.84	0.96	1.00
Pumpkin-okra-cabbage	0.58	0.77	0.86	0.92
Brinjal-Carrot	0.72	0.95	1.12	1.23
French Bean - okra-onion	0.44	0.58	0.62	0.69
Potato-chilli-carrot	0.66	0.85	1.00	1.12
Tomato-ridge gourd- spinach	0.75	0.94	1.05	1.15
Peas -Yam -cabbage	0.56	0.66	0.76	0.81
Pointed Gourd - Cauliflower	0.70	0.98	1.08	1.13
Average	**0.65**	**0.83**	**0.94**	**1.03**

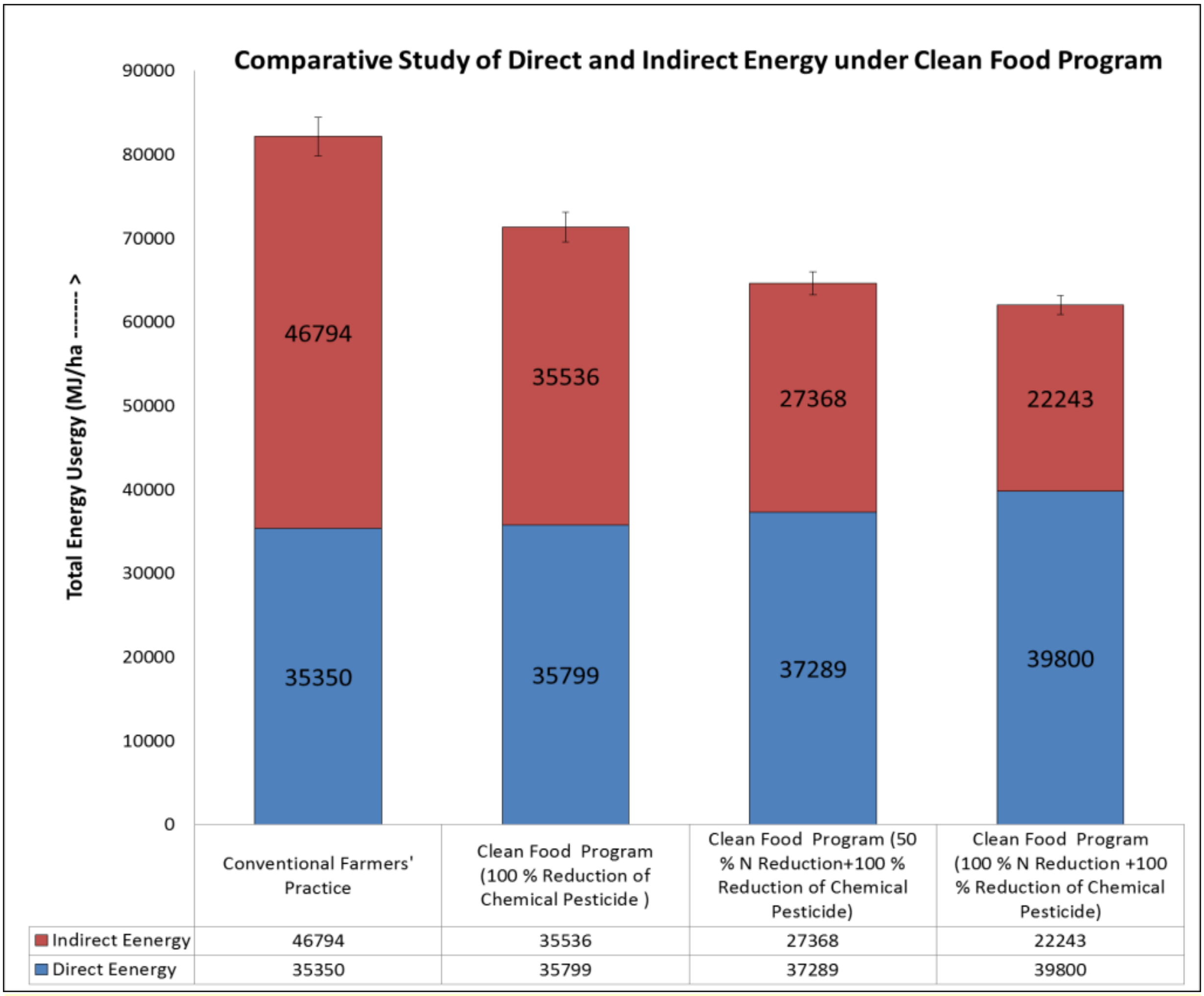
Clean Green Peas production at Nadia, West Bengal, India under IBM-IORF Sustainability Project

Energy Analysis of Cropping Sequences under Conventional Practice & different 'Clean Food' Models – 2

Crop Sequence	CFP	CF	CF_{50}	CF_{100}
Energy Use Efficiency (EUE)				
Tomato-cucumber-coriander	0.47	0.63	0.67	0.75
Potato-brinjal-cauliflower	1.39	1.84	2.17	2.39
Potato -Okra-cabbage	1.49	1.96	2.28	2.52
Brinjal-Frenchbean-Spinach	0.67	0.88	0.97	1.02
Pumpkin-okra-cabbage	0.65	0.88	0.95	1.03
Brinjal-Carrot	0.83	1.10	1.28	1.42
French Bean - okra-onion	0.79	1.05	1.11	1.24
Potato-chilli-carrot	1.55	2.03	2.39	2.67
Tomato-ridge gourd- spinach	0.60	0.75	0.84	0.92
Peas -Yam -cabbage	1.16	1.36	1.61	1.71
Pointed Gourd - Cauliflower	0.56	0.78	0.86	0.91
Average	**0.97**	**1.27**	**1.45**	**1.57**

NOTE :
CFP : Conventional Farmers' Practice; CF : Clean Food Program (100 % Reduction of Chemical Pesticide), CF_{50}: Clean Food Program (100 % Reduction of Chemical Pesticide + 50 % Reduction of N- Fertilizer); CF_{100} : Clean Food Program (100 % Reduction of Chemical Pesticide + 100 % Reduction of N- fertilizer)

Crop Diversity in the Project Area



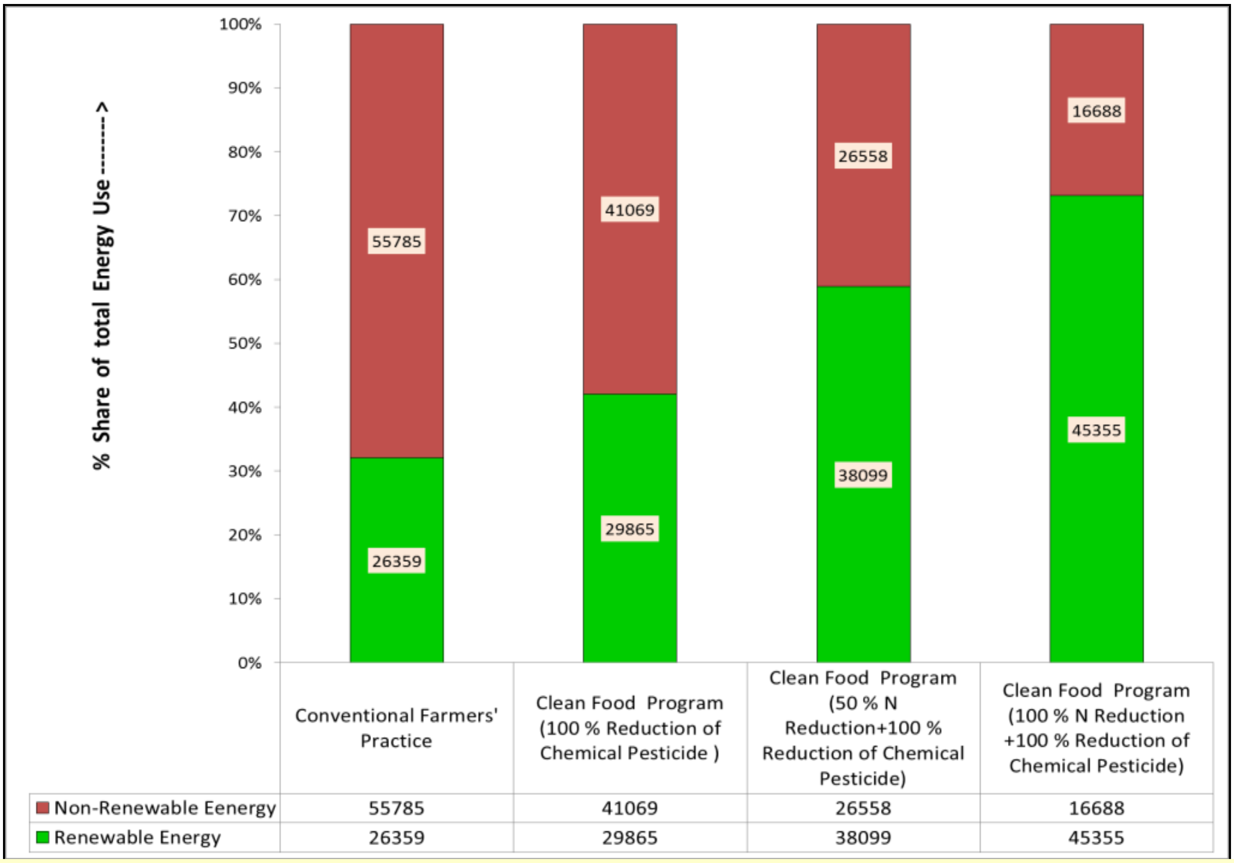
Comparative study of direct and indirect energy inputs under different management system at Nadia, West Bengal, India.

Agricultural energy demand can be divided into DIRECT and INDIRECT energy needs. The direct energy needs include energy required for land preparation, cultivation, irrigation, harvesting, post-harvest processing, food production, storage and the transport of agricultural inputs and outputs. Indirect Energy involves the energy associated with the resources used during manufacturing, packing, and delivering the inputs (*viz*. fertilizer, chemicals, & machinery) at the farm gate (*Walters et. al, 2016*).

Total energy usage was higher in case of Conventional farmers practice (82144 MJ/ha) and it was lowest in case of Clean Food with 100% Reduction of N- fertilizer & Chemical Pesticides Model (79991 MJ/ha). Ratio of Indirect and direct energy input also highest (1.32) in case of Conventional farmers practice where as that was lowest (0.56) under Clean Food with 100% Reduction of N- fertilizer & Chemical Pesticides Model

Evaluation reveals that as compared to Conventional Farming System, **Total Energy Demand is 13 to 25% Lower under the different 'Clean Food' Models.**

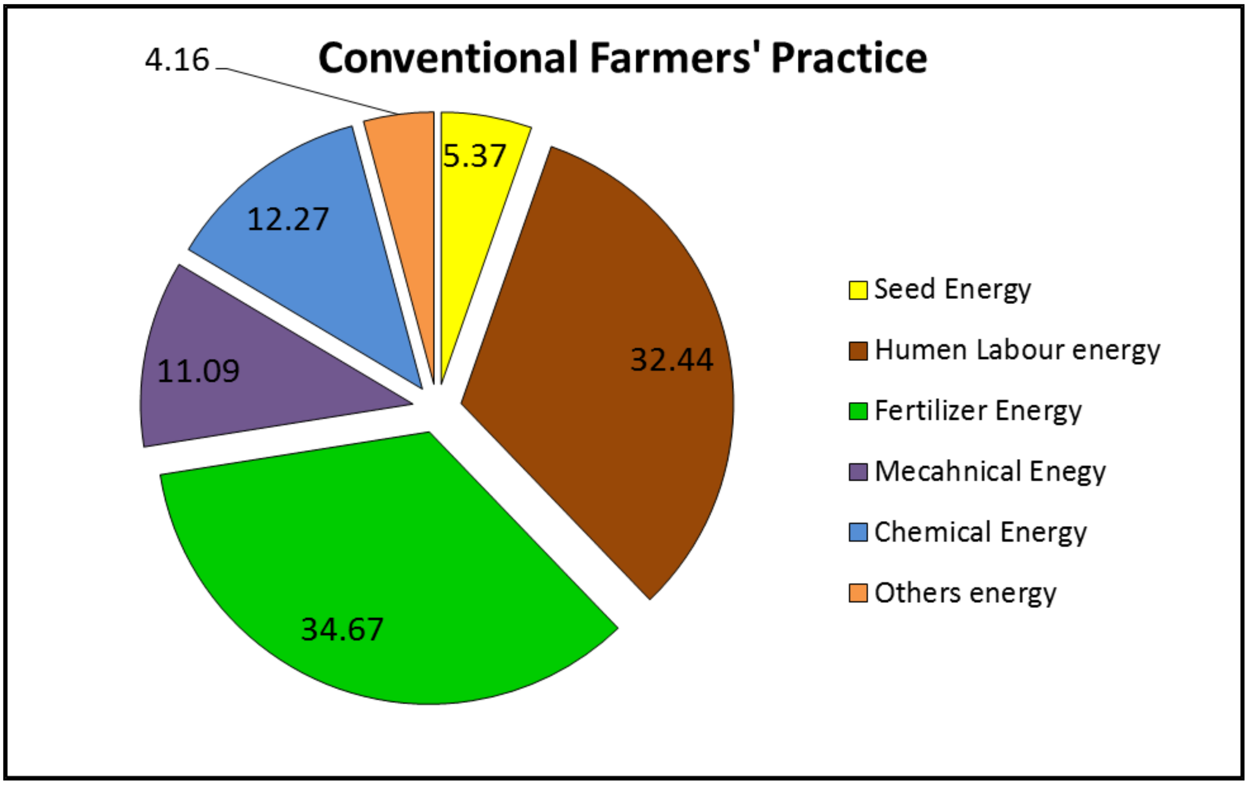
Moreover, with a progression towards Safe and Sustainable Agriculture i.e. 'Clean Food' production (CFP), the use of Indirect Energy decreases by a Significantly 24%. But most interestingly **a Stupendous Reduction (52%) in the demand is observed under Clean Food' Models where a 100% Elimination of Both N- fertilizer and Chemical Pesticide is achieved.**

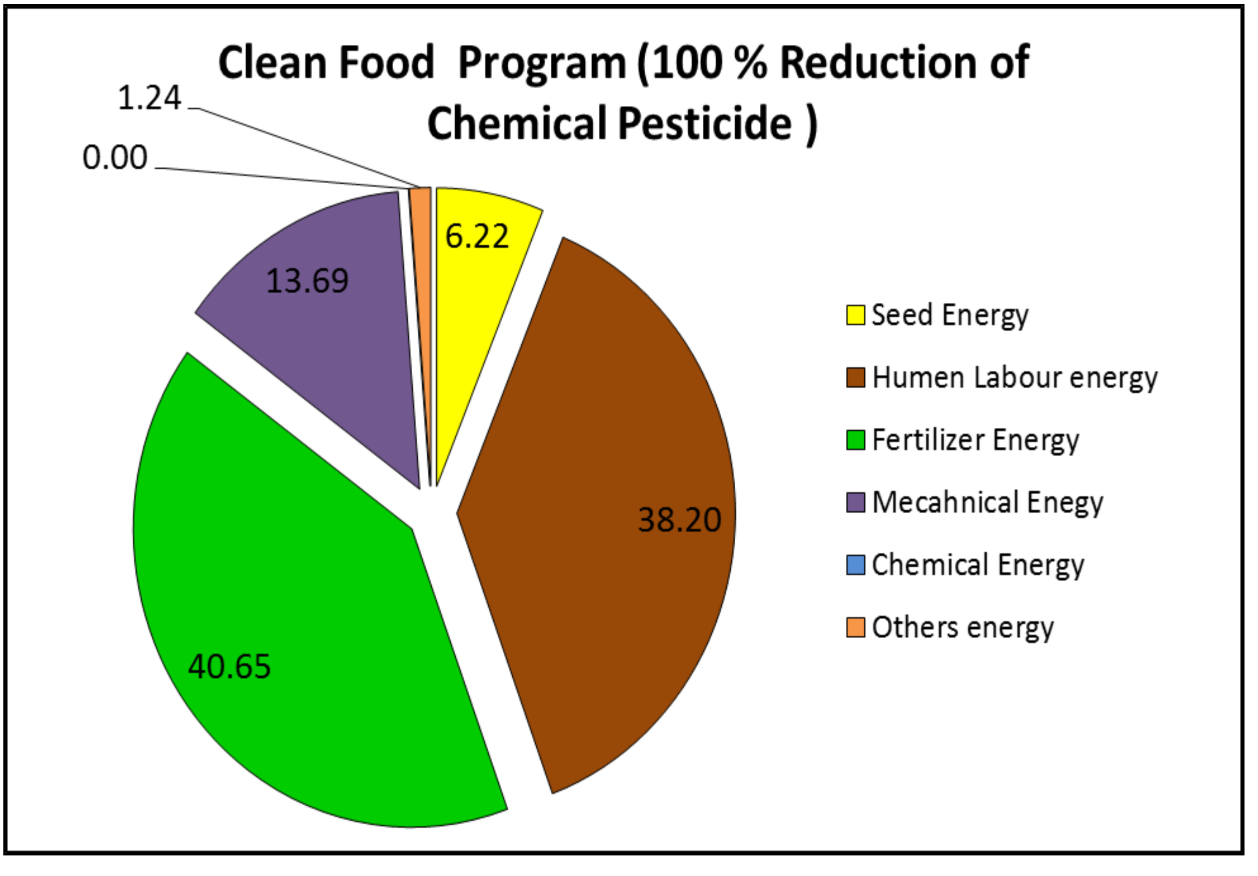


Comparative study of renewable and non-renewable energy inputs under different management system at Nadia, West Bengal, India.

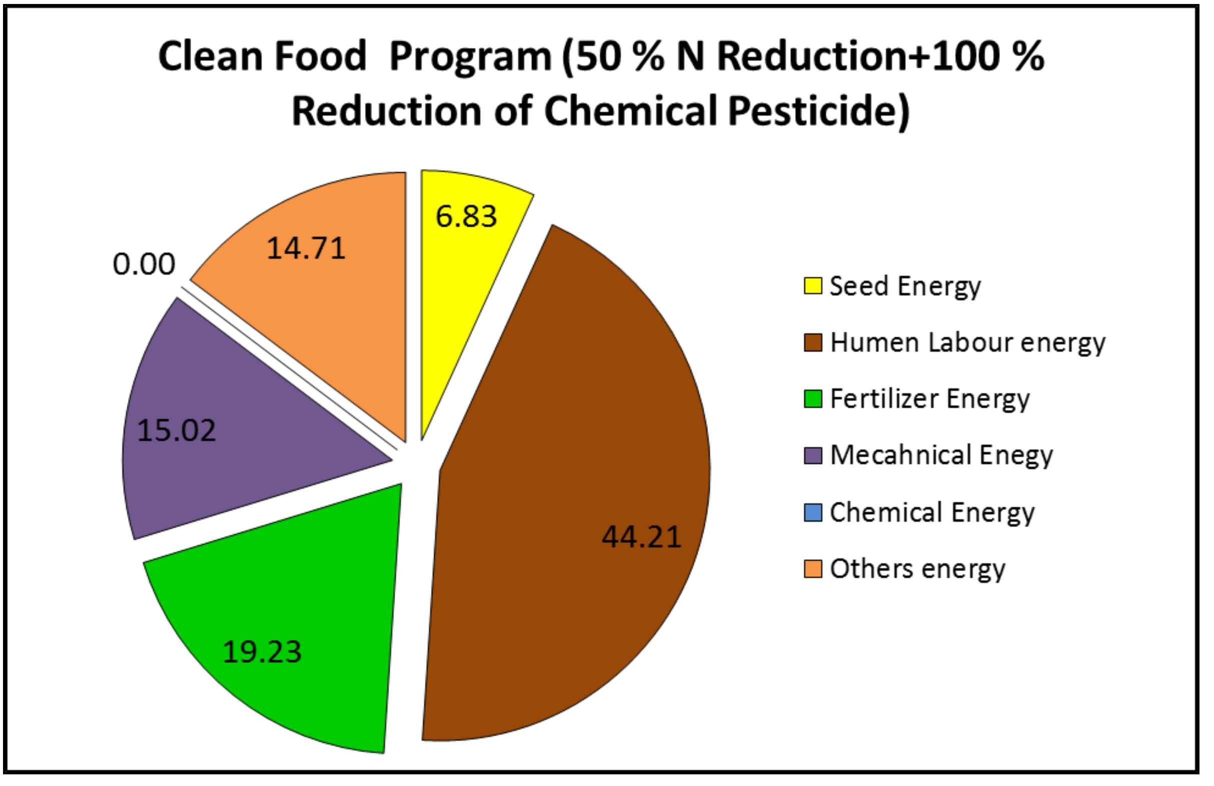
This Huge Reduction in the Demand of Indirect Energy under Safe and Sustainable Agriculture i.e. 'Clean Food' production (CFP), is primarily achieved through **HIGHER INCORPORATION of RENEWABLE ENERGY SOURCES i.e. from** 42% **to a whopping 73%,** (under CF with 100% Reduction of N- fertilizer & Chemical pesticides), when compared to a just 32% use under Conventional Farming System.

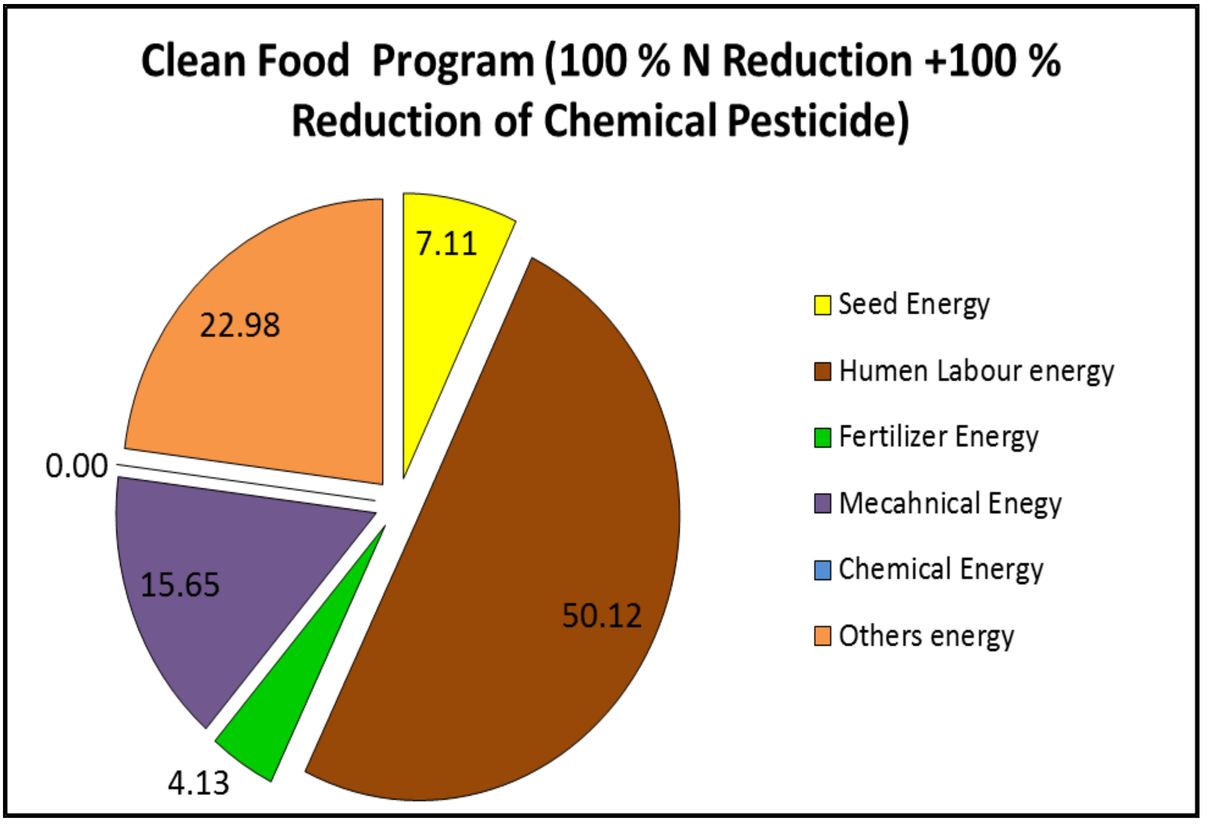
Pie- Chart distribution showing the Contribution of different Components towards Total Energy Demand under Conventional Farming System vs. 'Clean Food' Models / 1



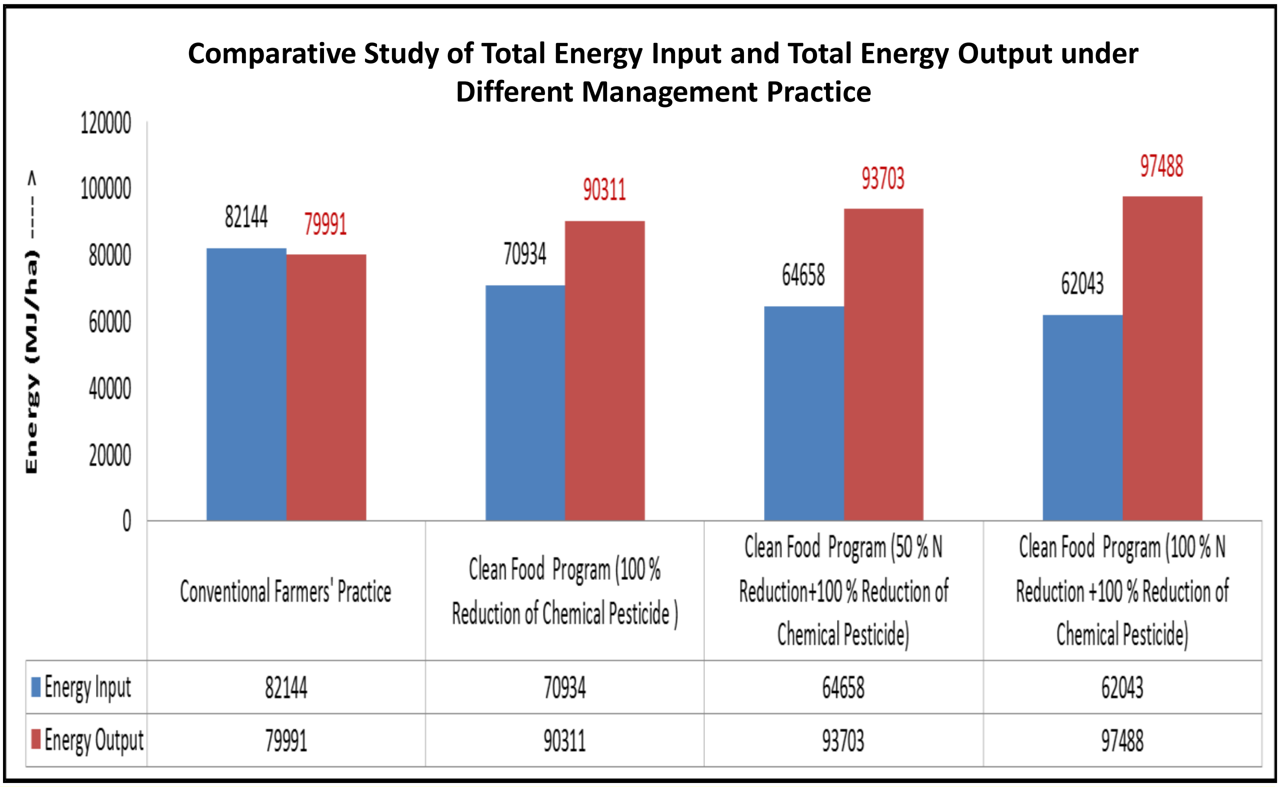


Pie- Chart distribution showing the Contribution of different Components towards Total Energy Demand under Conventional Farming System vs. 'Clean Food' Models / 2





The concept of agricultural and environmental sustainability refers to minimizing the degradation of natural resources while increasing crop productions. Hence, **assessment of inflow and outflow energy resources is helpful in highlighting the RESILIENCE of the system and its potential towards MAINTAINING its PRODUCTIVITY.**



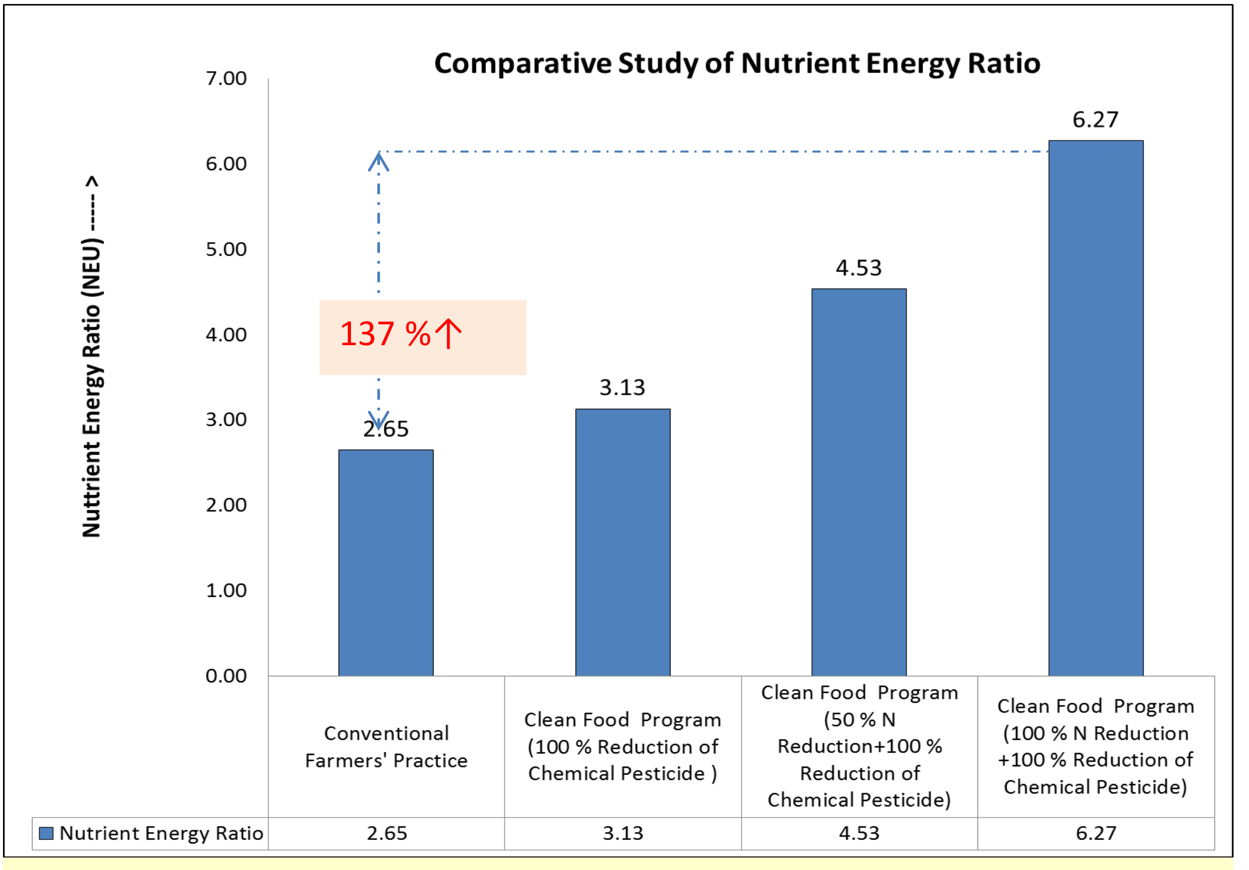
	Conventional Farmers' Practice	Clean Food Program (100 % Reduction of Chemical Pesticide)	Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide)	Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide)
Energy Input	82144	70934	64658	62043
Energy Output	79991	90311	93703	97488

Comparative study of total energy input and output under different management system at Nadia, West Bengal, India.

A higher Energy Output as compared to Total Energy Input under any crop production system indicates better production systems' management towards improved use of energy resources and sustained/ higher yields. The lower energy output under conventional farming system indicates system unsustainability in terms of higher energy consumption as against low energy recovery.

In this respect, 27 to 57% higher Energy Output, recorded under the different levels of 'Clean Food' Program, **indicates higher resilience of this crop production Model in terms of ensuring Crop and Economic Security** both in the present and future . Especially the highest Energy Output (57%) under 'Clean Food' program with 100% Reduction of both Chemical Pesticides and N- fertilizers, indicates that these are the primary hands of unsustainability, and when eliminated **can reduce not only the adverse effects on climate, but also mitigate the economic vulnerability of the resource poor marginal and small farmers.**

Nutrient Energy Ratio (NER) is the ratio of total energy use in nutrient management and total energy output. Higher NER denotes higher efficiency in nutrient management and better crop response, while **a low NER indicates higher risk of pollution and more spill over effect**.



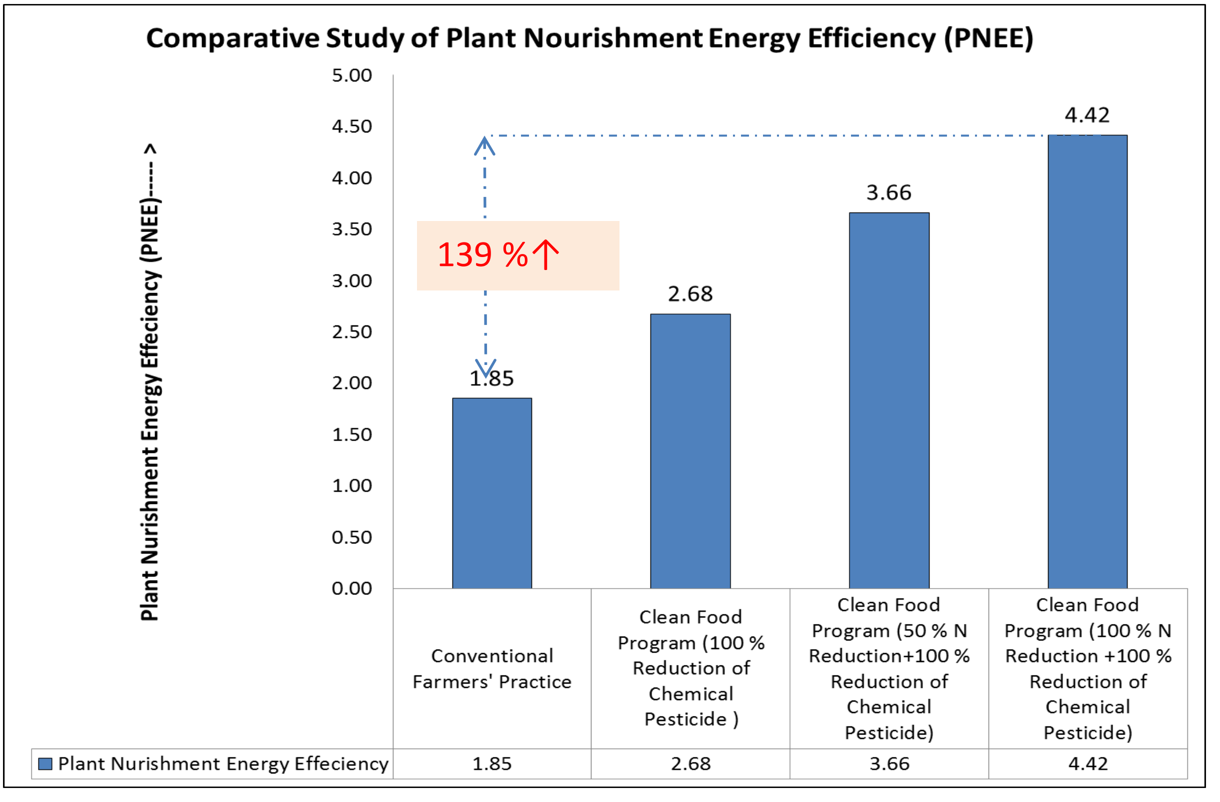
Comparative study of Nutrient Energy Ratio under different management system at Nadia, West Bengal, India.

Under ‘Clean Food’ program, NER increased with N- fertilizer reduction. On an average, a **137 percent increase in NER was recorded under the different cropping sequences under ‘Clean Food’ Model with 100% N- fertilizer Reduction + 100 % Reduction of Chemical Pesticides**. **The finding highlighted better nutrient utilization efficiency and higher crop response per unit nutrient application, under IRF technology.**

Moreover, the significant increase of NER under Clean Food Program with 100% Reduction of Chemical Pesticides but no intervention in soil, **reflects the relevance of IRF Plant Health Management towards higher crop resilience against pest and disease and improved crop production.**

Thus NER can be an important sustainability indicator to study the effectiveness of nutrient management under any sustainable agricultural initiative.

Plant Nourishment Energy Efficiency (PNEE) is the ratio of total energy output and total energy utilized for plant nourishment. In the case of conventional farming system this comprises nutrients, inputs for plant growth management and inputs related to plant protection from pest and diseases.

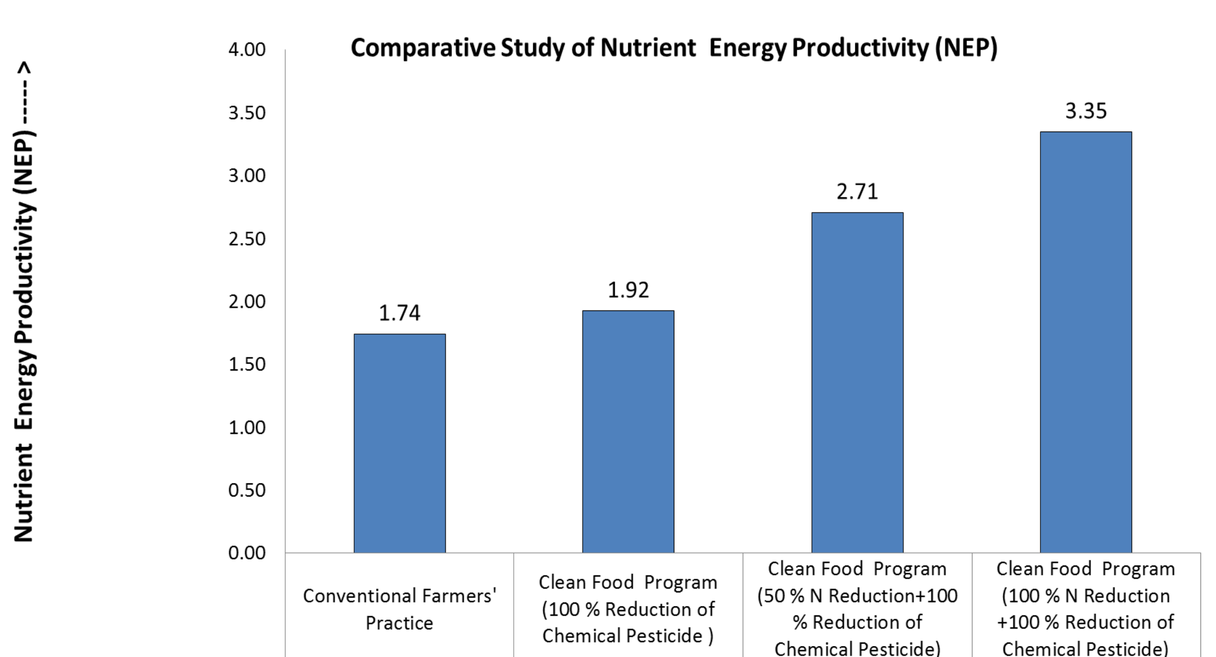


PNEE is the most crucial component of any sustainable initiative considering that the reduction/ replacement of unsustainable inputs can reduce environmental pollution and help to cut down GHG emissions, **however; to ensure sustainability in the truest sense i.e. higher PNEE, such replacement should not jeopardize crop yields or incur higher cost.**

The Higher PNEE (45% - 139% higher as compared to the value obtained under Conventional Farming System) under different 'Clean Food' Models, indicated that **successful replacement of non renewable energy sources** without compromising on crop yield is possible through adoption of an effective Crop Technology **(IRF Technology)**.

PNEE value enhanced significantly under 'Clean Food' program where 100% Reduction of both Chemical pesticides and N- fertilizers was achieved, indicating that it can serve as the Best Fit Agricultural Model towards the 'NET ZERO' Objective.

Nutrient Energy Productivity (NEP) is the ratio of total crop production and total energy use for nutrient management in same unit of area and expressed in kg/MJ. Nutrient energy productivity actually denotes the total nutrient energy spent for unit utilizable biomass generation. Thus this index can work as a sustainability indicator specially considering that conventional farming production system demands more energy for every unit of food production.

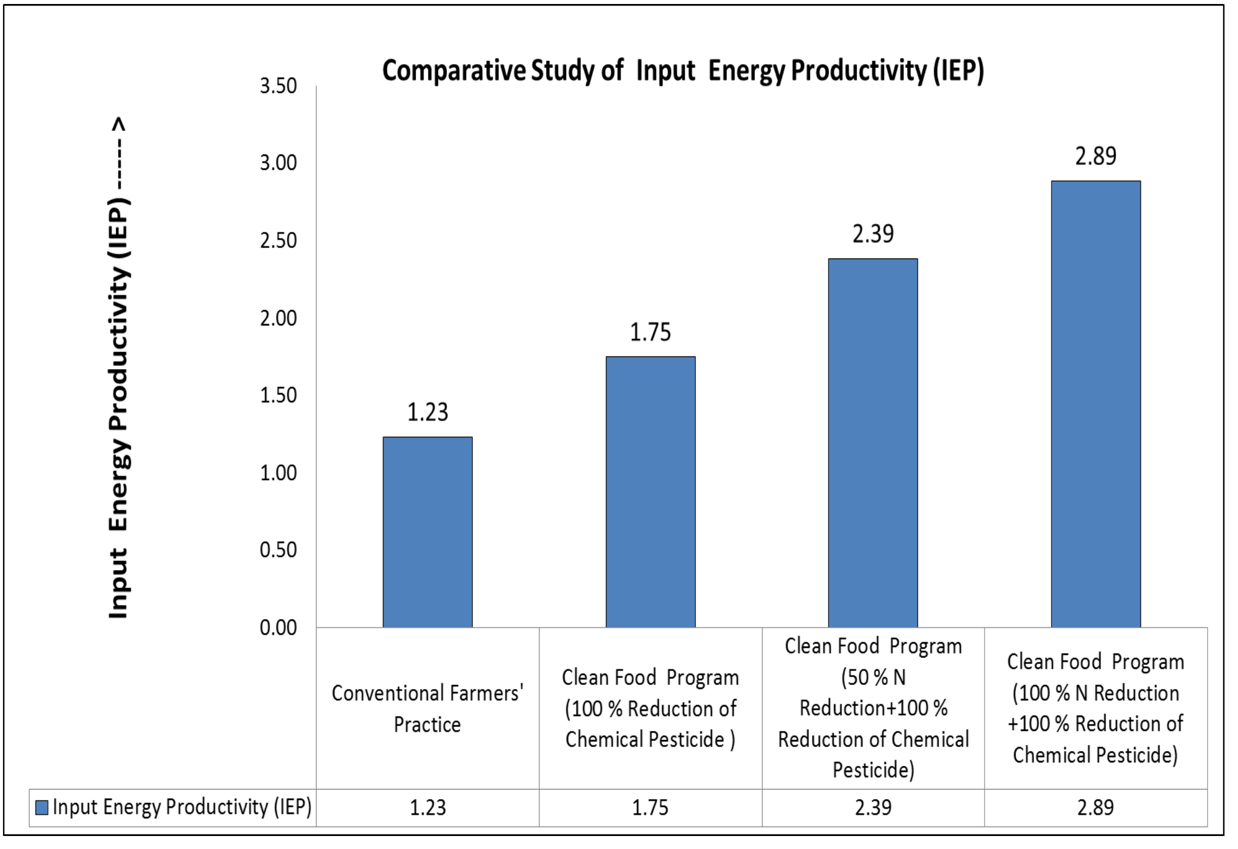


	Conventional Farmers' Practice	Clean Food Program (100 % Reduction of Chemical Pesticide)	Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide)	Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide)
Nutrient Energy Productivity	1.74	1.92	2.71	3.35

The NEP value increased significantly (up to a 93%) under 'Clean Food' program, as compared to that recorded for the conventional farming system, which was primarily influenced by the **intervention of IRF Technology**. This Crop technology not only enabled the elimination of non renewable energy sources in varying degrees, under the different levels of the 'Clean Food' Program; but did so without incurring any crop loss and without raising the cost of production. Considering that one-fifth of our rural households primarily are below the poverty line, this program for Safe and Sustainable 'Clean Food' production is actually a Potential Model for Low Input Sustainable Farming especially relevant for the resource poor marginal and small farmers.

Moreover the stupendous enhancement of the NEP value under 'Clean Food' program where 100% Reduction of both Chemical pesticides and N- fertilizers was achieved, indicates that it can **potentially serve as the Best Fit Agricultural Model towards the Net Zero Objective.**

Input Energy Productivity (IEP) **is the ratio of total crop production and total energy utilized in plant nourishment in the same unit of area** and expressed in kg/MJ. In the case of conventional farming system this comprises nutrients, inputs for plant growth management and inputs related to plant protection from pest and diseases.

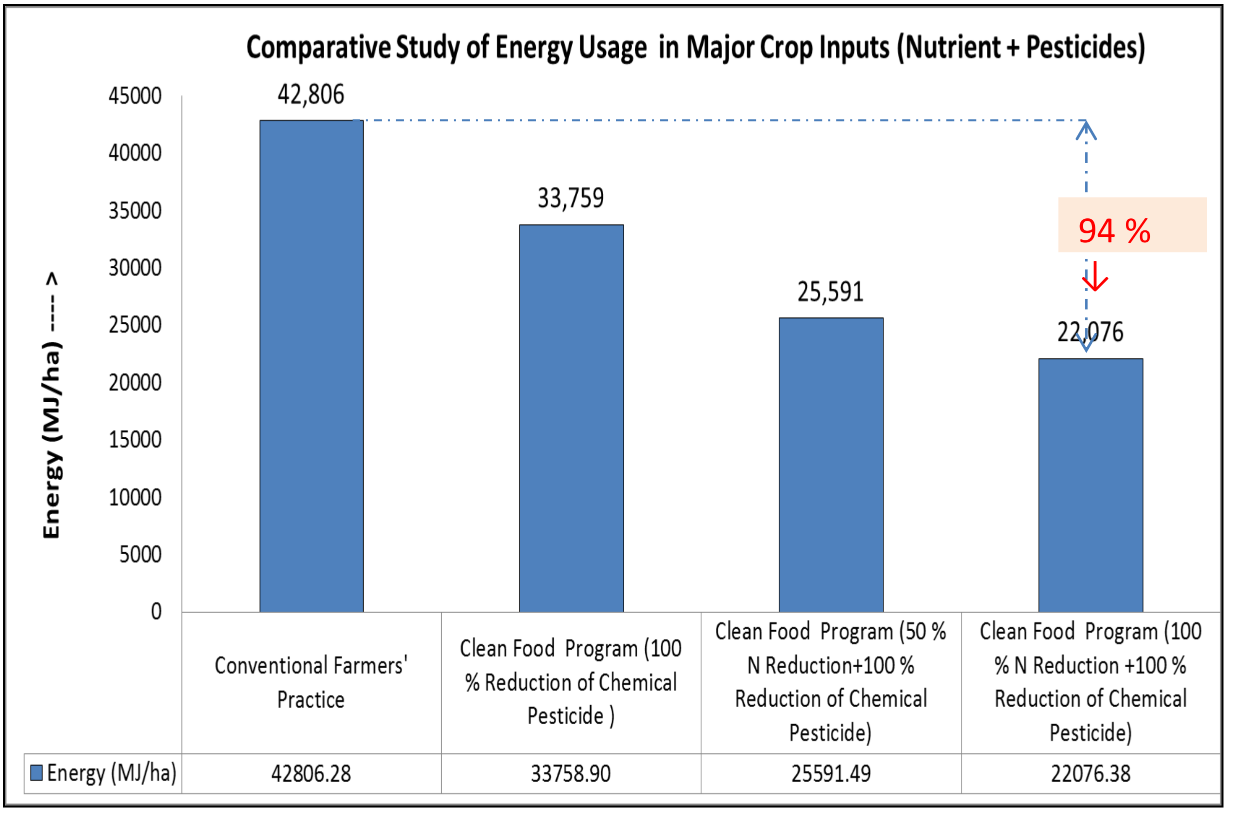


IEP value denotes efficiency of variable energy inputs under different crop management systems and **a high IEP value indicates better energy efficiency, LESSER SPILL OVER IMPACT and less GHG emission leading to HIGHER SUSTAINABILITY QUOTIENT**.

The IEP value increased significantly (up to 135%) under the ‘Clean Food’ Models indicating the efficacy of IRF Technology towards increasing crop production with minimal dependence on non-renewable energy sources; supporting human health soil and the environment by cutting down on the GHG emission .

Evaluation of Energy Investment

The graph indicates total energy use under the different crop management systems, in respect of two most unsustainable inputs of conventional farming i.e., N- fertilizer and Chemical pesticides.



The energy investment reduced by 21% under 'Clean Food' Model with 100% elimination of synthetic pesticides. However, **the investment lowered by a remarkable 94% when both chemical pesticides and N- fertilizers were completely eliminated.**

The significance of this impact can be judged from the fact that there was No Crop Loss during the process, which again substantiated the relevance of Inhana Plant Health Management (IPHM) and the significance of self- generated microflora in the applied Novcom compost towards speedy regeneration of soil health and crop sustenance under complete reduction of N- fertilizers ; leading to abatement of a crucial GHG- Nitrous Oxide

The results indicated a HIGHER SUSTAINABILITY QUOTIENT of the 'Clean Food' Models under IRF Technology developed under the IBM-IORF Sustainability Project.

The findings conclusively indicated that adoption of Sustainable Crop Technology will be crucial for reduction/ elimination of Non- Renewable Energies while Sustaining/ Improving Crop Production or in other words towards improving the Energy Productivity- a benchmark criteria for Sustainable Agriculture, which forms the only solution for Food Security and empowerment of the Food Growers especially under the existential climate change.

Chapter 6 : Study of GHG Footprint under the different Clean Food Models in major cropping sequences.

Summary

Agriculture is both a victim of and a contributor to climate change. On the one hand, agricultural activities contribute approximately 30 per cent of total greenhouse gas emissions, mainly due to the use of chemical fertilizers, pesticides and animal wastes which is bound to further rise as a result of an increase in the demand for food by a growing global population and the intensification of agricultural practices. On the other hand, these greenhouses gases include nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4), which all contribute to climate change and global warming and thereby have a profound impact on the sustainability of agricultural production systems.

Under IBM-IORF Sustainability project at Nadia, West Bengal, comparative study of GHG emission under conventional farmers practice and clean food was studied on 11 major crop sequence. The study showed **total GHG emission** (from Chemical Fertilizers & Pesticides) under conventional farmers practices varied for **0.10 to 0.20 Kg CO_2 eq** with the highest carbon footprint under French bean-Okra- Onion crop sequence.

Clean Food with 100% Reduction of N- fertilizer & Chemical Pesticides Model indicates a 258% reduction in the GHG emission or a GHG Footprint of (-)0.31 kg CO_2 eq. per kg crop when both the hands of unsustainability i.e., the N- fertilizers and Pesticides are eliminated.

Introduction

Increased emission of green house gases with enhanced industrialization, urbanization and conventional agricultural practice accelerates climate change which poses a fundamental threat to the environment, biodiversity and peoples' livelihoods. Specially the increasing risk of disruption in crop production due to climate change impact throw a major challenge towards mitigating global hunger, considering that an estimated 60 per cent more food need to be produced by 2050 to feed a world population of 9.3 billion.

The challenge is intensified by agriculture's extreme vulnerability to climate change. The negative impacts of climate change are already being felt, in terms of increasing temperatures, weather variability, shifting agro-ecosystem boundaries, invasive crops and pests, and more frequent extreme weather events. On farms, climate change is reducing crop yields, the nutritional quality of major cereals, and lowering livestock productivity (The World Bank, 2022).

But agriculture is also the second largest contributor of greenhouse gases (GHG). Emission enhances with industrial agriculture, with use of fossil fuel, chemical fertilizers (especially N), synthetic chemicals and involvement of machinery increases. According to an estimate by FAO, in 2018; global emissions due to agriculture was 9.3 billion tonnes of CO_2 equivalent (CO_2eqv.), which took a 14 percent growth since 2000 and accounted for 17 percent of global GHG emissions from all sectors.

However, agriculture is also the only sector that can enable GHG mitigation and adaptation due to its potential to store a vast amount of soil carbon up to 1 billion metric tons per year, which would offset around 10% of the annual GHG emissions of 8–10 billion metric tons per year. According to an estimate by Dr. Lal, the renowned Soil Scientist and the 2020 World Food Prize Winner, the carbon sink capacity of the world's agricultural and degraded soils is 50 to 66% of what it has been historically. This means our soil can hold 42 to 78 billion metric tons more carbon.

Increasing the amount of carbon in soil also makes it more productive for farmers which can only be through sustainable farming approaches. And for any sustainable farming, amelioration of soil is the most important criteria and quality manure, rich in self-generated microflora is prerequisite for ensuring time bound effectiveness irrespective of agro-ecological settings. Effective technology is the primary requirement towards effective bio-conversion of bio-resources, especially hard to biodegrade waste into quality manure and for GHG offsetting under the composting process towards making meaningful contribution in respect of climate change mitigation. In this aspect, analysis of GHG mitigation potential of agricultural ecosystems is a concrete approach to investigate and **assess carbon saving, and evaluate the SUSTAINABILITY QUOTIENT of any Crop Production System**.

GHG Estimation from Novcom Compost at the Project Site

Assessment of GHG Footprint under different cropping sequences were done in Model Farm under different 'Clean Food' Models which are as given below :

i) 'Clean Food' Program with 100% Reduction of Chemical Pesticides (CF).

ii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **50% Reduction of N- fertilizer** (CF_{50}).

iii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **100% Reduction of N- fertilizer** (CF_{5100}).

The data obtained was compared with the energy use under Conventional Farming Practice (CFP).

The Evaluation was done w.r.t. Eleven different Cropping Sequences followed in the project area *viz*., Tomato-Cucumber-Coriander, Potato-Brinjal-Cauliflower, Potato-Okra-Cabbage, Brinjal-Frenchbean-Spinach, Pumpkin-Okra-Cabbage, Brinjal-Carrot, French bean-Okra- Onion, Potato-Chilli- Carrot, Tomato-Ridge gourd- Spinach, Peas -Yam –Cabbage and Pointed Gourd – Cauliflower.

The assessment was done following IPCC methodology (IPCC, 2019) and Cool Farm Tool (Hillier, 2013).

GHG Footprint under Conventional Farmers' Practice

Study was done to evaluate the current GHG status under the conventional farmers' practice. The findings are elaborated in table 1 and fig 1 and 2.

Total GHG Emission from Nutrient Sources (Chemical NPK) was highest (6914 kg CO_2 eq /ha./year) in the case of Potato-Okra-Cabbage where as it was lowest (3613 kg CO_2 eq /ha./year) in case of Brinjal-French bean-Spinach.

Total GHG emission from chemical pesticides was highest (1886 kg CO_2 eq /ha./year) in case of Pointed Gourd – Cauliflower, and lowest (369 kg CO_2 eq /ha./year) in the case of Peas -Yam –Cabbage.

When evaluated in terms of per kg crop produced, the **total GHG emission** (from Chemical Fertilizers & Pesticides) under conventional farmers practices varied for **0.10 to 0.20 Kg CO_2 eq** with the highest carbon footprint under French bean-Okra- Onion crop sequence.

TABLE 1: GHG Emission (kg CO_2eq) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under Conventional Farmers' Practice (CFP).

Conventional Farmers' Practice	Crop Sequences											Avg. of eleven Crop Sequences
	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7	CS-8	CS-9	CS-10	CS-11	
Total GHG Emission from Nutrient Sources (Chemical NPK) kg CO_2 eq /ha./year	3894	6559	6914	3613	5779	3632	5774	6286	3871	6095	3653	5097
Total GHG from Chemical pesticides (kg CO_2 eq/ha./year)	1435	1640	1476	1476	1599	1497	1415	1353	1148	369	1886	1390
Total GHG for Chemical Fertilizers & Pesticides under Conventional Farmers' Practice (CFP) kg CO_2 eq /ha./year	5329	8199	8390	5089	7378	5129	7189	7639	5019	6464	5539	6488
Total Crop under Conventional Farmers' Practice (kg.ha.)	43125	79425	68025	45450	49050	41850	35175	57825	52725	63675	50400	53339
GHG (Chemical Fertilizers & Pesticides under Conventional Farmers' Practice (CFP) per kg crop (Kg CO_2 equivalent/ per kg. crop)	0.12	0.10	0.12	0.11	0.15	0.12	0.20	0.13	0.10	0.10	0.11	0.12

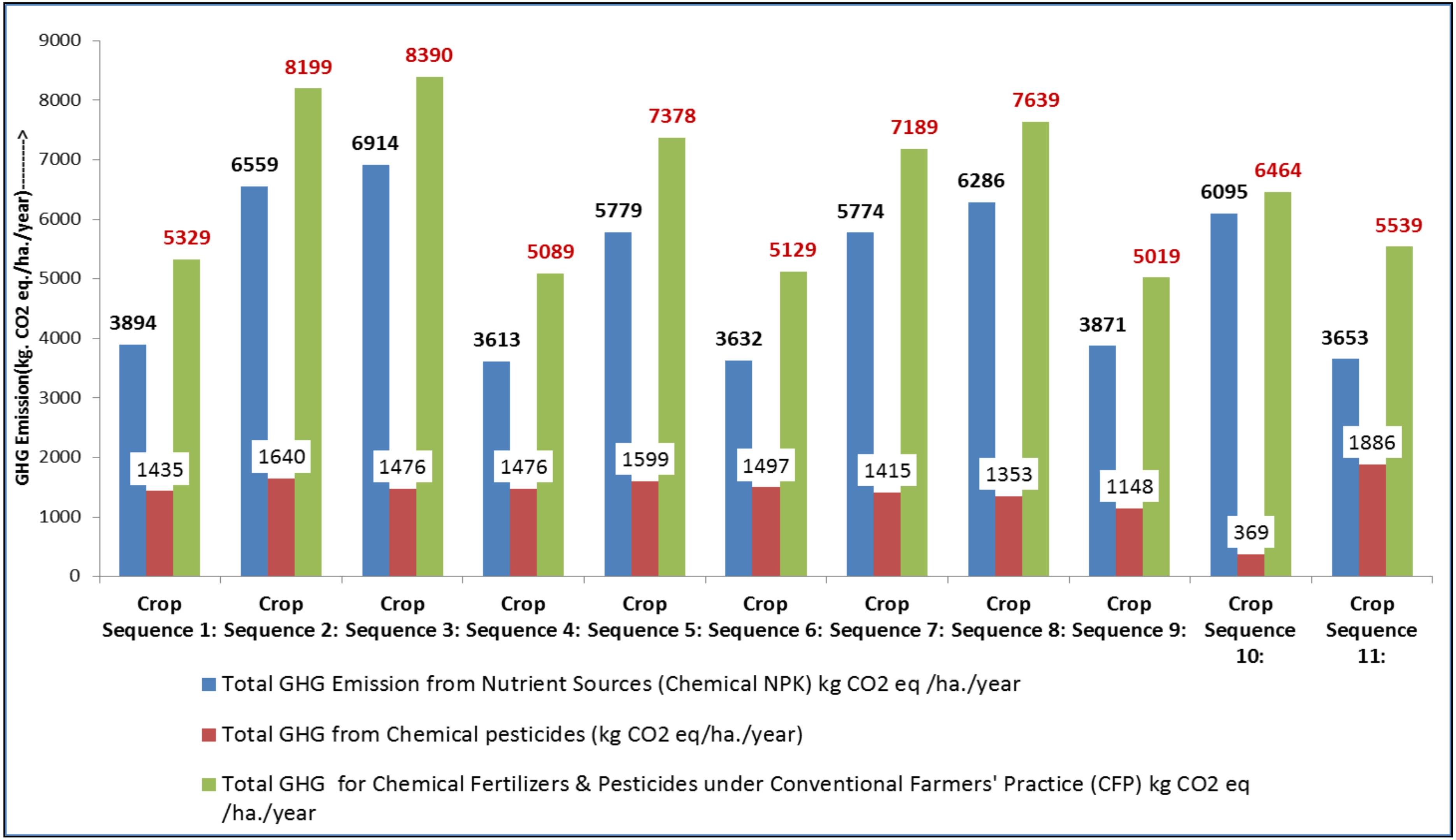


Fig 1 : GHG Emission (kg CO_2 eq) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under Conventional Farmers' Practice (CFP)

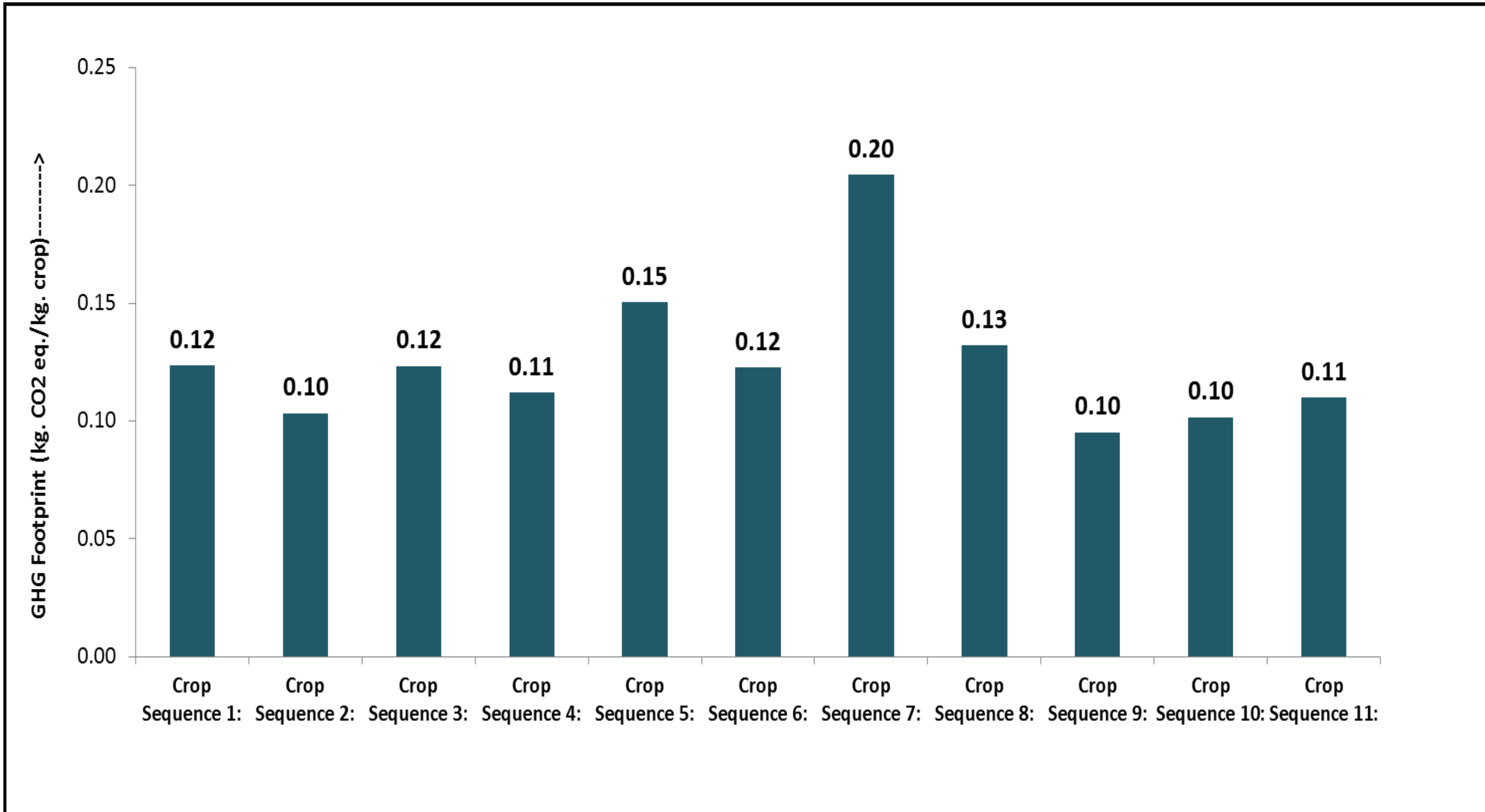


Fig 2 : Total GHG Footprint in eleven Major Crop Sequences under Conventional Farmers' Practice (CFP) (kg CO_2 eq. /kg. crop) (considering chemical fertilizers and pesticide).

In the case of 'Clean Food' Model with 50 % N Reduction+100 % Reduction of Chemical Pesticide, the highest GHG mitigation (-) 3636 kg CO_2 eq /ha./year was obtained under the Brinjal-Frenchbean-Spinach sequence with an average mitigation of (-) 3150 kg CO_2 eq /ha./year. But the potential just jumped by 290% when both N- fertilizer and Chemical Pesticides were fully eliminated. The average GHG mitigation per hectare per year under this 'Clean food' Model was recorded as (-) 12285 kg CO_2 eq.

When assessed in terms of GHG mitigation per kg crop the highest ((-)11237 kg CO_2 eq) mitigation was recorded under Potato-Brinjal-Cauliflower sequence w.r.t. the 'Clean Food' Model with 50 % N Reduction+100 % Reduction of Chemical Pesticide. While **under complete elimination of both N- fertilizer and Chemical Pesticides the average mitigation shot up by 67% (18773 kg CO_2 eq per kg crop)** with the highest abatement ((-)22397 kg CO_2 eq per kg crop) under Potato-Okra-Cabbage.

Table 3, fig. 5 and 6 indicates the Total and Net GHG Footprint under the 'Clean Food' Models with 50 % N Reduction+100 % Reduction of Chemical Pesticide and 100 % Reduction of both N- fertilizer and Chemical pesticides w.r.t. the Conventional farmers' Practice. The data indicates a 258% reduction in the GHG emission or a GHG Footprint of (-)0.31 kg CO_2 eq. per kg crop when both the hands of unsustainability i.e., the N- fertilizers and Pesticides are eliminated under the 'Clean food' Model.

ACFA (Version 1.0)

Agriculture Carbon Footprint Assessor - *An Evaluation Protocol based on IPCC Guideline*

Developed by
Advisory Team, IORF, Kolkata

1st Carbon Assessment Tool for Sustainable Agriculture in India

An Outcome of IBM-IORF Sustainability Project

TABLE 2: GHG Emission (Kg CO_2 eq/ha./year) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under Conventional Farmers' Practice (CFP) vs. Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide) and Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide)

Different Management Practices	Crop Sequences											Avg. of eleven Crop Sequences
	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7	CS-8	CS-9	CS-10	CS-11	
Conventional Farmers' Practice: Total GHG for Chemical Fertilizers & Pesticides under Conventional Farmers' Practice (CFP) kg CO_2 eq /ha./year	5329	8199	8390	5089	7378	5129	7189	7639	5019	6464	5539	6488
Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide): GHG Emission kg. CO_2 /ha./year	-3451	-3038	-2845	-3636	-3423	-2460	-3540	-3304	-3461	-2138	-2306	-3150
Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide): : GHG Emission kg. CO_2 /ha./year	-11643	-14028	-14007	-11643	-13987	-9318	-13987	-14069	-11642	-11786	-9236	-12285
Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide): Net GHG Emission over CFP kg. CO_2 /ha./year	-8780	-11237	-11235	-8725	-10801	-7589	-10728	-10943	-8480	-8602	-7845	-9637
Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide): Net GHG Emission over CFP kg. CO_2 /ha./year	-16972	-22227	-22397	-16732	-21365	-14447	-21176	-21708	-16661	-18249	-14775	-18773

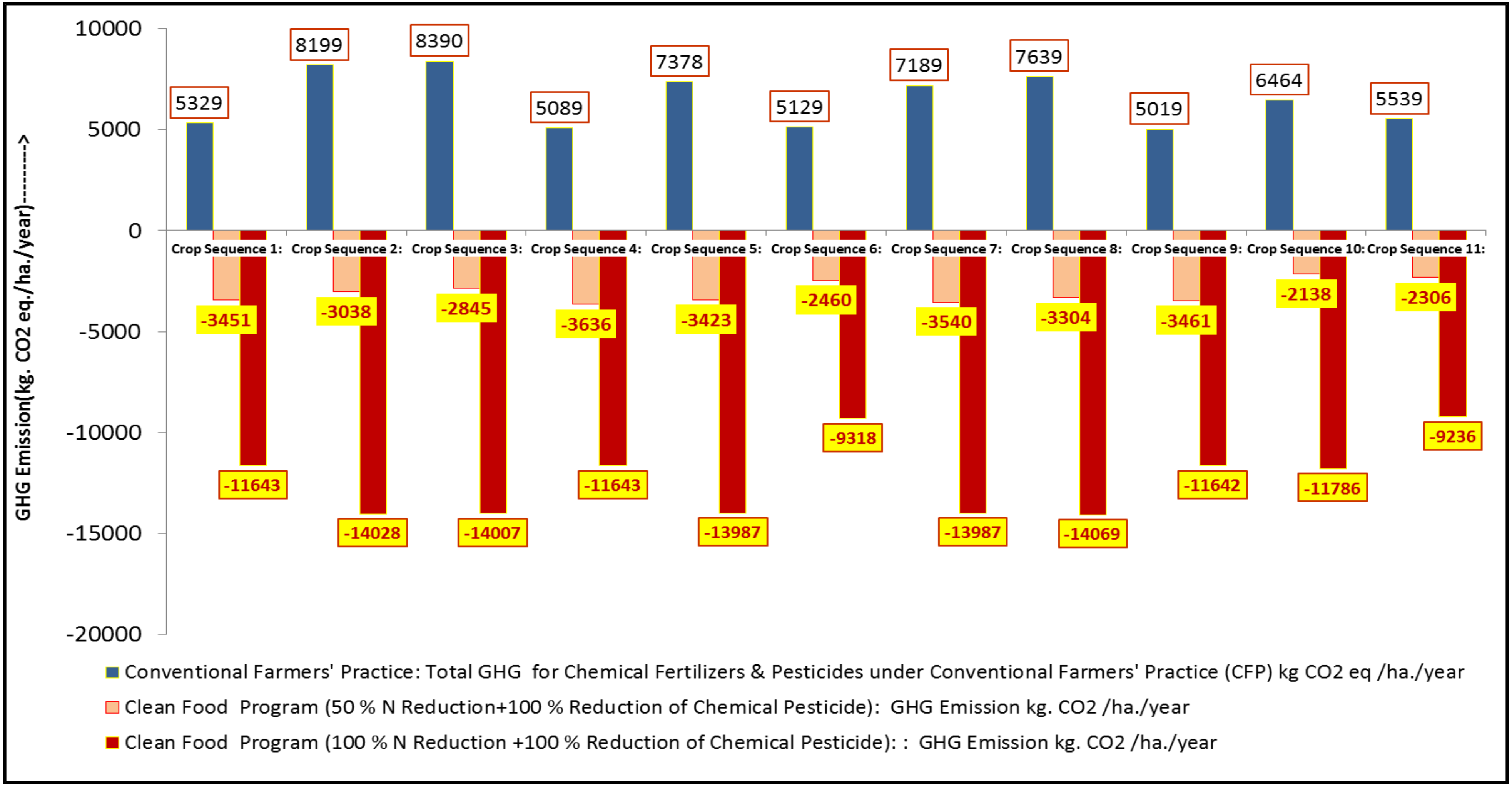


Fig 3: GHG Emission (Kg CO_2 eq/ha./year) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under Conventional Farmers' Practice (CFP) vs. GHG mitigation Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide) and Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide).

TABLE 3: GHG Footprint (kg CO_2 eq/ kg crop) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under Conventional Farmers' Practice (CFP) vs. Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide) and Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide).

Different Management Practices	Crop Sequences											Avg. of eleven Crop Sequences
	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7	CS-8	CS-9	CS-10	CS-11	
Conventional Farmers' Practice: Total GHG Footprint under Conventional Farmers' Practice (CFP) kg CO_2 eq /kg. crop	0.12	0.10	0.12	0.11	0.15	0.12	0.20	0.13	0.10	0.10	0.11	0.12
Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide): Total GHG Footprint kg. CO_2 /kg crop	-0.07	-0.03	-0.04	-0.07	-0.06	-0.05	-0.09	-0.05	-0.06	-0.03	-0.04	-0.05
Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide): : Total GHG Footprint kg. CO_2 /kg crop	-0.22	-0.15	-0.17	-0.22	-0.24	-0.19	-0.34	-0.20	-0.17	-0.16	-0.16	-0.19
Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide): Net GHG Footprint over CFP kg. CO_2 /kg. crop	-0.20	-0.14	-0.16	-0.18	-0.21	-0.18	-0.30	-0.18	-0.15	-0.13	-0.15	-0.17
Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide): Net GHG Footprint over CFP kg. CO_2 /kg. crop	-0.34	-0.25	-0.29	-0.33	-0.39	-0.32	-0.54	-0.33	-0.27	-0.26	-0.27	-0.31

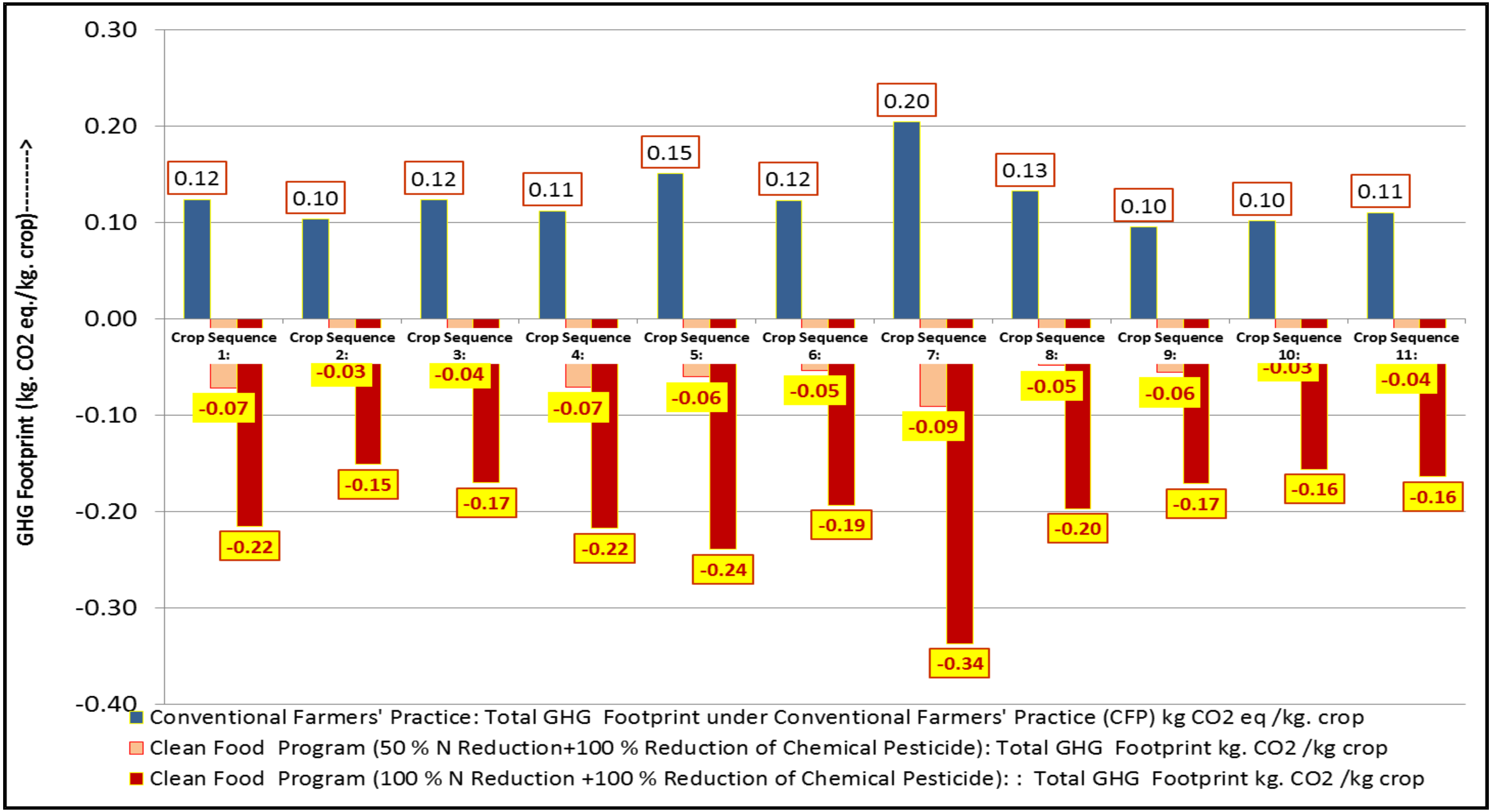


Fig 4 : GHG Footprint (kg CO_2 eq/ kg. crop) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under Conventional Farmers' Practice (CFP) vs. Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide) and Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide).

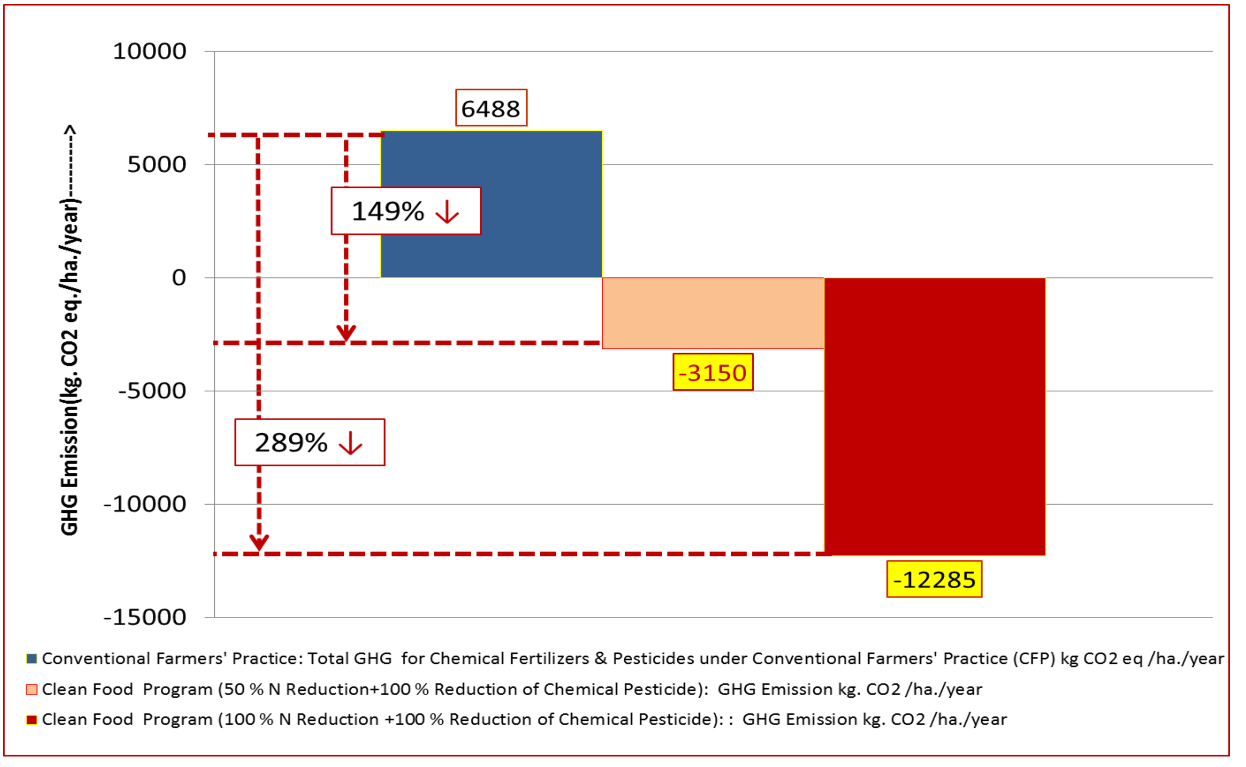


Fig 5 : Avg. GHG Emission (kg CO_2 eq/ha./year) from two major unsustainable sources (Chemical Fertilizers & Pesticides) in the Crop Sequences under Conventional Farmers' Practice (CFP) vs. GHG mitigation under 'Clean Food' Models with 50 % N Reduction + 100 % Reduction of Chemical Pesticide and 100 % Reduction of both N- fertilizer and Chemical Pesticide.

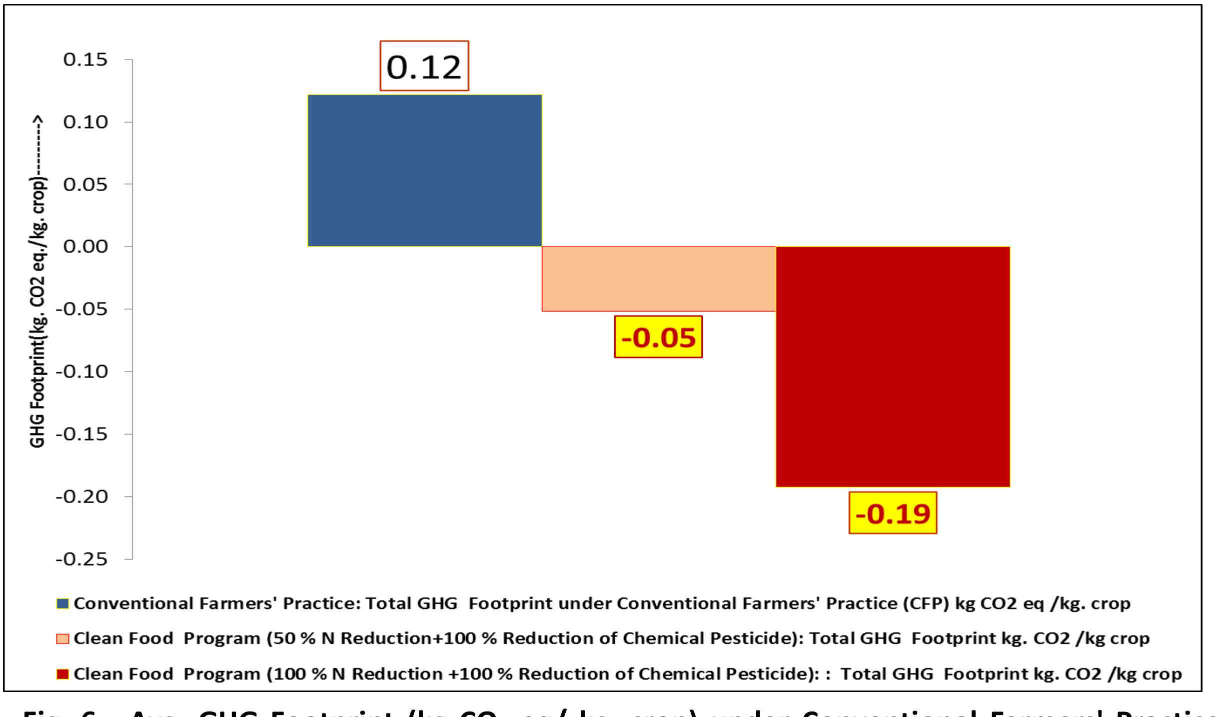


Fig. 6 : Avg. GHG Footprint (kg CO_2 eq/ kg. crop) under Conventional Farmers' Practice (CFP) vs. 'Clean Food' Models with 50 % N Reduction + 100 % Reduction of Chemical Pesticide and 100 % Reduction of both N- fertilizer and Chemical Pesticide.

Table 4 and fig. 7 chronicles the GHG abatement potential of 'Clean Food' with 100 reduction of only one hand of unsustainability i.e. chemical pesticides. **Assessment indicates that a minute 18-20 % reduction in GHG emission can be achieved eve with complete elimination of chemical pesticides. The finding substantiated the fact that N-fertilizers are the major GHG contributors under the conventional farmers' practice.** Under this Model the highest reduction in emission in terms of 7100 kg kg CO_2 eq per ha per year was achieved under the Potato-Okra-Cabbage while in terms of per kg crop Tomato-Ridge gourd- Spinach and Pointed Gourd – Cauliflower came out as the most carbon efficient (0.07 kg CO_2 eq) cropping sequences.

Component of GHG Emission and the total GHG Emission/ Mitigation under the different 'Clean Food' Models are presented in table 5 and 6. The tables indicated that Clean Food Program enabled GHG mitigation as opposed to the conventional farmers' practice which caused GHG emission.

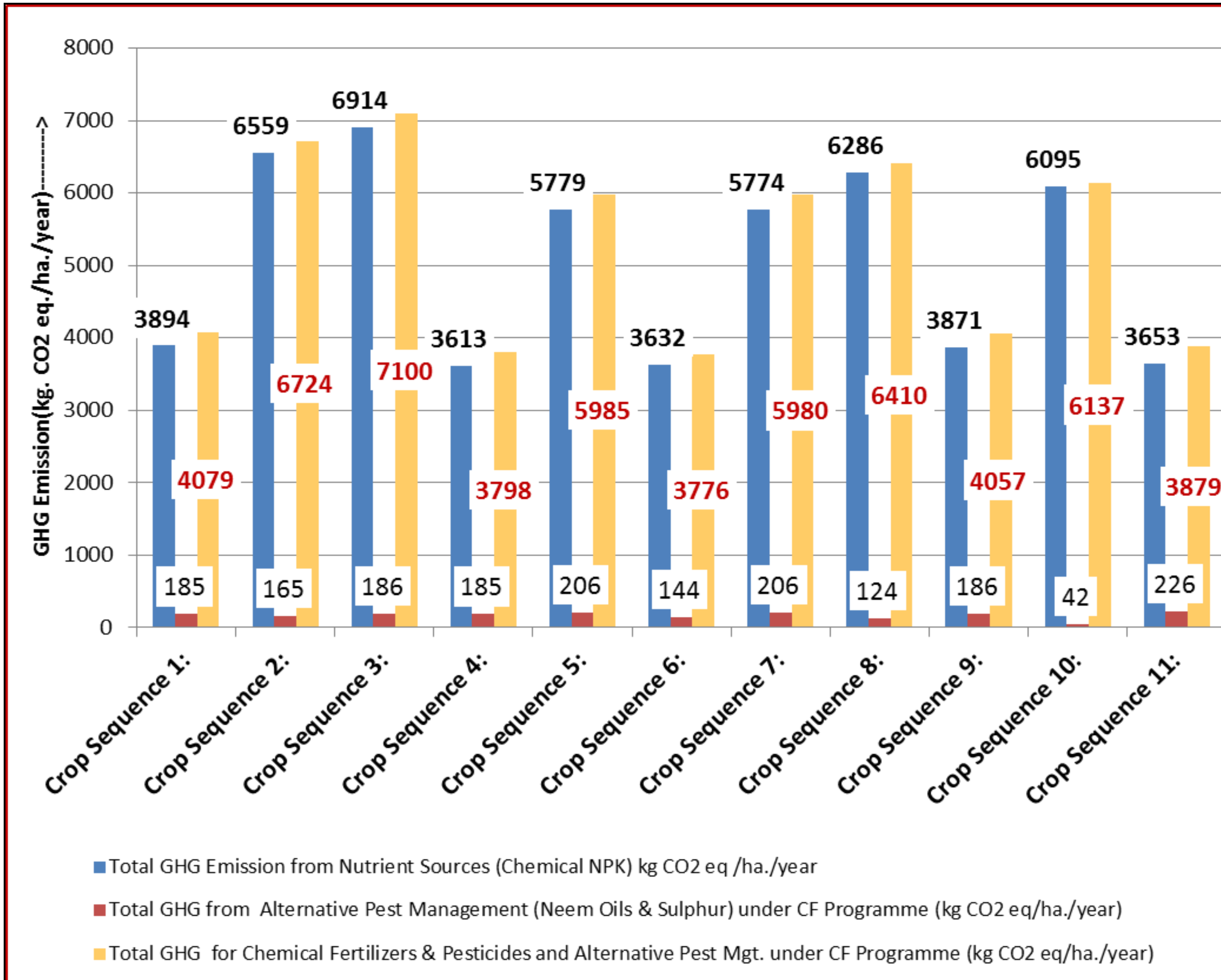
Average GHG emission was (+) 0.12 kg CO_2-eq/kg produce under conventionally managed crop sequence, where as (-)0.05 kg CO_2-eq/kg produce and (-)0.19 CO_2-eq/kg produce, under Clean Food Models with 50 % Chemical N Reduction+ 100 % reduction of chemical pesticides and 100 % Reduction of both N-fertilizer and Chemical Pesticide; respectively**.**

Comparative study of GHG Emission under Conventional Farmers' Practice *vs*. the GHG mitigation potential under the different 'Clean Food' Models under the Phase-II Project once again substantiated that, a progression towards Safe and Sustainable Agriculture especially complete elimination of both the hands of unsustainability i.e. the N-fertilizers and Chemical Pesticides can totally transform agriculture from a GHG Emitting Source to a GHG Guzzling Sink.

Application of Quality Novcom compost in soil to offset N fertilizers are the primary step towards GHG Mitigation.

TABLE 4: Total GHG Emission kg. CO_2 eq./ha./year & GHG Footprint Kg. CO_2 eqv./kg. Crop) under Clean Food Program (100 % Reduction of Chemical Pesticide).

Clean Food Program (100 % Reduction of Chemical Pesticide)	Crop Sequences											Avg. of eleven Crop Sequences
	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7	CS-8	CS-9	CS-10	CS-11	
Total GHG Emission from Nutrient Sources (Chemical NPK) kg CO2 eq /ha./year	3894	6559	6914	3613	5779	3632	5774	6286	3871	6095	3653	5097
Total GHG from Alternative Pest Management (Neem Oils & Sulphur) under CF Programme (kg CO2 eq/ha./year)	185	165	186	185	206	144	206	124	186	42	226	169
Total GHG for Chemical Fertilizers & Pesticides and Alternative Pest Mgt. under CF Programme (kg CO2 eq/ha./year)	4079	6724	7100	3798	5985	3776	5980	6410	4057	6137	3879	5266
Total Crop under Clean Food Program (100 % Reduction of Chemical Pesticide)	48450	86025	78525	47625	56325	42900	40800	65138	59325	70050	55125	59117
GHG (Chemical Fertilizers & Pesticides) emmision per kg crop under Clean Food Program (100 % Reduction of Chemical Pesticide)	0.08	0.08	0.09	0.08	0.11	0.09	0.15	0.10	0.07	0.09	0.07	0.09



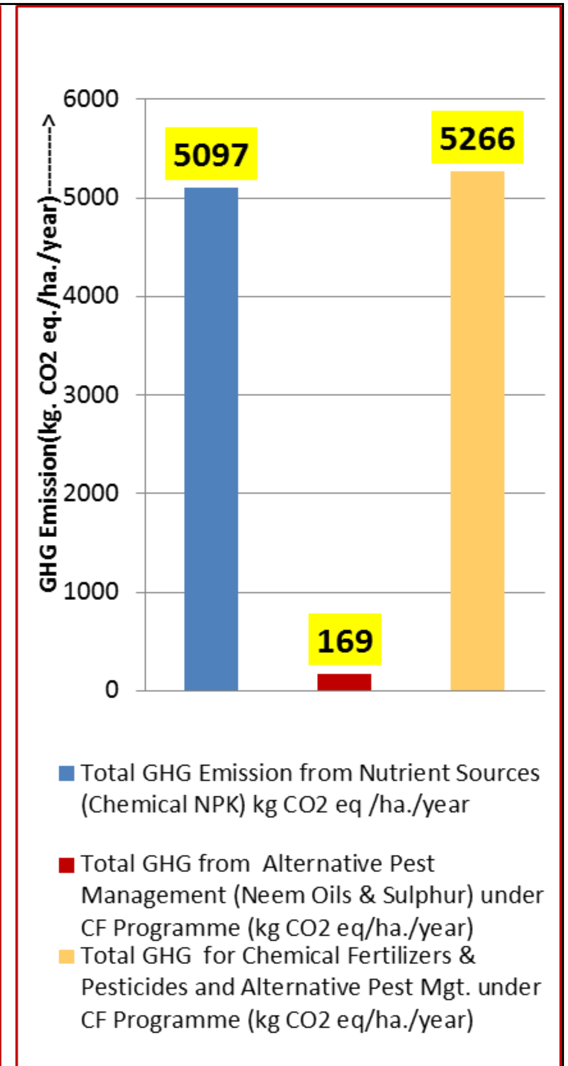


Fig 7 : GHG Emission (kg CO_2 eq) under Clean Food Program (100 % Reduction of Chemical Pesticide).

Table 5: GHG AUDIT (Total GHG Emission kg. CO2 eq./ha./year & GHG Footprint Kg. CO_2 eqv./kg. Crop) under Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide).

Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide)	Crop Sequences											Avg. of eleven Crop Sequences
	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7	CS-8	CS-9	CS-10	CS-11	
Total GHG Emission from Nutrient Sources (Chemical NPK + Compost Application) kg CO2 eq /ha./year	4202	6202	6374	4017	5776	3666	5659	5977	4191	5657	3738	5042
Total GHG from Alternative Pest Management (Neem Oils & Sulphur) under CF Programme (kg CO_2 eq/ha./year)	185	165	186	185	206	144	206	124	186	42	226	169
Total GHG for Chemical Fertilizers & Pesticides, Compost Application and Alternative Pest Mgt. under CF Programme (kg CO_2 eq/ha./year)	4387	6367	6560	4202	5982	3810	5865	6101	4377	5699	3964	5210
Total NOVCOM Compost Applied (kg/ha.)	38	45	45	38	45	30	45	45	38	38	30	40
kg CO_2 per ha. Saving - for Compost application **(7.5 tons or 15 tons/ha/crop)**	7838	9405	9405	7838	9405	6270	9405	9405	7838	7838	6270	8360
Actual GHG Emission kg. CO_2 /ha./year	-3451	-3038	-2845	-3636	-3423	-2460	-3540	-3304	-3461	-2138	-2306	-3150
Total Crop under Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide)	48113	90300	80100	51225	56775	45975	39000	68175	62250	74100	55650	61060
GHG (Chemical Fertilizers & Pesticides) emmision per kg crop under Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide)	-0.07	-0.03	-0.04	-0.07	-0.06	-0.05	-0.09	-0.05	-0.06	-0.03	-0.04	-0.05

Table 6 : Total GHG Emission (kg. CO2 eq./ha./year) & GHG Footprint (Kg. CO_2 eqv./kg. Crop) under Clean Food Program (100 % N Reduction+100 % Reduction of Chemical Pesticide).

Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide)	Crop Sequences											Avg. of eleven Crop Sequences
	CS-1	CS-2	CS-3	CS-4	CS-5	CS-6	CS-7	CS-8	CS-9	CS-10	CS-11	
Total GHG Emission from Compost Application kg CO_2 eq /ha./year	3847	4617	4617	3847	4617	3078	4617	4617	3847	3847	3078	**4057**
Total GHG from Alternative Pest Management (Neem Oils & Sulphur) under CF Program (kg CO2 eq/ha./year)	185	165	186	185	206	144	206	124	186	42	226	**169**
Total GHG for Compost Application and Alternative Pest Mgt. under CF Program (kg CO_2 eq/ha./year)	4032	4782	4803	4032	4823	3222	4823	4741	4033	3889	3304	**4226**
Total NOVCOM Compost Applied (kg/ha.)	75	90	90	75	90	60	90	90	75	75	60	**79**
kg CO_2 per ha. Saving - for Compost application **(15 tons or 30 tons/ha/crop)**	15675	18810	18810	15675	18810	12540	18810	18810	15675	15675	12540	**16511**
Actual GHG Emission kg. CO_2 /ha./year	-11643	-14028	-14007	-11643	-13987	-9318	-13987	-14069	-11642	-11786	-9236	-12285
Total Crop under Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide)	54000	92775	82125	53400	58425	48150	41475	71325	67875	75450	56250	**63750**
GHG (Chemical Fertilizers & Pesticides) emission per kg crop under Clean Food Program (100 % N Reduction+100 % Reduction of Chemical Pesticide)	**-0.22**	**-0.15**	**-0.17**	**-0.22**	**-0.24**	**-0.19**	**-0.34**	**-0.20**	**-0.17**	**-0.16**	**-0.16**	-0.19

Annexure - I

Winning Awards for 'Clean Food Model'

Winner in the category “Best Innovative CSR Project” at the 6th Edition CSR Summit & Awards 2022, held on 8 th Nov., 2022 at Bangalore.

Dr. P. Das Biswas & Dr. A Seal, IORF & Mrs. Shobha Mani, IBM receive the Winner Award

Dr. P. Das Biswas, , Founder Director of IORF along with Mr. Manoj Balachandran, Head - CSR , IBM India & South Asia and Mrs. Sobha Mani, Lead-Sustainability Accelerator Program, IBM, India; along with Dr. Antara Seal and Dr. Ranjan Bera at CSR Summit & Award Ceremony, 2022

Winner in the Category 'Environment' of the 8th CSR Impact Awards by CSRBOX and Dalmia Bharat Foundation, on 15th Nov., 2022 at New Delhi.

8th CSR Impact Awards Winner in Environment Category


CSRBOX

8th CSR Impact Awards 2022

Dalmia Bharat Foundation

We are delighted to present the

8th CSR Impact Award

to

IBM India Pvt. Ltd.

with implementation support from

Inhana Organic Research Foundation

in the *Environment (Small)* Category

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

on

November 15th, 2022

at the India CSR Summit, New Delhi

We appreciate the partner/s' and the implementing organisation/s' efforts and commitment to the Corporate Social Responsibility practices.

Mr. Bhomik Shah
CEO, CSRBOX

Mr. Pankaj Rastogi
Trustee, Dalmia Bharat Foundation,
CEO, Dalmia Bharat Sugar and Industries Limited

Evaluation Partners

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Jagran Lakecity University

Faculty of Social Sciences
University of Delhi

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TISS

Annexure - II

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

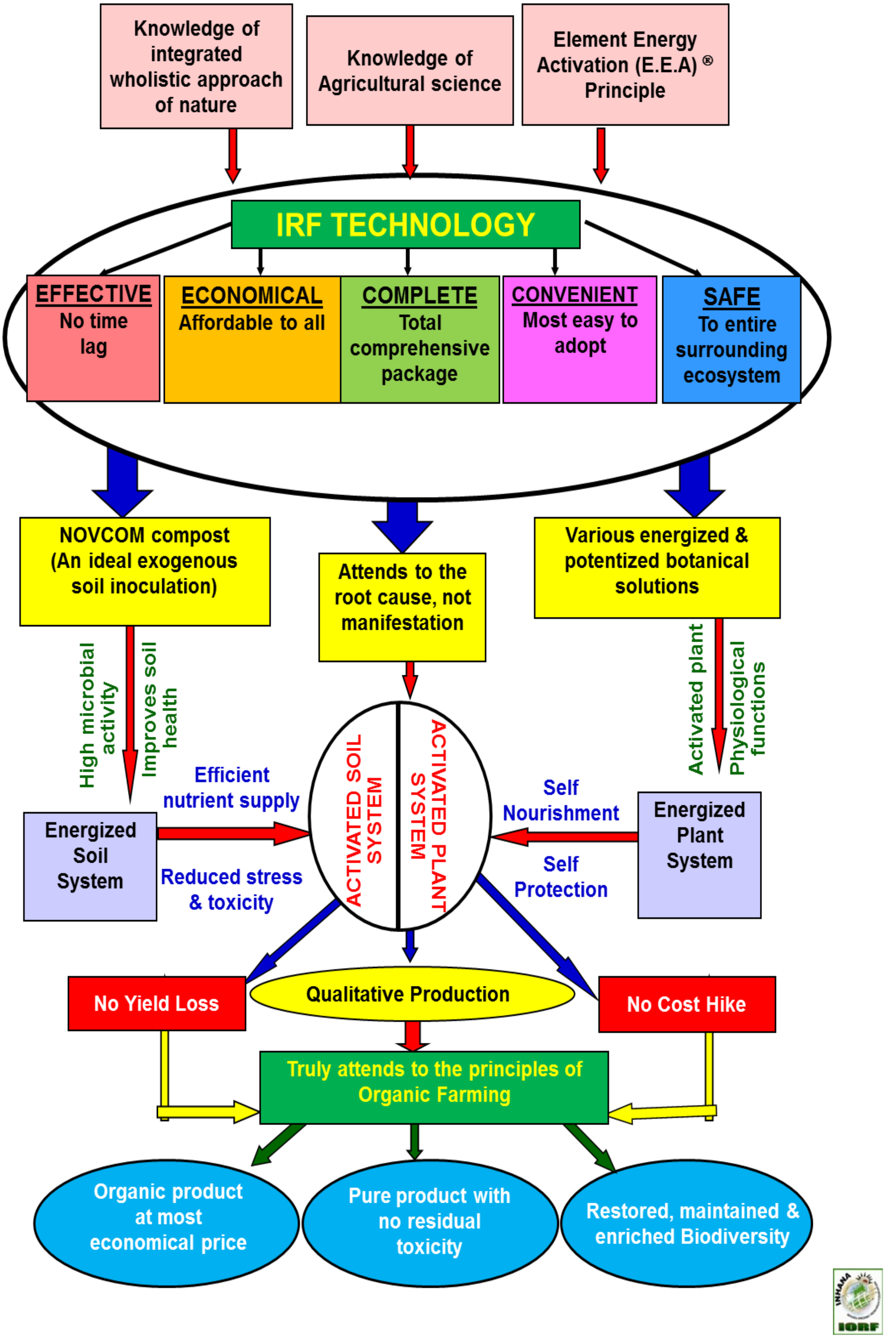
India's Traditional Wisdom stressed that 'Nature is not only Holistic, it is WHOLISTIC. . . . Once broken down, nature cannot be returned to its original state. . . . Union is always superior to the division . . the undifferentiated always superior to the differentiated'.

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

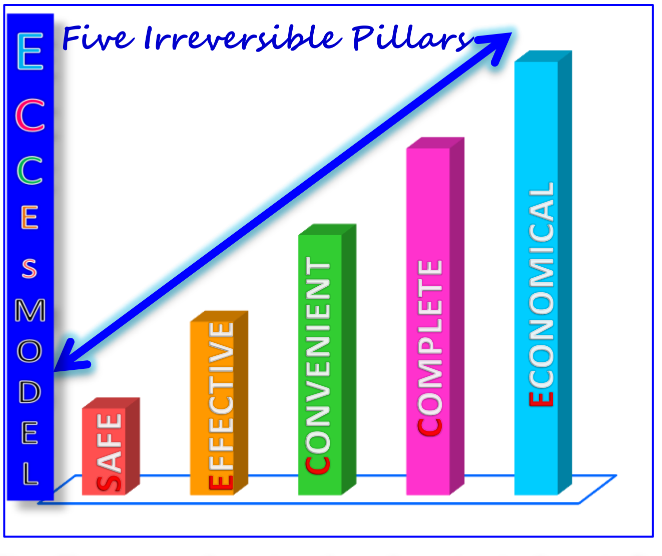


IRF TECHNOLOGY works on the 'Energy Element Activation (E.E.A.) Principle' towards Energy Infusion into the Soil and Plant so as to enable Ecologically & Economically Sustainable Crop Production. The objective of Plant Health Management is to reactivate the two inherent qualities of the plant system,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

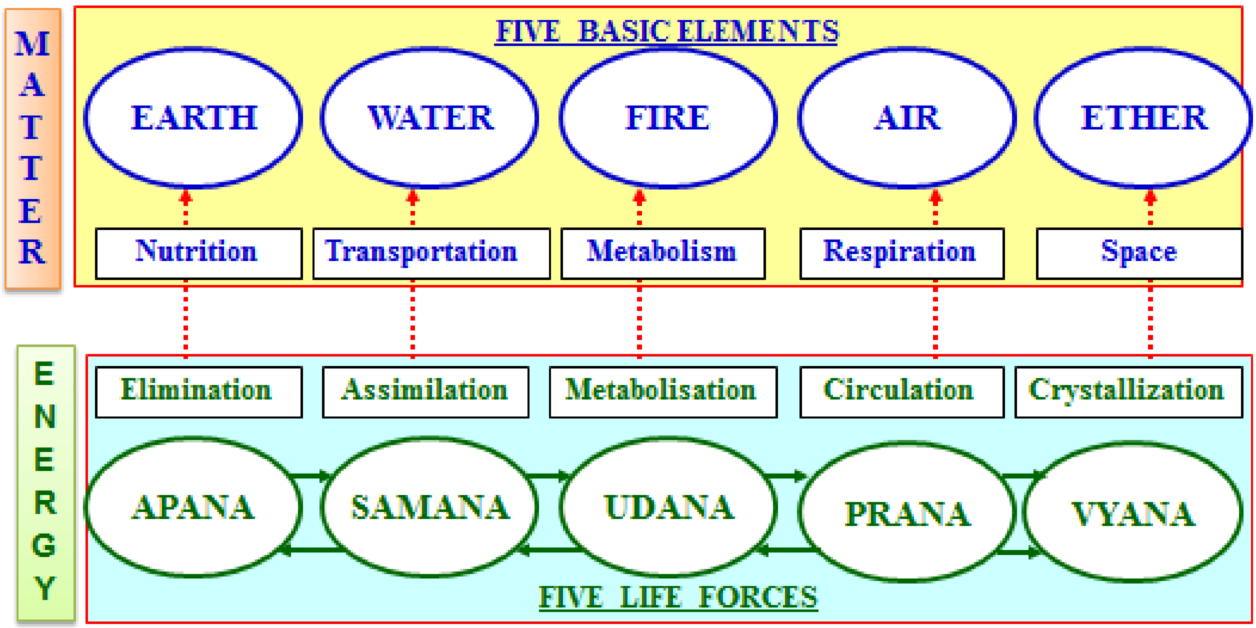
The uniqueness of this Crop Technology is that it is based on the **ECCES Model; i.e., Effective, Complete, Convenient, Economical and Safe;** that ensures Ecologically and Economically Sustainable and Safe crop production for the marginal and resource poor farmers which should be a prime criteria for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

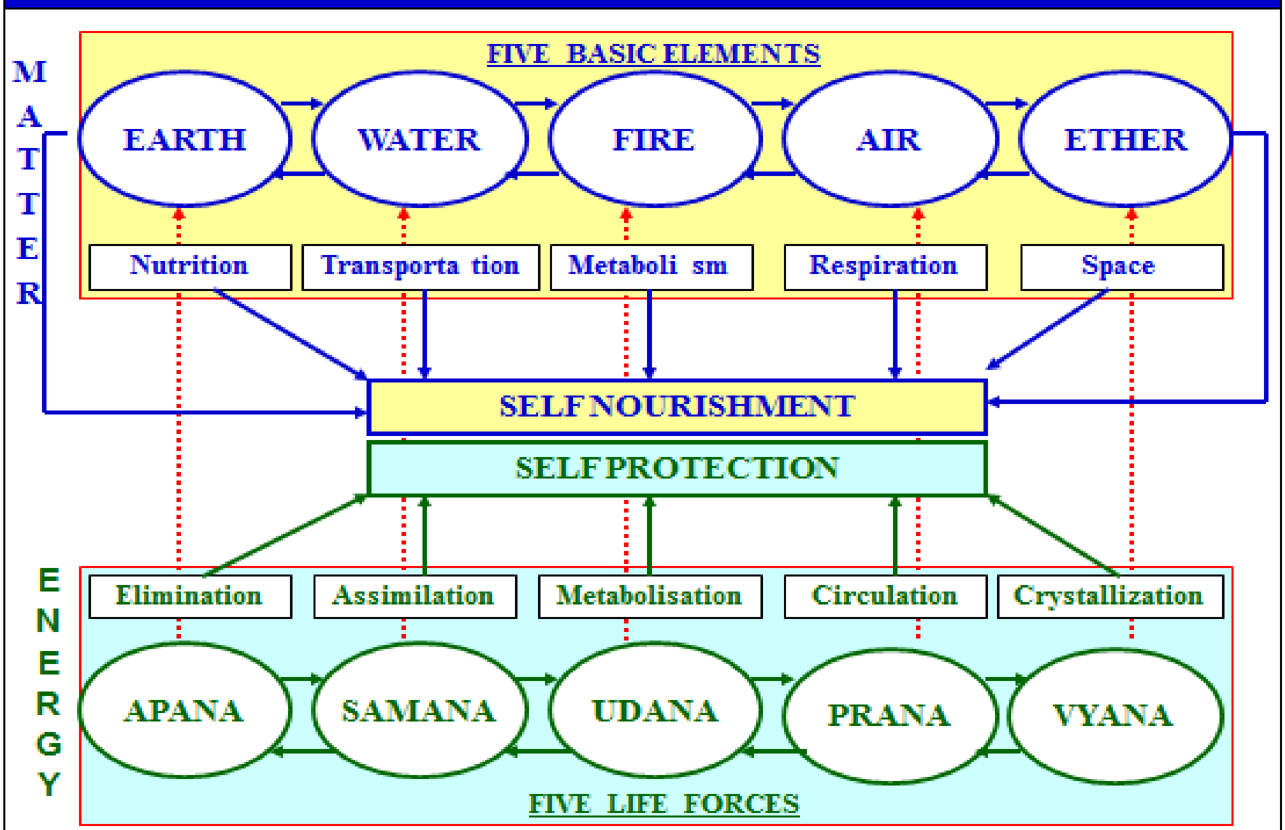
These five basic elements take care of **Self-Nourishment.**

Working Mechanism of E.E.A Principle



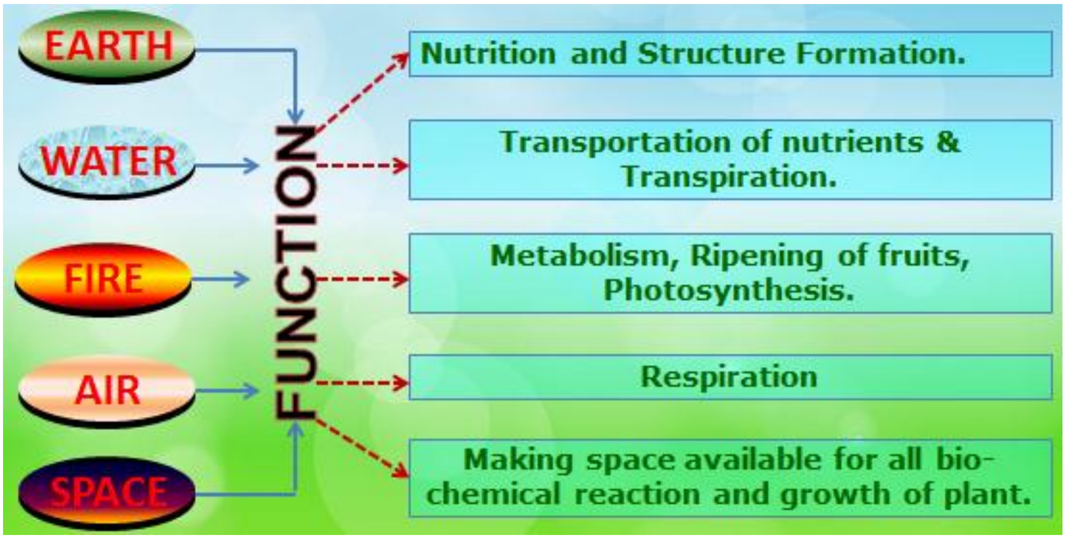
LIFE FORCES/ ENERGY	PREDOMINANT AREAS	BASIC ELEMENTS
APANA	ROOTS	EARTH
SAMANA	AERIAL PARTS	WATER
UDANA	LEAVES	FIRE
VYANA	WHOLE PLANT BODY	AIR
PRANA	CELLS	ETHER

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 :

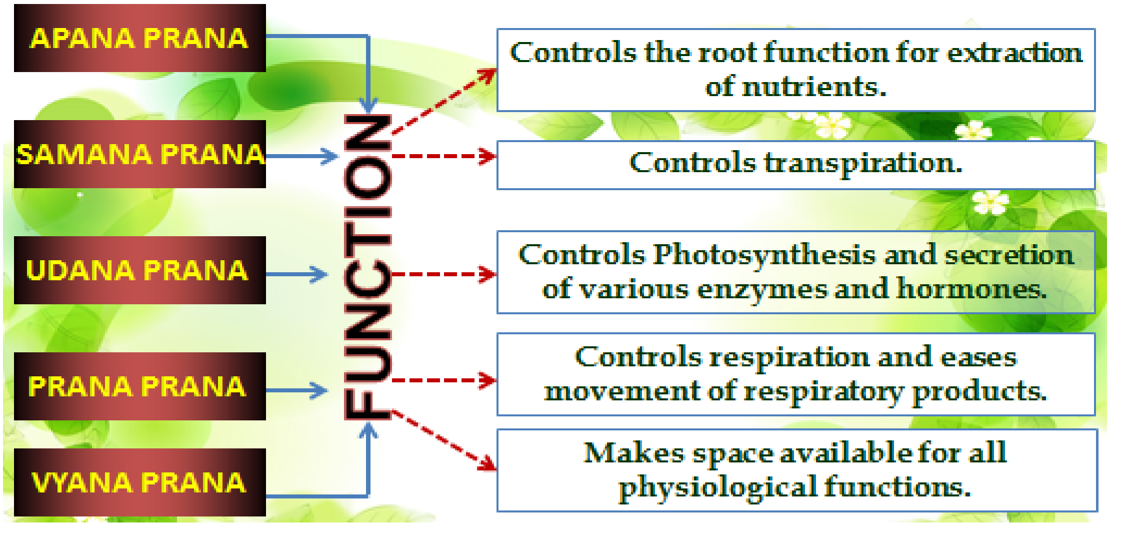


There are five different life forces or energies in all living bodies as well as in the plant system originated from the Basic Life Force i.e. Solar Energy. The **Self-Protection** mechanism is controlled by the Life Forces and they are also the vehicles of the basic elements and movement of nutrients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

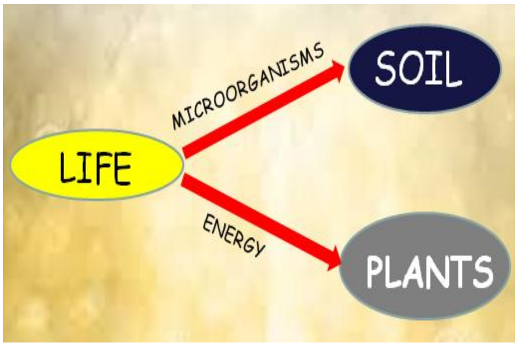
In plant system being 'PURE NATURE', energies directly activates on the matter or elements. Here Life Forces or Energies work as the power of expressing the former and moving the latter.

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**.

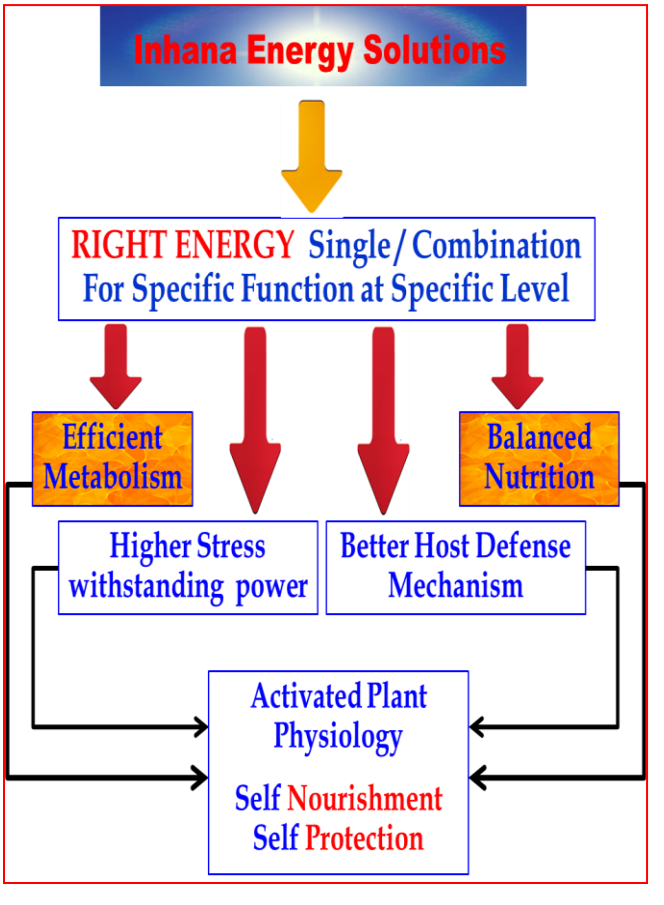
But He also realized that due to Resource Scarcity large scale Soil Rejuvenation will be a Long Term process. But REACTIVATION OF PLANT can be a CHOICE under IRF Technology and its Package of 'ENERGY SOLUTIONS' can be the TOOL for that.

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 ENERGIES for activation of plant physiology, towards Better Nutrient Uptake/ Utilization and Better Host- Defense mechanism of the plant system.



HOW INHANA SOLUTIONS WORK?

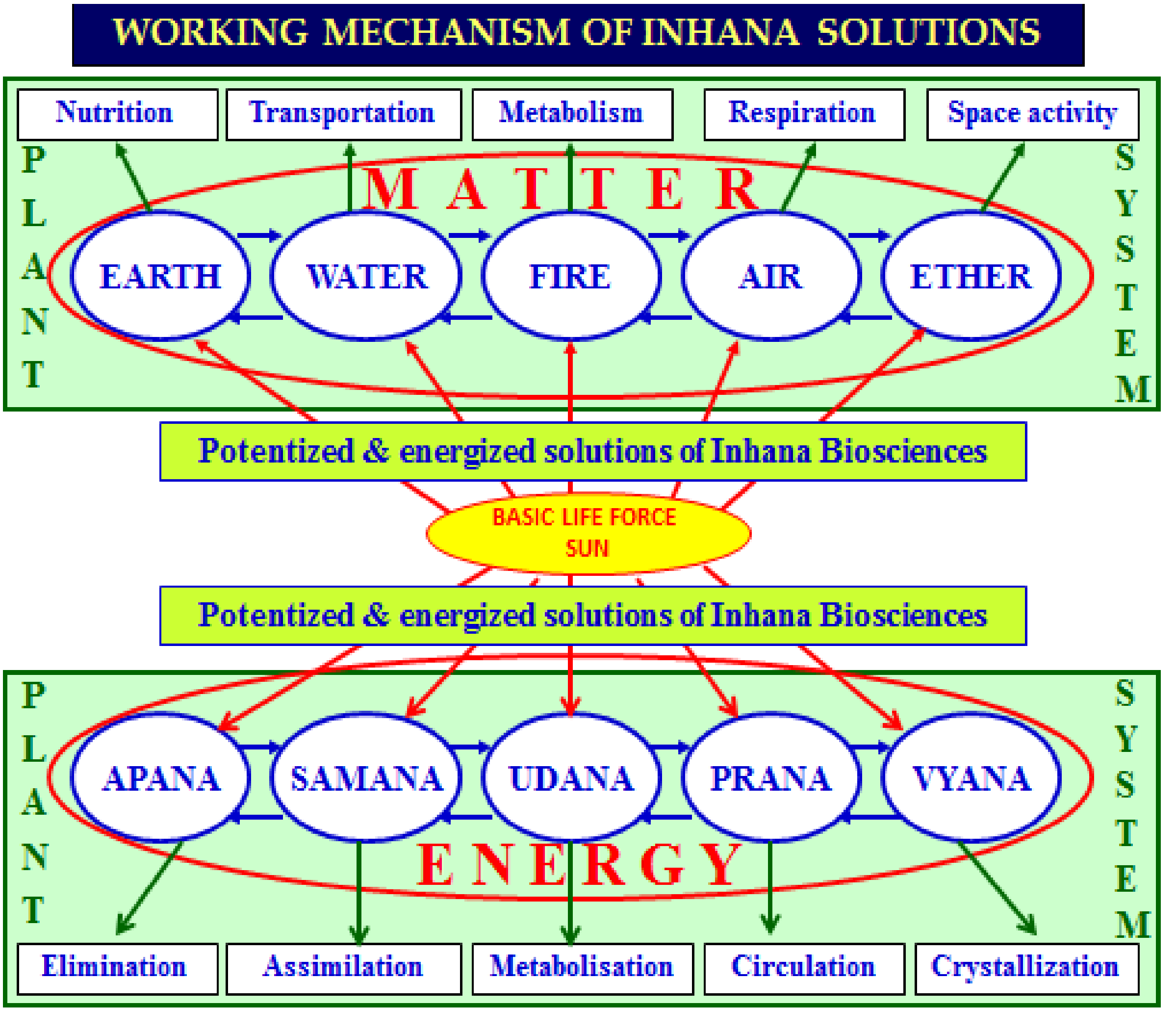
i. When Inhana Solutions are sprayed on the plants they just provide the necessary energy components that invigorate the various biochemical reactions.

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 <u>Activates the Metabolic Functions leading to 'HEALTHY PLANT'</u>



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

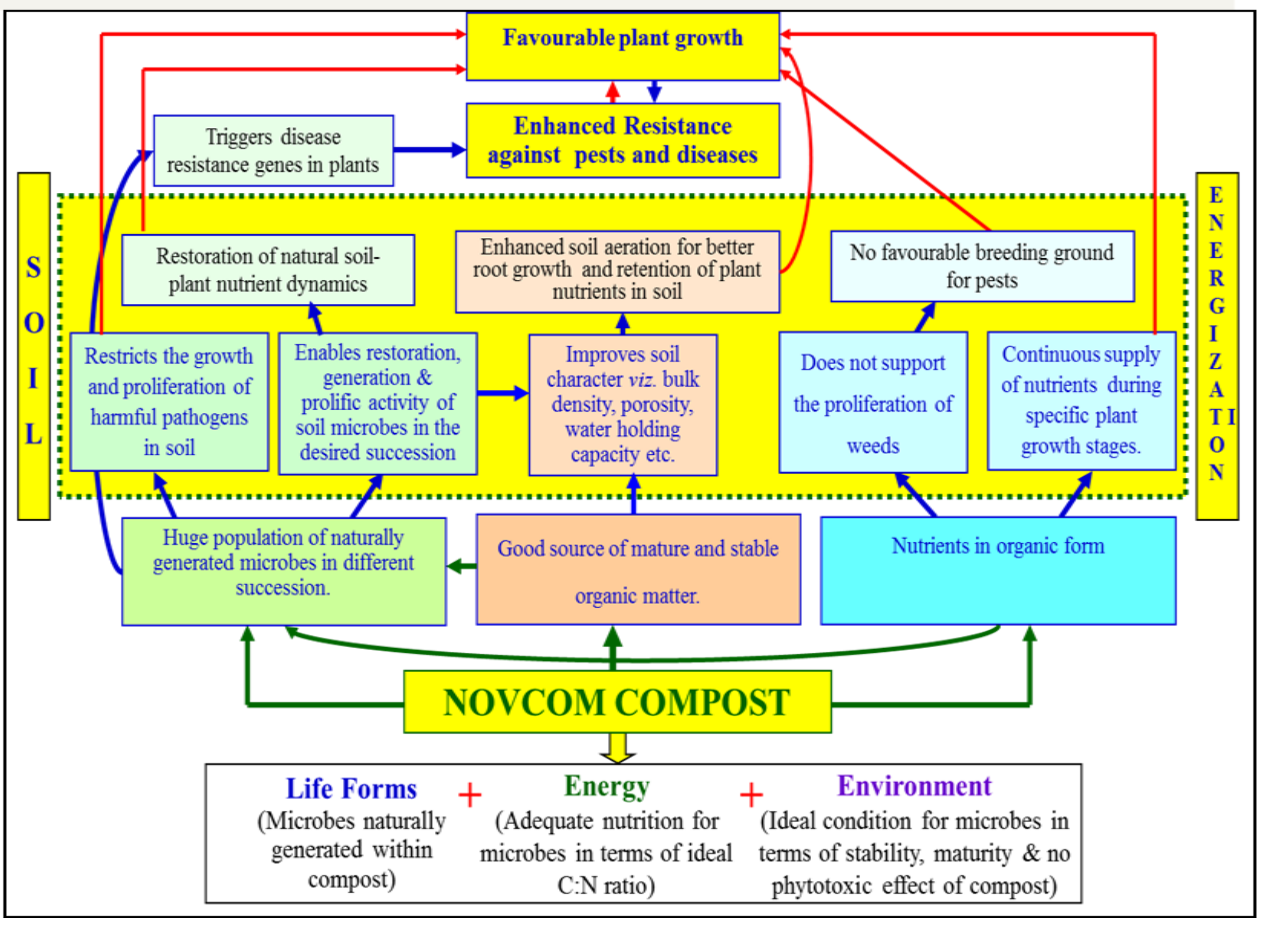
FACETS OF NOVCOM COMPOSTING TECHNOLOGY

- **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

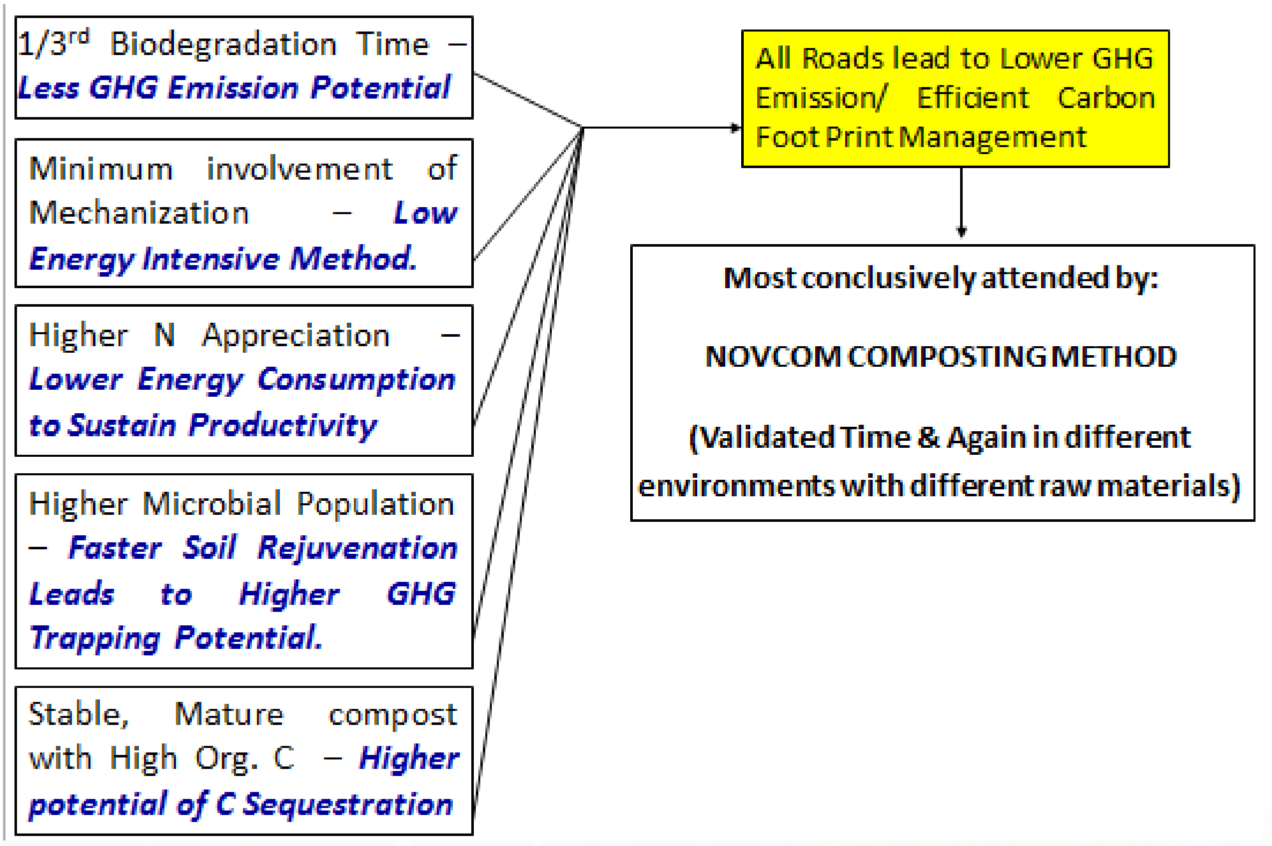


THREE WAY ACTION of NOVCOM Compost

- 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



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.

- $1/10^{th}$ 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

- $1/3^{rd}$ 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 $1/3^{rd}$ 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 ($C2H5OH$). 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.

Annexure - III

Summary of Project Milestones

IBM – IORF

SUSTAINABILITY PROJECT

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

PROJECT SITE :

District- Mandya , State- Karnataka, India

PHASE- 2 PROJECT

MILESTONES

Summary of Achievements

IBM **Corporate**
Social Responsibility

PROJECT SITE :

District- Mandya , **State-** Karnataka, India

MILESTONES

1. **Demonstration of Large Scale 'Waste to Wealth' Program through bioconversion of Coir Pith and Press Mud- High GHG Emitters and highly soil and water polluting materials; utilizing Novcom Composting Technology.**

2. **Demonstration of Sustainable Management Practice in Sugarcane Cultivation**

3. **Demonstration of Sustainable Management Practice in Vegetable Cultivation (Model Plots).**

4. **Development of Clean Food 'NET ZERO' encompassing THREE LAYERS OF SAFETY- Safe for Human Health, Safe for Soil Life & Safe for the Environment.**

5. **Safety Authentication of the Clean Food 'NET ZERO' using the Food Safety Assessment Tool.**

6. **Soil Quality Appraisal of the Project Area & Soil Health Card for the farmers**

7. **Development 'Reclamation Model' for converting Degraded Land to Agriculturally Suitable Land through adoption of IRF Technology.**

8. **Developing a GHG Mitigation Model with added Social and Environmental Impact and a potential for mitigating 30 – 40 lakh metric ton CO_2 equivalent/ year, in India.**

9. **Development of Resource Maps of the Project Area**

New 100 hectare Project- Mandya, Karnataka

Demonstration of Large Scale 'Waste to Wealth' Program through bioconversion of Coir Pith and Press Mud- High GHG Emitters and highly soil and water polluting materials; utilizing Novcom Composting Technology.

SUMMARY

Coir pith, a byproduct of coir industry can take decades to decompose when left untreated. Due to absence of effective and viable composting technology/ies for its effective bioconversion, dumping of coir pith in open lands leads to environmental pollution specially **METHANE emission**. Under IBM-IORF Sustainability project at Mandya, Karnataka, Novcom Composting Technology was utilized towards effective bioconversion of coir pith into safe and mature compost for sustainable soil health management and elimination of Chemical fertilizer, especially N- fertilizer.

Periodical study confirmed effective degradation of organic matter as demonstrated by the rapid decline of C:N ratio from 1:100 to <1:25, appreciation of total nitrogen by 98 percent and 60 % degradation of lignin within a 30 days' time period.

And the values are corroborated by the respective very high (*in the order of 10^{16} c.f.u. per gm or One Trillion Billion Microflora per ton compost*) population of bacteria, fungi and actinomycetes. Phytotoxicity Bioassay test values, **confirmed not only the absence of phytotoxic elements in compost, but also indicated that this compost can actually accelerate seed germination and root growth process.**.

Milestone-1 Summary

Study of the GHG mitigation potential during bio- conversion of coir pith utilizing Novcom Composting Technology **as per IPCC guideline**, indicated that, **this Composting Technology can be the most effective and economic option towards GHG abatement**.

Considering the reference value of 200 kg GHG emission per tonne, treated wet waste, during composting, **Novcom coir pith composting was about 31 times MORE EFFICIENT in terms of GHG mitigation, especially w.r.t. SOURCE POINT METHANE MITIGATION.** This might be due to the prolific (*in the order of 10^{16} c.f.u. per gm or One Trillion Billion Microflora per ton compost*) self- generated population of native microflora within the compost heap, that also speeds up the biodegradation process and alternately shortens the biodegradation period to 30 days.

Under IBM-IORF sustainability, 1000 ton of Novcom coir pith compost was made which potentially mitigated about 6000 ton GHG in terms of CO_2 equivalent.

In addition to on- field study, ACFA Version-1, a carbon Footprint Assessment Tool developed by IORF, was also utilized towards evaluation of the GHG emission/ mitigation under Novcom Composting technology.

The Pearson correlation coefficient (r) value (r = 0.9863) indicated that there was high degree of POSITIVE CORRELATION between measured and calculated GHG values and thus AFCA (version 1.0) can be utilized for GHG evaluation specially where Novcom Composting Technology is adopted.

Thus Novcom coir pith composting could be an important component towards attending the **Net Zero Goal, enable successful reclamation of degraded lands and improve crop productivity**; while also generating additional mandays and options for income generation; that can empower farmers' livelihood.

Demonstration of Sustainable Management Practice in Sugarcane Cultivation

SUMMARY

In India Karnataka stands 3rd in cane production next to Uttar Pradesh and Maharashtra States and 2nd with respect to sugar recovery after Maharashtra. The state contributes 11.53 per cent of production and 8.83 per cent of the area. It has the second highest productivity, followed by Tamil Nadu.

While Mandya is known as Karnataka's sugar bowl, the district has lost that status to Belagavi, that has overtaken Mandya in terms of Sugarcane Production in the recent years.

Sugarcane is the third largest crop grown in the district in terms of the sown area but while Karnataka has witnessed positive growth, in **Mandya; productivity has actually reduced by 18%.** Moreover, **while sugar content has increased in Karnataka by about 16%, in respect of Mandya it has actually depleted by about 4%.** Scarcity of quality planting material also forms a major challenge for these sugarcane farmers.

Climate change forms a major bottleneck, but among the other constraints, depleting soil quality, and the rising incidence of pests and disease are the major cause of concern. **If the soil deterioration continues and the crop productivity goes down, the already low sugar recovery will be like a double whammy effect on the Mandya Sugarcane growers.**

Another Critical Component is the **RISING COST OF CULTIVATION** primarily due to **Rise in the Pest/ Disease Incidence**, leading to Higher Requirement of pesticides along with the Rising Cost of Chemical Inputs i.e., fertilizers and pesticides. **But the farmers have no choice in respect of Reducing the Chemical Load due to Complete Lack of Effective Technology/ ies in this respect.**

These very limitations formed the objectives for this intervention.

Milestone-2 Summary

Hence, the Clean Sugarcane 'NET ZERO' program was taken up under the Project with the adoption of **Inhana Rational Farming (IRF) Technology– A Comprehensive Crop Technology for Safe & Sustainable Crop Production.**

Attaining 'NET ZERO' Status – A 1st of a Kind Initiative in Sugarcane Cultivation

This Program aims at demonstrating the Pathway for Net Zero GHG Emission in Agriculture through GHG Omission from Source, GHG Abatement during crop production and through High C- sequestration in Soil. The Dual Approach of Inhana Soil Health Management & Plant Health Management in this program was aimed at attaining these very objectives.

Pic. : Planting of Sugarcane seed material in marginal soil, having <1.0% Organic carbon and close to 50% gravels

Bioconversion of raw coir pith into Stable, Mature and Non- phytotoxic compost within a shortest period of time (30 days) demonstrated **GHG Omission especially METHANE from this Very High GHG emitting Waste**. 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. The approach** on one hand demonstrates **GHG Mitigation from Source** while also aiming at Restoration of Soil Biological productivity, towards **Higher Soil-C Sequestration**.

Inhana PLANT HEALTH MANAGEMENT (IPHM), driven by Inhana '**ENERGY SOLUTIONS**' has been adopted towards reactivation of Plant Physiology - for higher agronomic efficiency leading to Sustained/ Higher Crop Yields. This approach also **Curtails the Accumulation of Ready Food Source** for Pests, in Plants' Cell Sap to **Discourage Pest Incidence leading to the ELIMINATION OF PESTICIDES. Evaluation of Crop Yield and Sugar content on Clean Sugarcane 'Net Zero' will be done when the Crop will be ready for harvest around June.**

New 100 hectare Project- Mandya, Karnataka

Demonstration of Sustainable Management Practice in Vegetable Cultivation (Model Plots).

SUMMARY

The total geographical area of Mandya district is 4,98,244 hectares, out of which 2,48,825 hectares forms the sown area. That means more than half of the district's total land area is used for agricultural purpose.

In terms of the Net Sown Area (NSA), the major crops of interest are Millets (32%), Rice (32%), Sugarcane (12%) and Coconut (8.4%). **Only about 2-3% NSA is under Vegetables. However, these endless rows of a single crop (mono cropping) year after year**, continuous application of chemical fertilizers especially nitrates and lack of soil health management **has initiated the cycle of soil depletion and led to higher and repeated pest leading to a higher application of pesticides and therefore a highly toxic and unsustainable environment that is threatening the farmers' livelihood.**

The soils of Mandya district are inherently thin gravelly and underlain with a murrum zone containing weathered rock. The soils are highly leached and poor in bases and the water holding capacity is low. **The high gravel content of the soil (sometimes upto 50%) coupled with Very Low Soil Organic Carbon means the soil are HIGHLY PRONE TO EROSION and this proneness has become multifold with repeated and high and injudicious fertilizer application. The fact is vividly demonstrated by the MODERATELY ERODED SOILS that measure 249,166 ha and account for about 50.28% of the total geographical area of the district.**

Among the challenges faced by the District Farmers Four, are Critical and Need Immediate Attention to Ensure both Present and the Future Crop Sustainability :

Soil Degradation

Increasing Incidence of Pest and Disease

Rising Cost of Cultivation

Milestone-3 Summary

While some efforts are being made through programs such as the Integrated Watershed Management, **Effective Models are Still lacking that can Singlehandedly Mitigate all the three Constraints.**

Coconut is a major crop in Mandya, but in the last 10 Years its yield has drastically reduced and is now about 50% lower than the Highest Producing State and 30% lower than the National Average. In this respect, **coconut based intercropping can help out in improving the output and economic return from these plantations**. **But only those intercropping models that encompass safe and sustainable agriculture, can ensure the desired benefits.**

Coconut based 'Net Zero' Intercropping Model was initiated under IBM-IORF Sustainability Project. **This Approach is Significant considering the fact that WASTE generated from Coconut Processing i.e. Coir pith was recycled into the plantation** post bio- conversion under Novcom Composting Technology to serve **TWO OBJECTIVES :**

- **Demonstrate 'Net Zero' Vegetable Cultivation as intercrop in Coconut Plantation**
- **Improve the Productivity of the primary Crop- Coconut**

This Model not only **enhanced the System Productivity By 442 % with incorporation of VEGETABLES AS INTERCROP,** the initiative also **enhanced the ENERGY EFFICIENCY** (in terms of crop productivity per unit of energy investment w.r.t nutrient management) **by 822 %. GHG assessment was also done under this Program.** The major mitigation was obtained from coir pith bioconversion into safe and mature Novcom compost that was utilized for soil health management in the platation w.r.t both coconut and vegetables; which were grown as intercrops. So far it is indicated that **this agriculture model, can potentially offset more than 500 MT CO_2 eq /ha,** and it **can be one of the MOST SUITABLE MODELS for any NET ZERO INITIATIVE, that can simultaneously Enhance the Livelihood of Coconut Growers.**

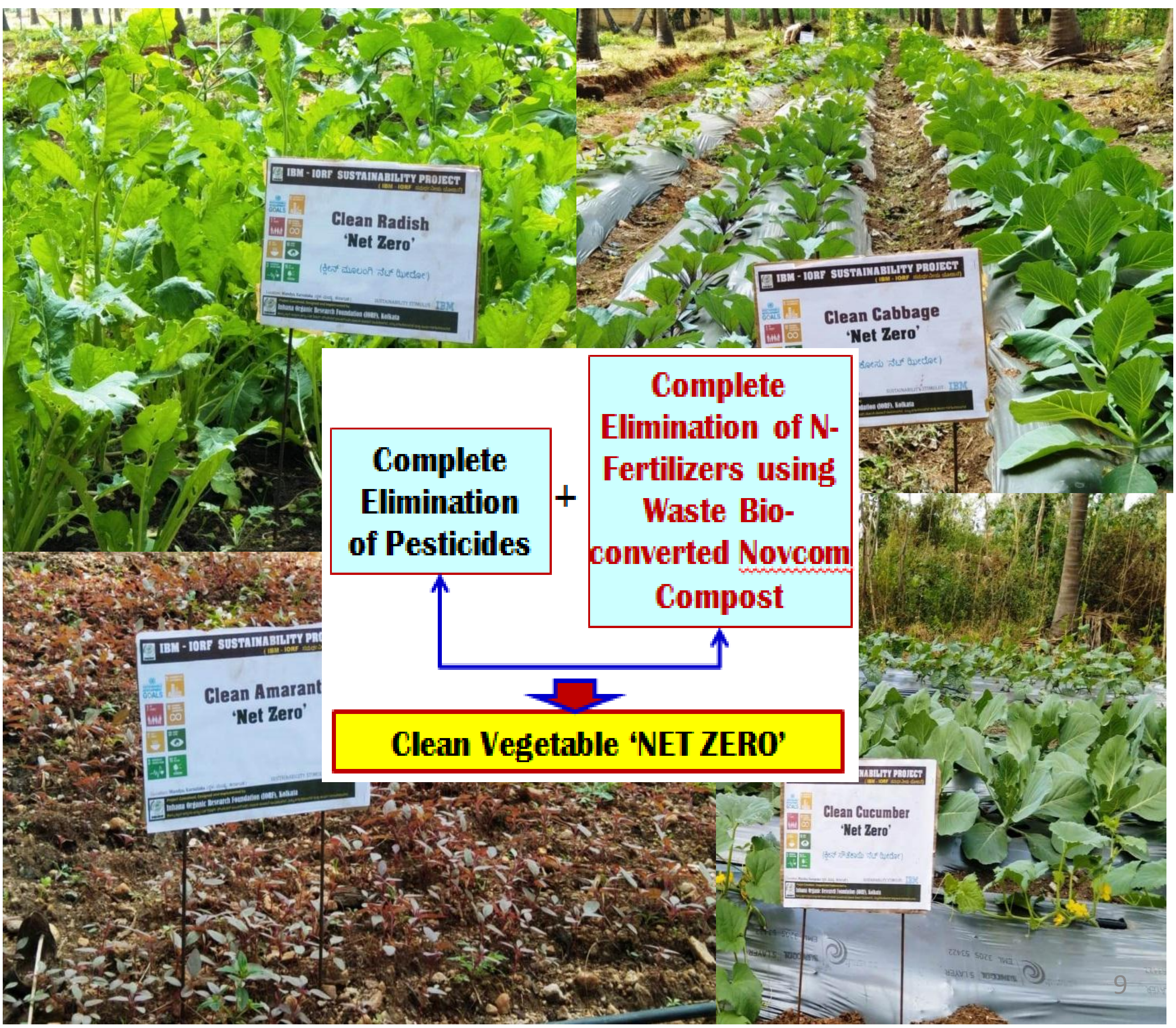
Milestone-3 Summary

The Coconut- Intercropping
Model driven by IRF Technology

Attaining 'NET ZERO' Status– A 1st of a Kind & a Numero Uno Initiative in Vegetable Cultivation that too in Agriculturally Unsuitable Soils

The Phase-I Project had Conclusively demonstrated the critical relevance of Inhana Plant Health Management towards the objective of SAFE Food 'CLEAN FOOD' – Safe for Human Health

Addition of INHANA SOIL HEALTH MANAGEMENT through Waste Recycling along with Inhana Plant Health Management demonstrates a 1st EVER and a STUPENDOUS MODEL for SAFEST Food– CLEAN FOOD 'NET ZERO'- Safe for Human Health, Soil & Environment



New 100 hectare Project- Mandya, Karnataka

Development of Clean Food 'NET ZERO' encompassing THREE LAYERS OF SAFETY- Safe for Human Health, Safe for Soil Life & Safe for the Environment.

SUMMARY

Climate change is sowing the seeds of food crisis in its path. **Agricultures' vulnerability to climate change is reflective in the depleting crop yields especially under the extreme climatic events and the rising pest intensity.**

Besides climate change, **SOIL DEGRADATION** which contributes to 36–75 billion tons of land depletion every year, threatens the global food supply; which implies that now; More Crop has to be Produced from Less Land.

Hence, the major challenge facing mankind today is to produce sufficient food, for the rising human population, from a comparatively lesser land, while combating the climate change impact.

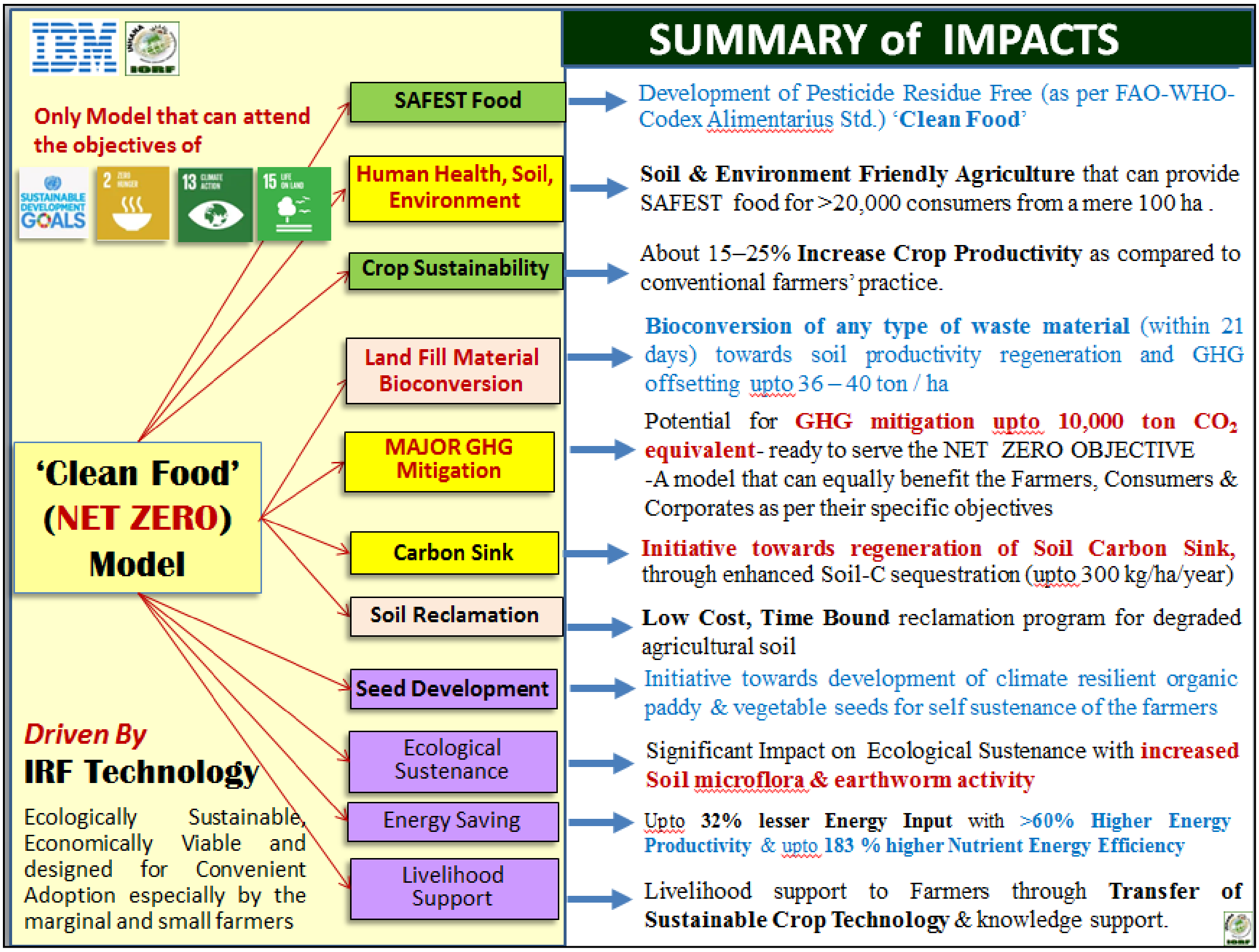
Sustainable Soil Management in terms of lowering/ eliminating fertilizer use, especially nitrate fertilizers and higher application of microbial (self- generated) rich organic amendments for improving the Soil- C sequestration can serve towards GHG mitigation. **Healthy soil will also support better crop performance that can serve the adaptation strategies.**

Two initiatives, i.e., increasing the productivity of Marginal Soils and Reclamation of Degraded Soils for restoring its suitability for agriculture; though herculean tasks can provide significant impact in this arena.

In the Phase-I Project, IORF demonstrated the pathway to produce '**Clean Food'- Safe for Human Health and Sustainable for all**, with an impact area in respect of SDG-2 'Access of Safe and Nutritious Food' for all (SDG 2.1).

Hence, in the Phase-II Project at Mandya District, IORF initiated the Clean Food 'NET ZERO' Model towards SAFEST FOOD production i.e., Safe for Human Health, Soil and the Environment, through elimination of both Chemical-Fertilizers and Pesticides. Inhana Rational Farming served as the interventional Crop Technology

Milestone-4 Summary



In the Mandya District of Karnataka, more than half of the total land area is used for agricultural purpose. But **Only about 2-3% of the Net Sown Area is under Vegetable cultivation.** This initiative under Phase-II Project **demonstrates the Potential for Vegetable Cultivation specially undertaking a Safe and Sustainable Agricultural practice. But apart from vegetables paddy, maize and ginger were also taken under this initiative.**

This was a CONSIDERABLE LEAP denoting the fact that about 50.28% of the total geographical area of the district represent MODERATELY ERODED SOILS. The Model Farm selected for the program was an exact representation of such soils as depicted by Very Low Soil Organic Carbon (0.5 to 0.6%) and more than 50% Gravel Content that pose major challenges w.r.t. crop cultivation especially for vegetable crops.

Milestone-4 Summary

Crop		Yield (Tonne/ ha) under Conventional Farmers' Practice	Clean Food 'NET ZERO' Yield (Tonne/ ha)
BRINJAL	:	15.4-23.4	26.1
RADISH	:	14.1-18.4	19.6
FRENCH BEANS	:	7.4-9.4	10.8
CAULIFLOWER	:	18.4-24.6	26.1
CABBAGE	:	20.6-24.4	28.1
KNOL KHOL	:	16.6-18.7	20.2
CAPSICUM	:	12.1-14.6	15.8
CUCUMBER	:	13.4-15.1	16.2
TOMATO	:	21.1-26.6	28.4

Crop		Yield (Tonne/ ha) under Conventional Farmers' Practice	Clean Food 'NET ZERO' Yield (Tonne/ ha)
CHILLI	:	8.1-10.6	11.4
PUMPKIN	:	18.4-22.6	24.4
BITTER GOURD	:	9.4-11.6	12.4
BOTTLE GOURD	:	15.6-18.4	21.6
RIDGE GOURD	:	16.0-18.0	24.6
OKRA	:	9.2-10.8	11.6
SPINACH	:	10.2-12.4	12.8
CORIANDER	:	3.62-4.20	4.25
RED AMARANTH	:	12.0-16.0	16.2

Crop		Yield (Tonne/ ha) under Conventional Farmers' Practice	Clean Food 'NET ZERO' Yield (Tonne/ ha)
PADDY	:	3.85-4.25	4.02-4.65
MAIZE	:	2.7-3.2	29.4-34.6
GINGER		8.6-12.4	9.2-13.7

On an average the yield of all the crops under Clean Food 'NET ZERO' Model was close to 10% higher as compared to yield obtained under the conventional farmers' practice.

For crop varieties like bottle gourd, French beans, cabbage., etc. about 15-20% higher yield was obtained, under this model.

Higher Crop Yield (*especially in the case of paddy*) was a Phenomenal Achievement because it was obtained under complete elimination of N- fertilizers and chemical pesticides. This indicated the Relevance of Inhana Plant Health Management (IPHM) and the effectiveness of Novcom Coir- pith Compost, towards Climate Resilient, Safe & Sustainable Crop Production.

Safety Authentication of Clean Food 'NET ZERO' using the Food Safety Assessment Tool.

SUMMARY

The Phase-1 of Project Demonstrated the **'CLEAN FOOD' MODEL- SAFE** for Human Health @ Same Cost, Hence Sustainable for All - **aligned with SDG-2**, **that can be Adopted across Agro-ecological Zones and variable Farm Economies.**

Moreover, Clean Food means Safety Authentication NOT BY AUDIT but through ACTUAL ANALYSIS

The **chromatographic technique** for residue analysis however, is **hugely expensive, complex, time-consuming and require specific resources and infrastructure** which offer major hindrance towards regular analysis for monitoring of food safety. Especially for a country like India, with **absolute dominance of marginal farmers in vegetable cultivation**, lack of awareness, resource scarcity, inability to take economic risk and flaws in maintaining the standard practices w.r.t. chemical usage; enhances the availability of pesticides in food product. **Moreover the short time gap between the field harvest of vegetables and consumption, limits the scope for safety analysis even if the infrastructure and economics is not considered.**

In this background an **effective, speedy, yet an affordable method** was needed to enable pesticide residue analysis in situations of limited resources, more so for safety authentication of Clean Food.

In this respect the **Colorimetric Assay Test** was identified as a solution that can tick off all the requirements. The Colorimetric Pesticide Assay Test can serve as the **MOST STRINGENT TEST** for Food Safety, due to the scope for detection of the Collective Presence/ Absence of the Pesticide Residues up to the Lowest- Group Specific Permissible Limits. **And Most Importantly at just 1/10th of the Conventional Cost of Residue Analysis. This test method was utilized under Phase-II Project to evaluate the Safety Aspect of Clean Food 'Net Zero'.**

Milestone-5 Summary

Comparative Safety Assessment of 18 different varieties of vegetables (*viz. brinjal, radish, French beans, cabbage, capsicum, cucumber, tomato, chilli, red amaranth, bitter gourd, etc.*) developed under **Clean Food 'NET ZERO' Model (in Model Farm)** was done **vis-à-vis organic vegetables as well as the conventionally grown counterparts.** A total of **224 Samples** were studied for the purpose

While **No Residue** was detected in respect of the Clean Food 'NET ZERO' and Organic Samples; **44% *(on an average)* of the conventionally grown vegetables were found to be tainted with pesticides.** Out of the conventionally grown vegetables chances for pesticide residue was found to be highest in the case of brinjal followed by French beans and cucumber and lowest for pumpkin.

Clean Food 'NET ZERO' Safety Assessment- THE MOOT POINTS

- **Clean Food 'NET ZERO'** – SAFEST FOOD – SAFE for Human Health, Soil & Environment. Also SAFETY is the Cursor for **SUSTAINABILITY.**
- For Safety Authentication of Clean Food 'NET ZERO', especially for Multiple Harvest Crops like vegetables- **Batch wise Testing was a must**.
- But the Conventional Process of Pesticide Analysis is **COSTLY & TIME CONSUMING**– due to high investment, lack of infrastructure, resources and technical manpower.
- **Hence, frequent Safety Assessment of Produce especially multiple harvest crops like vegetables is beyond question** because majority of the growers are small and marginal land holders.
- The **Colorimetric Pesticide Assay Test developed in Phase-1 of the IBM-IORF Sustainability project** came out as the Right Solution considering that it can enable **Both Qualitative & Quantitative Residue Analysis**, at **1/10th of Conventional Cost and Time required for Analysis** *(respectively).*

Soil Quality Appraisal of the Project Area & Soil Health Card for the farmers.

SUMMARY

Soil health is an integrative property that reflects the capacity of soil to respond to agricultural intervention, so that it continues to support agricultural productivity, food quality, environmental resiliency, and ecosystem sustainability. Soil health plays an important role in agricultural productivity, food quality, environmental resiliency, and ecosystem sustainability as **HEALTHY SOILS PRODUCE HEALTHY CROPS** that in turn nourish people and animals (FAO, 2015)

But Most Importantly, the knowledge about Soil Health Status is Crucial in order to judge what steps to undertake for Sustainable Soil Management.

10 hectare Grid was considered for soil sampling and samples were collected from the project area. **The soil of Mandya district is derived from granites and gneisses and the texture range from red sandy loams to red clay loam very thin on ridges and higher elevations and comparatively thick in valley portions.**

The soil analysis data was evaluated in respect of seven different land use types in order to provide a basic idea regarding the soil health status under different anthropogenic use

The soil is light in texture, with very low organic carbon (0.42 to 0.57 %.) and low bulk density (1.26 – 1.48 gcm^3). Moreover, presence of small to medium gravels (40 to 60%) **hinder proper root penetration in soil increasing the proneness to abiotic stress.**

At the same time, due to higher sand percent, gravel content and lack of organic matter in soil, soil aggregates in majority area is very low to low and **prone to soil erosion specially in the undulating plains.**

Milestone-5 Summary

In general the low organic carbon and humus content in red soil causes an inherently lower microbial activity, and conventional agricultural practices in such soil further depletes the microbial status.

The other biological parameters also depict poor biological activities in the soil **which is major cause of concern both in respect of crop sustainability as well as soil erodibility potential.**

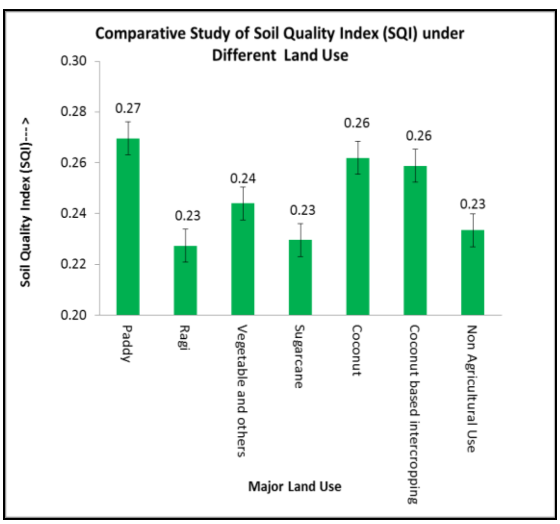


Fig : Comparative Study of **Soil Quality Index (SQI)** under Different Land Use at Mandya, Karnataka

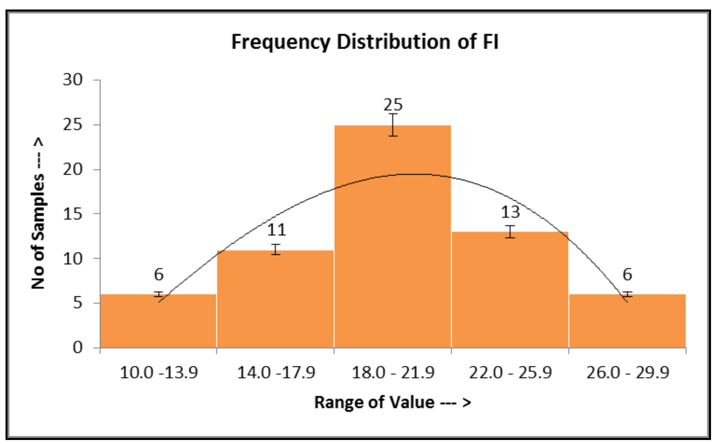


Fig : Frequency Distribution of Fertility Index (FI)

- The Microbial Activity Potential (MAP) was very low in most of the soil indicating limited biological activity- could cause major limitation towards crop sustainability.
- **SQI value was found to be very low in most of the soil, primarily due to poor to very poor microbial activity and limitation w.r.t. soil physical characteristics**

IBM **Corporate**
Social Responsibility

MILESTONE 7

New 100 hectare Project- Mandya, Karnataka

Development 'Reclamation Model' for converting Degraded Land to Agriculturally Suitable Land through adoption of IRF Technology.

SUMMARY

29.7% (97.85 mha) of India's Total Geographical Area has already undergone Land Degradation. Some 83.69 mha underwent desertification in 2018-19 (*Desertification and Land Degradation Atlas of India*). In last 13 -14 years, about 3.32 million hectares has been degraded. India has a **National Commitment** for 'Restoration of 26 mha of degraded land by 2030' *(14th Session of the Conference of Parties of United Nations Convention to Combat Desertification (UNCCD), 2021.*

Some of the most primary impacts of Soil Degradation

- Loss of Soil Productivity
- Loss of crop productivity
- Loss of Biodiversity
- Loss of Livelihood support
- Increase in Green House Gas (GHG) Emissions

It is necessary to halt Soil Degradation and undertake Reclamation of Degraded lands **from the Food Security objective as well as to sustain Farmers' Livelihood**; but more so to **Reduce the Total Projected Carbon Emissions by one billion tonnes** by 2030- India Commits; and this will require a significant contribution from agriculture & forestry– the largest potential sink w.r.t. GHG Mitigation opportunities.

SOIL BIOLOGICAL PRODUCTIVITY IS THE KEY for Reclamation of Degraded Land. Bur restoration of Soil Biological Productivity is a very difficult task considering that the Top 6 inches or 15 cm of Soil in 1 hectare area weighs about 22,40,000 kg, so application of a high dose of compost like **22 Tons, will actually add only about 5 g Organic Matter per kg soil- Consequently, this will provide just 0.1% Organic Carbon in the Top 6" Soil in 1 hectare area.**

The Indian Soils on an average contain about 0.5% Organic Carbon. Hence, on a large scale even if a modest target of increasing Soil Organic Carbon to 1% is set, it will require **110 Ton of compost per hectare.**

Milestone-7 Summary

It is Not the Organic Matter Load or Organic Carbon Load , rather the COMPOST MICROBIAL LOAD IS THE KEY TO ACCOMPLISH THE TARGET. But the Microbial Load should be Inherent to the Compost, Self- generated under the Composting Process and Well Diversified

Biodegradable Waste of any kind especially landfill material can best serve the objective. But technology is crucial for their bioconversion into Safe & Quality Compost. **Coir pith,** an agro waste; is dumped in open lands and forms a major soil and water pollutant, besides being a Very High GHG Emitter (6.0 mt CO_2-eq per ton approx.), primarily METHANE, which has 75 times Higher Global Warming Potential as compared to CO_2. **Karnataka alone, Produces about 5,00,000 - 6,00,000 ton of Coir Pith annually.**

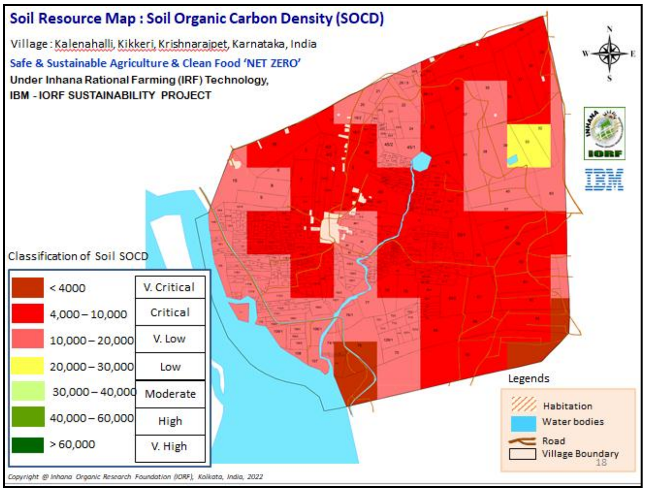
The **IBM-IORF Sustainability Project** Demonstrated that Coir-pith can Serve as an **Excellent Resource for Soil Health Management** when bio- converted into a Stable, Mature & Non-phytotoxic Compost – **1st Ever in Indian Agriculture**. **1000 ton of Coir pith was bio- converted and use for Soil Health Management.**

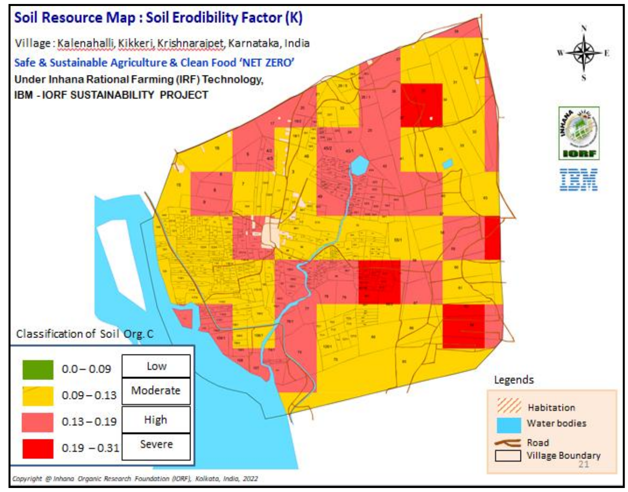
A Study was undertaken to assess the Soil Organic Carbon Density (SOCD) to understand the overall soil organic carbon stock in the major root zone (30 cm). **The Study revealed that majority (60%) of the area was under critical to very critical zone.** This together with the physical characteristics of soil pointed towards a Higher Potential for Erosion and a low Soil Productivity Potential.

Evaluation of Soil Erodibility (K) of the project area revealed a moderate soil erosion susceptibility in a majority (57%) area. **Also about 7% and 36% area suffered from severe and high soil erosion respectively, which is a major concern point.**

The evaluation indicated that there was **high risk of top soil loss if proper measures are not taken,** which is a **major concern point for crop sustainability specially considering marginal soils with an inherently poor soil quality.**

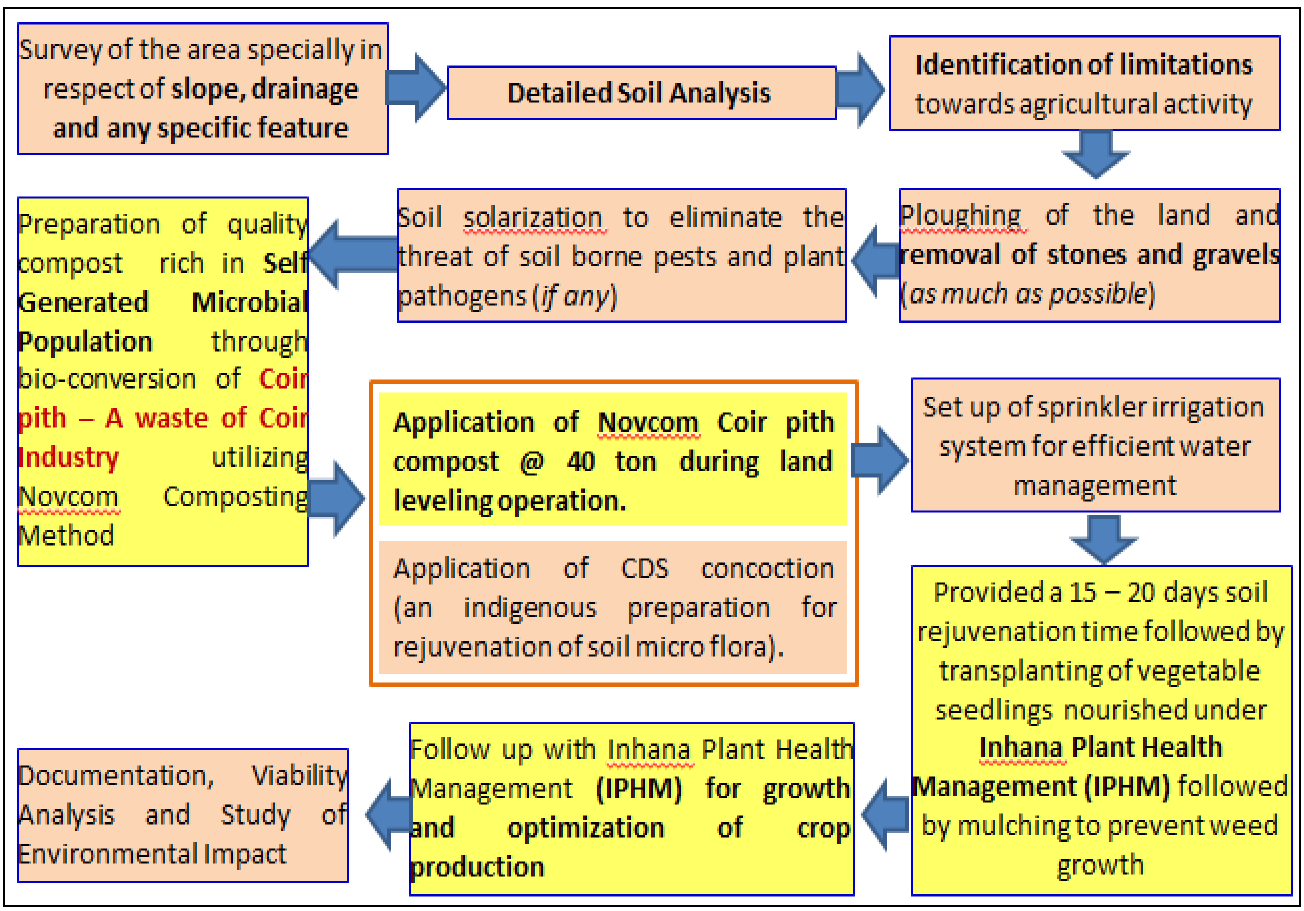
Milestone-7 Summary





Resource Maps showing Soil Organic Carbon Density & Soil Erodibility Factor in the Project Area

Flow Diagram of Soil Reclamation Model under IBM – IORF Sustainability Project



MILESTONE 8

New 100 hectare Project- Mandya, Karnataka

Developing a GHG Mitigation Model with added Social and Environmental Impact and a potential for mitigating 30 – 40 lakh metric ton CO_2 equivalent/ year, in India.

SUMMARY

Climate change is now affecting every country on every continent, disrupting national economies and affecting lives, costing people, communities and countries dearly today and even more tomorrow. The poorest and most vulnerable people are being affected the most. Disruption in crop production system due to **climate change impact will be a major threat towards mitigation of GLOBAL HUNGER** as **50% Higher Food Production will be required to meet the Food Requirement by 2050.** While Agriculture faces the major challenge w.r.t. climate change, it is also a major contributor to climate change, being the second largest emitter of GHGs. But it is also the only sector, which can enable both GHG mitigation and Adaptation.

Under IBM-IORF Sustainability Project at Mandya, Karnataka, an effort was initiated utilizing Novcom Composting Technology, towards effective **BIOCONVERSION OF COIR PITH** into safe and quality compost for sustainable soil management, **to establish a GHG Mitigation Model in Agriculture that will demonstrate both Environmental and Social impacts.** The GHG offsetting potential under Novcom Composting Technology was documented **through actual field study and also evaluated using ACFA (Version 1.0) – Agriculture Carbon Assessment Tool** developed by IORF as per Intergovernmental Panel on Climate Change (IPCC) guidelines (2018).

The significance of this initiative can be judged from the fact that it demonstrated a FIRST EVER MODEL for METHANE MITIGATION in agriculture - a critical GHG considering that it traps 80 times more heat in the atmosphere than CO_2 (The Associated Press, 2022) over the first 20 years after it reaches the atmosphere. Also, methane sets the pace for warming in the near term (EDF, 2022) as it has a radiative forcing approximately 120 times more than CO_2, and it also forms ground-level ozone, a hazardous air pollutant and greenhouse gas, exposure to which causes 1 million premature deaths every year.

Milestone-8 Summary

Debate on GWP of Methane on 100 Years Basis or on a Shorter Scale

Scientists have recognized **that acting now to reduce methane emissions** will have immediate benefits to the climate that reductions in carbon dioxide cannot provide on their own (EDF, 2022). But there is an emerging debate whether, GWP of methane will be taken on 100 years basis (as IPCC recommended) or on a shorter scale. Today more scientists are beginning to model the warming effects that today's methane emissions will have over the next 20 or 30 years, in order to **predict more accurately whether humanity can avoid overshooting targets such as stopping global warming at 1.5 degrees Celsius.**

In the latest IPCC report [2021], it has been clearly maintained that, IPCC does not recommend an emissions metric because the appropriateness of the choice **depends on the purposes for which gases or forcing agents are being compared**. Emissions metrics do not define policy goals or targets but can support the evaluation and implementation of choices within multi-component policies (e.g., they can help prioritize which emissions to abate). **The choice of metric will depend on which aspects of climate change are most important to a particular application or stakeholder and over which time horizons.**

- Evaluation revealed that untreated **coir pith can potentially emit methane in the range of 5897 – 6025 kg CO_2 equivalent** (taking $GWP_{24\ years}$ of methane: 75).
- Methane emission was found to be **NEGLIGIBLE (0.61 kg CO_2 equivalent per ton wet coir pith)** under Novcom Composting Technology, **as compared to that documented (2.25 – 600 kg CO_2 eq/ ton wet waste, considering $GWP_{24years}$ of CH_4 : 75) for other standard biodegradation processes**
- The **Total GHG Emission** during coir pith bioconversion under Novcom Technology, was about **31 TIMES LOWER (6.47 kg CO_2 eq/ ton treated waste)** than the reference values **(200 kg kg CO_2 eq/ ton treated waste)** recorded in respect of any other standard biodegradation process.

The GHG Mitigation Model developed under Phase-II Project can enable Methane Mitigation of about 6000 ton CO_2 eq per 1000 ton WASTE, directly from SOURCE POINT, while Also Improving Soil Health & Farmers' Livelihood .

Development of Resource Maps of the Project Area

SUMMARY

Soil Resource Mapping and development of thematic maps is the most useful tool for identification of potential and problematic areas in order to enable the formulation of an effective and customized soil management program.

Soil evaluation especially in terms of the microfloral activity and soil quality; followed by resource mapping can enable the maintenance of soil resource base while tapping the potential areas simultaneously, with the target of better farm maintenance.

It can also help to **prevent soil degradation with good planning, reduce the costs of remediation when it is necessary, and contribute to issues related to climate change (e.g., reduction of greenhouse gas emissions)** and human health (e.g., soil contamination). **Also, without access to information regarding soil quality; farmers are prone to use higher and injudicious amount of fertilizers.** In this respect, incorporation of detail soil maps in the precision agriculture database can make considerable contributions to decreasing fertilizers (Cullu, 2019).

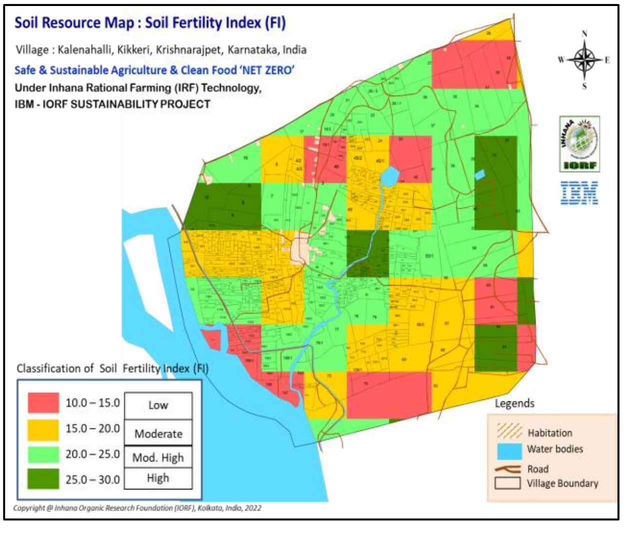
Significance of Soil resource mapping increases manifold especially in respect of Sustainable Soil Management, where judicious application of organic soil inputs has a direct bearing on the practical feasibility and the related economics; especially considering the existential scarcity of resources for on-farm production of quality compost in the required quantity.

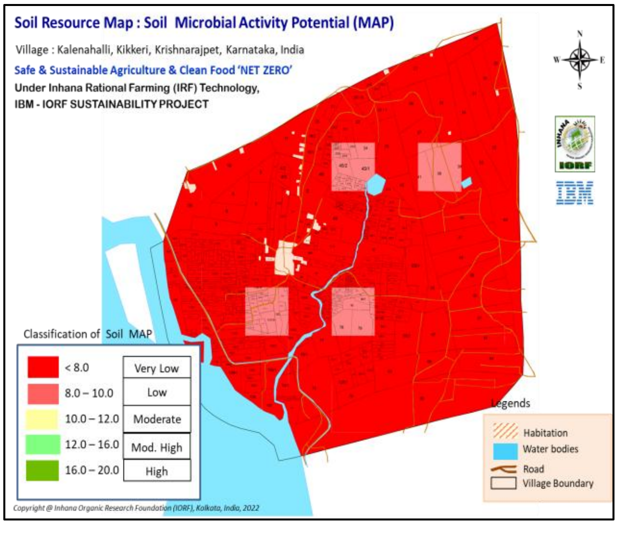
In the Phase-II project 18 different Resource Maps were developed for the project Area, towards the objective of Sustainable Soil Resource Management.

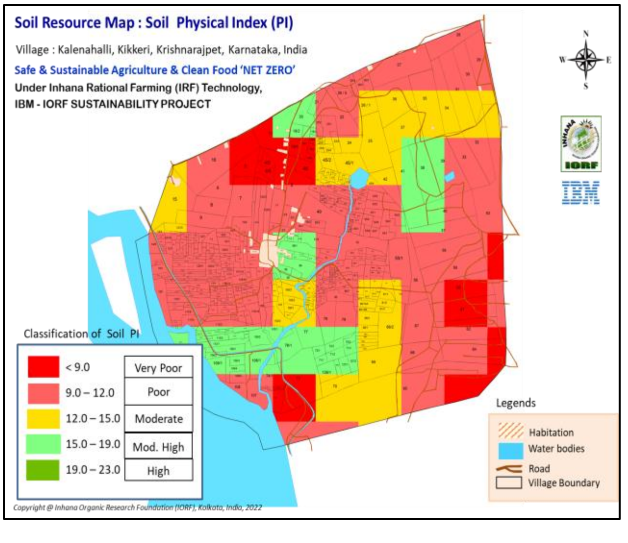
The Soils were analyzed for physical, physicochemical, fertility and microbial properties as per standard guidelines. The area is a combination of plain and undulating plains with mostly reddish colour soil with 40 to 60 % gravel content.

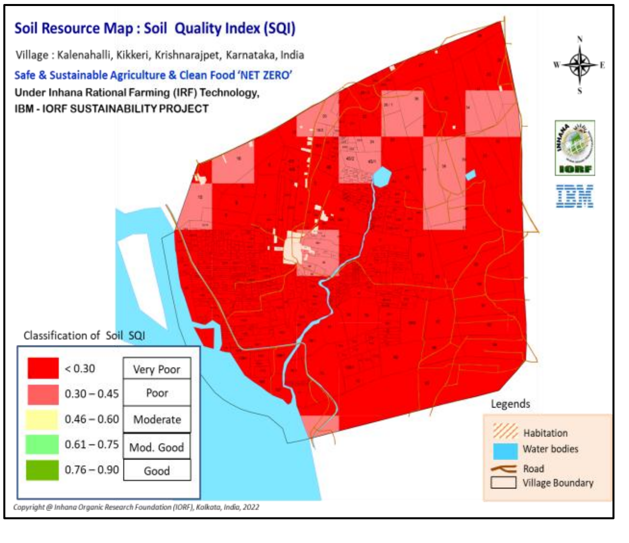
Milestone-9 Summary

As per textural class , the soils varied from sandy loam to sandy clay loam, sand percentage varying from 59 to 86 percent. Though the soils are light textured but due to presence of small to medium gravels proper root penetration is hindered. Soil organic carbon is one of the most limiting factor in the project area, mean value under different land use varied from 0.42 to 0.57 %. Soil Quality Index (SQI) value in the project area was found to be very low in most of the soil, primarily due to poor to very poor microbial activity and limitation w.r.t. soil physical characteristics.









IBM – IORF

SUSTAINABILITY PROJECT

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

PROJECT SITE :

Block– Haringhata, District- Nadia , State- West Bengal, India

Year 2022 - 23

MILESTONES

Summary of Project Achievements

MILESTONES

1. SOIL HEALTH CARD OF INDIVIDUAL FARM LANDS FOR ABOUT 400 PROJECT FARMERS.
2. SOIL- SITE SUITABILITY EVALUATION OF MAJOR CROPS
3. MODEL DEMONSTRATION OF SAFE & SUSTAINABLE ‘CLEAN VEGETABLE SEED’ PRODUCTION.
4. DEVELOPMENT OF SUSTAINABLE IMPACT STORIES RELATED TO IBM SUSTAINABILITY PROJECT.
5. RESEARCH PUBLICATIONS BASED ON SPECIFIC SCIENTIFIC OUTCOMES.
6. MODEL DEMONSTRATION OF SAFE & SUSTAINABLE ‘CLEAN PADDY SEED’ PRODUCTION.
7. ESTIMATION OF ENERGY USE EFFICIENCY
8. ESTIMATION OF CARBON SAVING AND GHG MITIGATION
9. ANALYSIS OF SAFETY, QUALITY & SEED RESILIENCE OF CLEAN PADDY & VEGETABLE SEEDS
10. SAFETY AUTHENTICATION OF 'CLEAN FOOD' THROUGH 'FOOD SAFETY ASSESSMENT TOOL'

SOIL HEALTH CARD OF INDIVIDUAL FARM LANDS FOR ABOUT 400 PROJECT FARMERS.

IBM **Corporate Social Responsibility**

Which IBM program is this grant for?

Other

Target Reporting Date

09/26/2022

Milestone Name

Continuation Project 100 ha -Comprehensive Soil Health Card of individual farm lands for about 400 Project farmers.

Milestone Goal

Enabling access of marginal and small farmers to complete soil health report of their individual farm lands, in order to enable sustainable soil management- the 1st Step in the Journey of Safe & Sustainable Agriculture.

Describe the expected progress toward the goal by this target reporting date.

Enabling access of Soil Health Card to about 400 Project Farmers by the target date.

Expected progress toward milestone goal, as a number

400

Expected Progress Units

Comprehensive Soil Health Card

MILESTONE NO. 1 - SUMMARY

In the Project area, the **small and marginal farmers comprise 96% of the Total Farmers** with an average land holding size <0.26 hec. that is less than 1/6th of the set limit (2.0 hec.). **But in stark contrast, the cropping intensity is very high (about 2.5 to 3.0),** meaning extreme dependence on land, and also extreme resource poorness due to the land demography. Hence, these farmers are in dire need of a sustainable pathway for crop production, **which starts with Soil Test Based Soil Health Management. But lack of access to Land Specific Soil Health Card is again an existential problem.**

The Soil Health Card that the Govt. of India (GOI) provide to the farmers evaluate soil in terms of only 12 Quality parameters, namely pH, EC, OC (Physical parameters), N,P,K,S (Macro-nutrients) and Zn, Fe, Cu, Mn, Bo (Micro - nutrients). **However, Soil Health Assessment in terms of mere physicochemical and fertility does not help** because sustainability issues are much broader and will be difficult to achieve **until strong emphasis is given to the dynamic soil property i.e. SOIL MICROFLORA**

Moreover in the present SHC protocol of GOI, only one sample is taken from a 2.5 ha grid (under irrigated ecosystem). But considering the average landholdings of marginal farmers (0.30 – 0.40), 6 – 10 farmers lands will fall under a single grid, which means all of them get the **Same Soil Health Card**. And as experienced from the ongoing IBM-IORF Sustainability Project in the Nadia District of West Bengal, India, **somewhere between 10 – 30 farm lands can be present within a single grid area which is the reality of fragmentation of land in West Bengal.**

Now despite different land use and management practice, the present system provides opportunity only for a single soil sample analysis, so has **very limited practical usage in respect of undertaking soil management in individual farm land based on the generalized analytical report.**

Hence, initiative was taken up for Soil Resource Mapping of the entire area with the objective of providing **Every Individual Project Farmer his own 'Soil Health Card' aligning with our mission 'KNOW YOUR SOIL'**.

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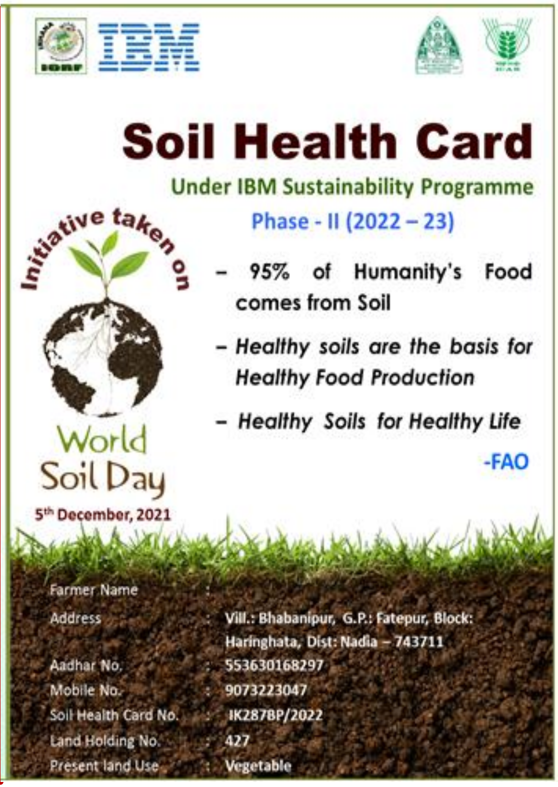
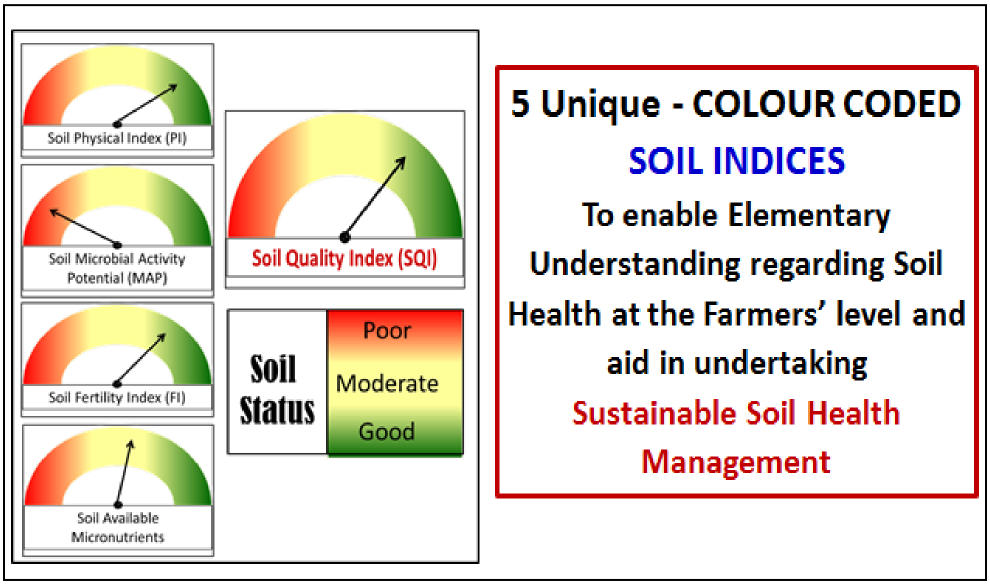
The relevance of IBM-IORF 'Soil Health Card' is paramount considering that sample analysis has been done on a grid of 0.26 ha as against 2.5 ha for normal testing protocol.

HIGHLIGHT

The GOI launched the Soil Health Card (SHC) Scheme in 2015, which was a first time crucial initiative post independence. The Soil Health Card developed under the IBM-IORF 'Clean Food' Project **can serve to strengthen the Govt. SHC Program due its Comprehensiveness** in terms of **25 Soil Quality Parameter** Analysis especially focusing on **Soil Biological Parameters**; that actually determines the soil dynamism and most importantly **'Soil Health'**.



Also **5 IMPORTANT SOIL INDICES** namely Physical (PI), Fertility (FI), Microbiological (MAP), Micronutrient and finally Soil Quality Index (SQI) as overall **SOIL HEALTH INDICATOR**; have been provided in **SIMPLE COLOUR CODING** to facilitate easy understanding by the farmers through visual interpretation.



Pic- Inside Right- page of the IBM-IORF Soil Health Card

SOIL- SITE SUITABILITY EVALUATION OF MAJOR CROPS

IBM Corporate Social Responsibility

Which IBM program is this grant for?

Other

Target Reporting Date

09/30/2022

Milestone Name

Soil- Site Suitability evaluation of Major Crops.

Milestone Goal

The goal is to assess the suitability of the soil of the project area in relation to the major crops grown so as to evaluate their vulnerability under the existential climate change impact.

Describe the expected progress toward the goal by this target reporting date.

Expecting 100 percent completion of Suitability Evaluation of major crops by the Target Reporting Date.

Expected progress toward milestone goal, as a number

100

Expected Progress Units

Soil-site Suitability

MILESTONE NO. 2 - SUMMARY

Productivity of a particular crop depends on land resources and the climate of the area. The inherent ability of soils to supply nutrients for crop growth and maintenance of soil physical conditions to optimize crop yields is the most important component of soil fertility that virtually determines the productivity of agricultural system (Jayasree, 2022). **So, identification of crop requirements and matching them with the resource available to optimize the productivity in a sustainable manner assumes a greater importance as the present level of productivity of most of the crops has either reached the plateau or has started declining.**

Hence, Soil - site suitability evaluation is the pre-requisite for land use planning (Sys et al., 1993). Also as soil- site suitability evaluation clearly indicates the nature of constraints that hamper optimal production, scope remains for taking up proper reclamation and management of natural resources within the selected land use framework (Varheye, 1993). **Hence, from agricultural point of view, it helps in identifying the suitability of soils to produce different crops on a sustainable basis without degradation of the land.**

The importance of soil- site suitability evaluation has grown multifold considering the continuous depletion of soil as a resource under conventional agricultural practice. **Soil- site suitability of major crops was undertaken to assess whether the presently grown crops are appropriate for the area, and to ensure that the land use plan adopted by the farmers provides better economic returns and livelihood sustenance, under the existential climate change impact.**

Soil site suitability evaluation was carried out following the criteria outlined by FAO [4], Sys et al (1993) and Naidu et al. (2005). The FAO framework involves formulation of climatic and soil-site criteria to meet the requirement of crops and rating of these parameters for **highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and unsuitable (N) classes**. These were matched with existing land qualities to arrive at a specific suitability class.

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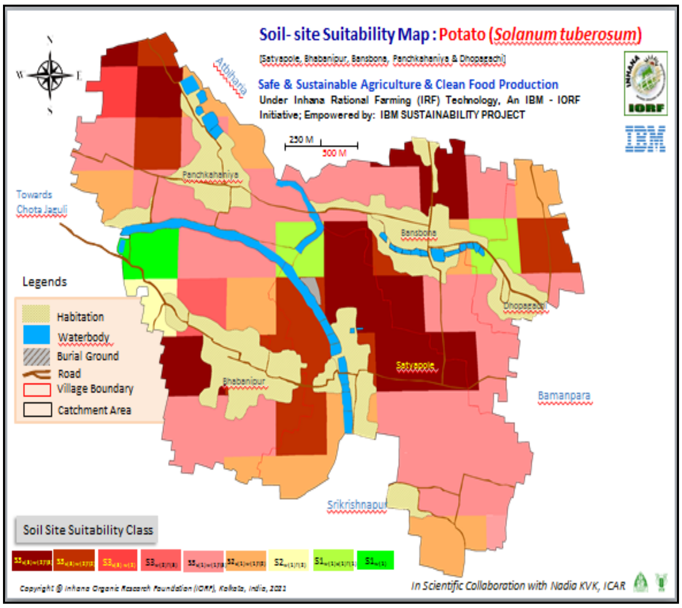
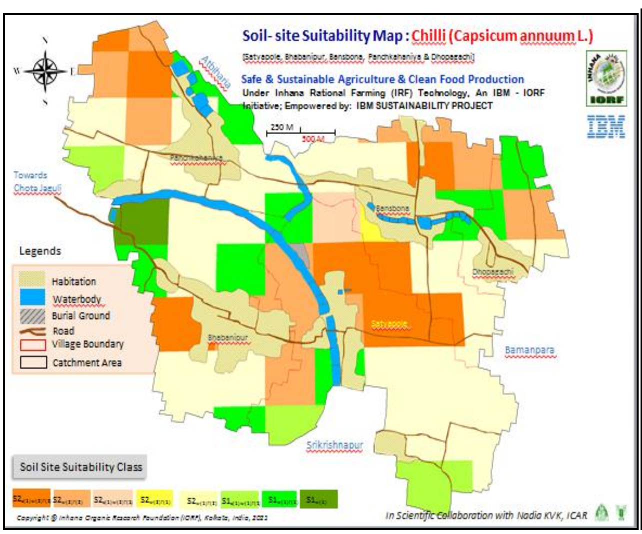
MILESTONE NO. 2 - SUMMARY

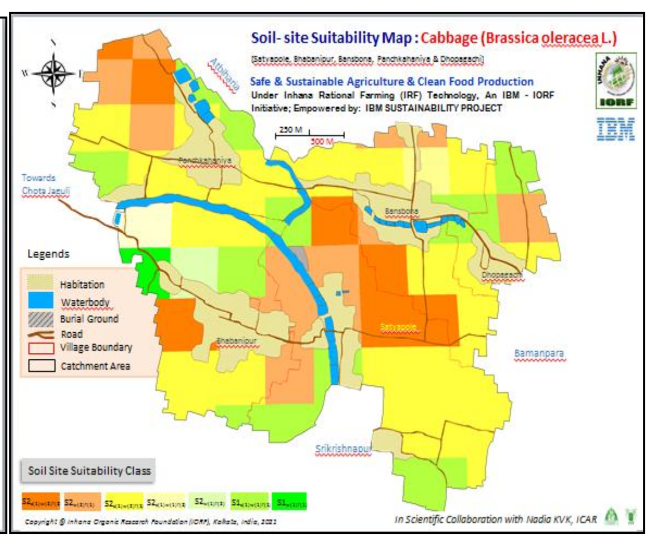
Soil-site suitability of major crops viz., wet season paddy, potato, cabbage, chilli, tomato, carrot, beans, onion, green peas, banana, guava and papaya were evaluated in the study area on a 10 ha grid basis. The potential land suitability sub-classes were also determined after considering the improvement measures to correct these limitations (Sys et al. 1991).

A TOTAL OF 12 SOIL- SITE SUITABILITY MAPS HAVE BEEN DEVELOPED



Evaluation revealed that **SOIL FERTILITY** formed the major bottleneck towards crop cultivation especially due to the poor microbial dynamics in soil, leading to improper nutrient mineralization and availability in the soil solution. **Hence, improvement of this aspect can actually promote the suitability aspect of these soils with respect to the presently cultivated crops.**





IBM **Corporate Social Responsibility**

MILESTONE NO. 3

MODEL DEMONSTRATION OF SAFE & SUSTAINABLE ‘CLEAN VEGETABLE SEED’ PRODUCTION.

IBM **Corporate Social Responsibility**

Which IBM program is this grant for?

Other

Target Reporting Date

12/16/2022

Milestone Name

Model demonstration of Safe & Sustainable 'Clean Vegetable Seed' production.

Milestone Goal

The seeds developed under conventional farming are generally high fertilizer responsive hence; lack the quality traits that are required for sustaining crop yields irrespective of the changing climatic patterns. The objective is to demonstrate/ develop 'Clean Seed' without any Crop Loss or increasing the Cost of Production to generate better progression towards Sustainable Agriculture

Describe the expected progress toward the goal by this target reporting date.

"Expecting 100 percent achievement of this Milestone by the target date"

Expected progress toward milestone goal, as a number

100

Expected Progress Units

Clean Vegetable Seed

MILESTONE NO. 3 - SUMMARY

Safe and Sustainable Crop Production has become emergent looking at the crop vulnerability and the increasing risk of food chain toxicity. The risk increases under the existential climate change and there has been no solution under conventional farming that can help mitigate the issue while enabling safe and sustainable crop production. Shifting over from conventional farming to nature friendly sustainable practice is also not easy and needs great effort, from suitable technological intervention to efficient resource utilization.

However, the most important thing to start with is 'Quality Seeds' which are suited to perform under low input environment and possess great resilience towards biotic and abiotic stress factors. Furthermore, adaptation is the key to achieving resilience in our food and agricultural system. Adapting seed to changing climates, resource availability, and environmental conditions is one way to mitigate risks for farmers and the food supply they serve.

It is estimated that more than 95% of organic/ low input agriculture is dependent on seeds varieties that were bred for the conventional high input sector**. Recent findings have sown that such varieties lack important traits required under organic and low– input production system, which have major importance towards climate change mitigation strategies** (van Bueren, 2011).

Moreover, vegetable crops are highly sensitive to climatic vagaries, where sudden rise in temperature or irregular precipitation at any phase of crop cycle can affect growth, flowering, pollination and fruit development, which may subsequently lower the crop yield (Afroza et al., 2010). In respect of vegetable seeds, only 50% of the national demand is met by domestic production (Shrestha and Dhakal, 2020). Although vegetable production in India has increased (187.47 mt) with time but shrinking land resources (10.43 mha) and increasing environmental challenges have made the development and use of quality seeds more important (NHB 2018-19, 1st advance estimate) for sustainable vegetable production.

In this background, a Program was undertaken in Phase II Project to develop **'NET ZERO' Clean Vegetable Seeds** through the adoption of Inhana Rational Farming (IRF) Technology – A Comprehensive Organic Technology for Safe and Sustainable Crop Production.

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MILESTONE NO. 3 - SUMMARY

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But the significance of this initiative was that Vegetable Seed Production was done with '**Complete Elimination of Pesticides and 100% Reduction of N-fertilizers**' following **COMPLETE ORGANIC MANAGEMENT** (through Inhana Plant Health Management and utilization of Waste bio-converted Novcom Compost for Inhana Soil Health Management).

Crop		Clean Food 'NET ZERO' Yield (Tonne/ ha)	'NET ZERO' Clean Seed Yield (Tonne/ ha)
BRINJAL	:	29.12	Process Ongoing
CHILLI	:	18.28	Process Ongoing
OKRA	:	17.90	1.278
TOMATO	:	32.09	0.214
GREEN PEAS	:	10.52	0.272
CAULIFLOWER	:	30.24	Process Ongoing
CARROT	:	12.96	Process Ongoing
RED AMARANTH	:	16.20	1.62
CABBAGE	:	22.22	Process Ongoing
BEANS	:	16.42	5.255
SPINACH	:	36.18	3.618
ONION	:	9.80	Process Ongoing
MUSTARD	:	0.528	0.528

HIGHLIGHT

The 'Net Zero' Clean Vegetable Seeds were Produced under Complete Organic Management, in the farmers' field, without any specific seclusion from the surrounding fields and still without increasing the cost of production – A STUPENDOUS ACHIEVEMENT, considering that production of Vegetable Seeds under Conventional Practice is a Cost Intensive Affair primarily considering the Longer residence time in the field, and Higher Pest/ Disease Incidence.

IBM **Corporate**
Social Responsibility

MILESTONE NO. 4

DEVELOPMENT OF SUSTAINABLE IMPACT STORIES RELATED TO IBM SUSTAINABILITY PROJECT.

IBM **Corporate Social Responsibility**

Which IBM program is this grant for?

Other

Target Reporting Date

12/23/2022

Milestone Name

Development of Sustainable Impact Stories related to IBM Sustainability Accelerator.

Milestone Goal

To create awareness regarding the 'Clean Food' Program- a definite pathway for Safe and Sustainable Agriculture especially concerning the Statement of the UN "It is currently not clear or well defined what constitutes productive and sustainable agricultural practice" as well as to bring forth the program's impact area w.r.t. SDG-2, 12 and 13; through the various social platforms.

Describe the expected progress toward the goal by this target reporting date.

"Expecting 100 percent achievement of the Milestone by the target date"

Expected progress toward milestone goal, as a number

100

Expected Progress Units

Sustainable Impact Stories

MILESTONE NO. 4 - SUMMARY

This Milestone Highlighted the **'Clean Food' Model and the transformation journey towards Clean Food 'NET ZERO' Model development**

Today we need HIGHER FOOD PRODUCTION FROM LESSER LAND AREA WHILE REDUCING/ ELIMINATING THE USE OF UNSUSTAINABLE/ NON RENEWABLE INPUTS. Hence, the situation demands a **TRANSFORMATIVE CHANGE** in Agricultural Practices to ensure **SUSTAINED production and availability of Safe Food for the rising global population while Mitigating Climate Change Impact** (*The Future of Food and Agriculture- Trends and Challenges, FAO-2017*).

Sustainable agriculture that integrates three main goals i.e., environmental health, economic profitability, and social equity is the only solution especially for a country like India with 224.3 million undernourished people. But the **CHALLENGE** is exhibited by UN's own Statement "**It is currently not clear or well defined what constitutes productive and Sustainable Agricultural Practice**".

The relevance of Sustainable Agriculture increases multifold in the **Indian context** where **more than 90% farmers are marginal and resource poor, with a land holding less than 0.38 hec**. Moreover, any disruption in their livelihood can destabilize the very fundamental base of our food production system, considering that these farmers contribute **51 per cent of total agricultural output and 70 per cent of high value crops** (TOI, 2nd Sept. 2022).

This was the background behind 'Clean Food' initiative of IORF, to enable Farmers' Access to an Effective, Economically Viable and a Conveniently Adoptable Crop Technology that can ensure Elimination of Chemical Pesticides from the crop production system with No Crop Loss and No Hike in the Cost of Production, leading to Safe and Sustainable 'Clean Food' production - SAFE FOR HUMAN HEALTH, SUSTAINABLE FOR ALL.

This IBM-IORF Sustainability Project in the **Nadia District of West Bengal** is a **First of a Kind and the Largest 'Clean Food' Program for Pesticide Free - Pure Food Production in India** encompassing 100 ha area and about 400 marginal and small farmers; that has demonstrated '**Clean Food' (Vegetables) development - SAFE FOR HUMAN HEALTH**

Contd..

MILESTONE NO. 4 - SUMMARY

Apart from Chemical Pesticides, chemical fertilizers especially N- Fertilizers form the **other major unsustainable component** of conventional food production. However, **reduction/ elimination of N- Fertilizer Without Crop Loss** is practically possible only through application of Quality Compost in soil. But; the acute scarcity of raw material for on- farm compost production, especially in respect of marginal and small land holders; forms the primary bottleneck towards the objective.

WASTE of any type especially landfill/ legacy waste/ MSW, etc., perfectly fits the bill, also because these are abundant resources and economic option. But apparently there is **dearth of Environmentally Safe and Economically Viable Composting Technology/ ies that can transform these Toxic, especially METHANE EMIITING pollutants** into Safe and mature Compost, suitable for agricultural use.

The Novcom Composting Technology of IORF successfully enabled the bio- conversion of Landfill Waste to provide an **adoptable solution to these resource poor farmers towards on- farm compost production.** Most importantly, bio- conversion of WASTE and application of waste bio- converted Novcom compost in soil rendered **Three Way GHG Mitigation** – i) METHANE Mitigation from source (Landfill Waste) during waste bioconversion, ii) NITROUS OXIDE Abatement due to elimination of N- Fertilizers enabled by application of compost in soil and iii) the related Soil- C Sequestration.

This insight actually led to the development of Clean Food 'Net Zero" (CFNZ) Model.

CFNZ is a first of a Kind **CLIMATE ACTION (SDG-13) MODEL in Agriculture** that will actually deliver **SAFEST FOOD –** Safe for Human Health, Soil & Environment.

A switch over from Conventional Farmers' Practice to Clean Food 'NET ZERO' Model, can totally transform the present GHG Emitting agriculture to a **GHG Sink Agriculture**; as depicted by the **GHG Mitigation Potential of more than 500 MT CO_2 eq. (case specific) per ha of CFNZ production.**

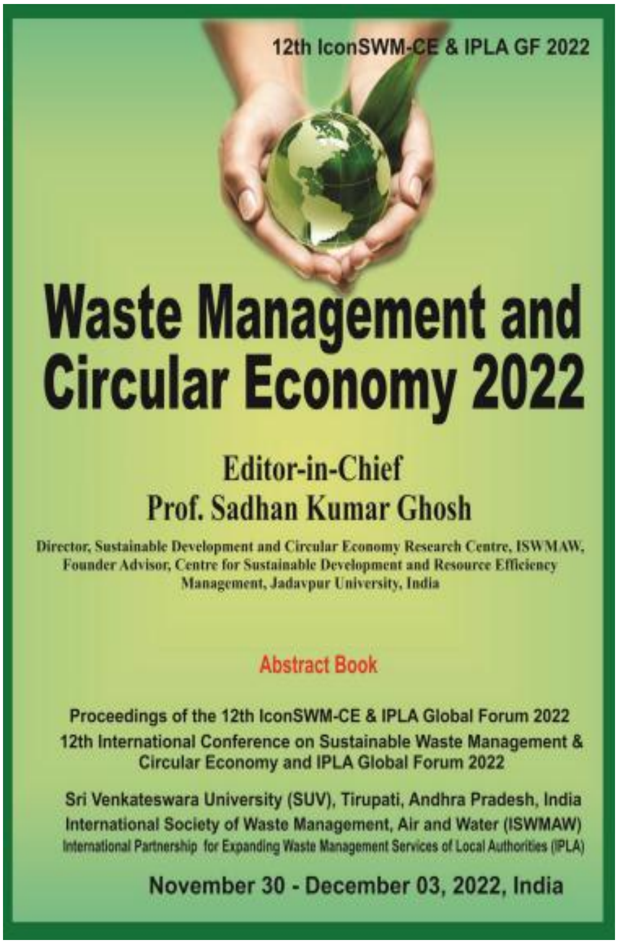
This Climate Action (**SDG-13**) Model attends the Most Critical Area of Sustainability- **SDG 2. But** it is also the **Model for Degraded Soil Reclamation** with clear impact area w.r.t. **SDG-15,** and impacts **4 other Crucial SDGs** i.e., **SDG-1**, **SDG-3, SDG-11** and **SDG-12**.

IBM **Corporate Social Responsibility**

MILESTONE NO. 5

Research Publications based on specific scientific outcomes

MILESTONE NO. 5 - SUMMARY



Three Research Articles were published :

1. **Induction of Novcom Composting Technology for Highest GHG Mitigation under 'Waste to Wealth Program'– A Case Study from IBM-IORF Sustainability Accelerator Project, West Bengal, India.**
2. **Technological breakthrough for large scale bioconversion of coir pith, a highly soil and water polluting material, huge GHG emitter with a very high GWP value, towards development of an effective GHG Offsetting Model.**
3. **Establishment of an Innovative Model for Safe & Effective management of Landfill Waste that can Generate Sustainability Imprints in Agriculture, Ecology & Economics – A Barometer for Circular Economy.**

These Research Articles highlighted the Impact of Climate Change on Food Production, the Agriculture sector being the second largest contributor of GHGs and also the only sector that can serve as a potential sink of GHG's, where an effective 'Waste to Wealth' program can play a crucial strategic role.

The articles highlighted the Very High GHG Mitigation Potential under Novcom Composting Technology– 17 times Lower value as compared to any Standard Composting Process (200 kg CO_2 eq/ ton wet raw material), **which became 31 times Lower, when Landfill Waste like Coir pith bio- conversion is done under this process. Another crucial finding was >99.0% Abatement of Methane from Source Point under Novcom Composting Technology.**

MILESTONE NO. 6

Model demonstration of Safe & Sustainable 'Clean Paddy Seed' production.

MILESTONE NO. 6 - SUMMARY

RICE production system is one of the most climate change sensitive agro-ecosystems, which faces huge threat of crop loss under any drastic fluctuation in the weather pattern. In West Bengal almost half of the arable land is under rice cultivation. Moreover, the major rice is grown during the Kharif (rainy) season and is majorly affected by weather fluctuations.

The most important reason why this crop was selected for 'NET ZERO' Clean Seed production is because it is also **one of the most CHALLENGING crops w.r.t. climate change mitigation considering the HIGH WATER and NITROGEN USAGE and HIGH GHG EMISSION POTENTIAL.**

'NET ZERO' CLEAN PADDY SEED grown under **COMPLETE ORGANIC MANAGEMENT** utilizing Inhana Rational Farming (IRF) Technology

The average yield of 4021 kg/ ha obtained under **'NZ' Clean Paddy Seed program** exclusively demonstrated the relevance of **Inhana Plant Health Management** towards not only yield sustenance, rather yield improvement, especially significant, because this was obtained overcoming the extreme climatic events that occurred during the tillering and seed setting phase.

Evaluation of seed quality as per the Indian Seed Certification Standards indicated a Germination Rate of 92% on an average, indicating a high seed viability. Study related to Germination under water stress and salt stress also pointed out the higher resilience of NZ Clean Paddy Seeds towards abiotic stress factor; in comparison to conventional seeds.

QUALITY (RESILIENT) SEEDS are the primary requirement for **SAFE & SUSTAINABLE AGRICULTURE**. In this respect the Seed Vigour Test that defines seed ability to germinate and establish seedlings rapidly, uniformly, and robustly across diverse environmental conditions; forms a crucial indicator. The test results conclusively indicate **'NZ' Clean Paddy Seeds** (*developed under IRF technology*), **as 'High Vigour' seeds, which indicates their potential to enhance the critical and yield-defining stage of crop establishment** - the primary objective of Safe & Sustainable Agriculture.

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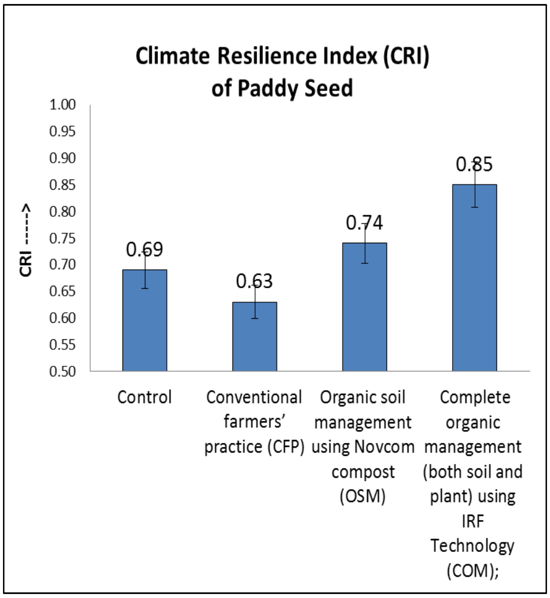
MILESTONE NO. 6 - SUMMARY

"CLIMATE RESILIENCE INDEX (CRI)"



"Climate resilience index (CRI)" which was developed majorly as a function of seed germination under abiotic stress, showed 35.5% and 14.6% higher value in case of the 'NZ' Clean Paddy seeds (COM) as compared to CFP and OSM respectively. The overall better performance of 'NZ' Clean Paddy seeds critically indicates that **the concept of "feed the soil" for sustainable organic farming does not hold true till focus is generated towards "PLANT HEALTH MANAGEMENT".**

ATTRIBUTES OF 'NET ZERO' CLEAN PADDY SEEDS

- ✓ **Climate Resilient Seed**
- ✓ **ZERO CO_2 Footprint Seed**
- ✓ **Zero Pesticide Foot print Seed**
- ✓ **Seed with Zero Seed borne Diseases**
- ✓ **Seed with Higher Germination Potential**
- ✓ **Biotic & Abiotic Stress Resistant Seed**
- ✓ **Seed with Higher Nutrient Utilization Potential**
- ✓ **Seed with 25% Lower Requirement than conventional seeds**

The **'NET ZERO' Clean Paddy Seeds developed under West Bengal Project** was provided to the **Project Farmers of Phase-II, IBM-IORF Sustainability Project at Mandya (Karnataka)** and it is for the **First Time in the Indian Agricultural Scenario that Safe & Sustainable 'Climate Resilient' Seeds has been used for Safe and Sustainable 'NET ZERO' Clean Paddy production through the utilization of Novcom Coir-pith Compost.**

The initiative is also significant considering that a **MAJOR OBJECTIVE** is to test the **CLIMATE RESILIENCE OF THESE SEEDS** in a completely different agro-ecological setting; and to **TRANSFORM** the production scenario from **COARSE GRAIN TO FINE GRAIN VARIETY**.

Estimation of Energy Use Efficiency

MILESTONE NO. 7 - SUMMARY

Efficient use of energy in agriculture is crucial for minimization of the environmental problems, to prevent destruction of natural resources and promote sustainable agriculture as economical production system

But the major Challenges for Energy Transition in agri-food systems is to decouple the use of fossil fuels in food-system transformation and related innovations **WITHOUT COMPROMISING FOOD SECURITY.** With the growing demand for energy and food, the transformation of both systems is necessary to align them more closely with global climate and sustainability goals. **In particular, the energy transition can directly affect and be affected by changes in food systems – and vice versa** *(Source: Renewable energy for agri-food systems, 2021 by IRENA and the FAO, UN).*

In this aspect, Energy Analysis of agricultural ecosystems is a concrete approach to investigate and **assess Energy Use Efficiency, and evaluate the SUSTAINABILITY QUOTIENT Of any Crop Production System**.

Assessment of energy requirements of different crop sequences were done in Model Farm under different levels of 'Clean Food' Program which are as given below :

i) 'Clean Food' Program with 100% Reduction of Chemical Pesticides.

ii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **50% Reduction of N- fertilizer.**

iii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **100% Reduction of N- fertilizer.**

The data obtained was compared with the energy use under Conventional Farming System. **The Evaluation was done w.r.t. Eleven different Cropping Sequences followed in the project area** *viz.*, Tomato-Cucumber-Coriander, Potato-Brinjal-Cauliflower, Potato-Okra-Cabbage, Brinjal-Frenchbean-Spinach, Pumpkin-Okra-Cabbage, Brinjal-Carrot, French bean-Okra- Onion, Potato- Chilli-Carrot, Tomato-Ridge gourd- Spinach, Peas -Yam –Cabbage and Pointed Gourd – Cauliflower.

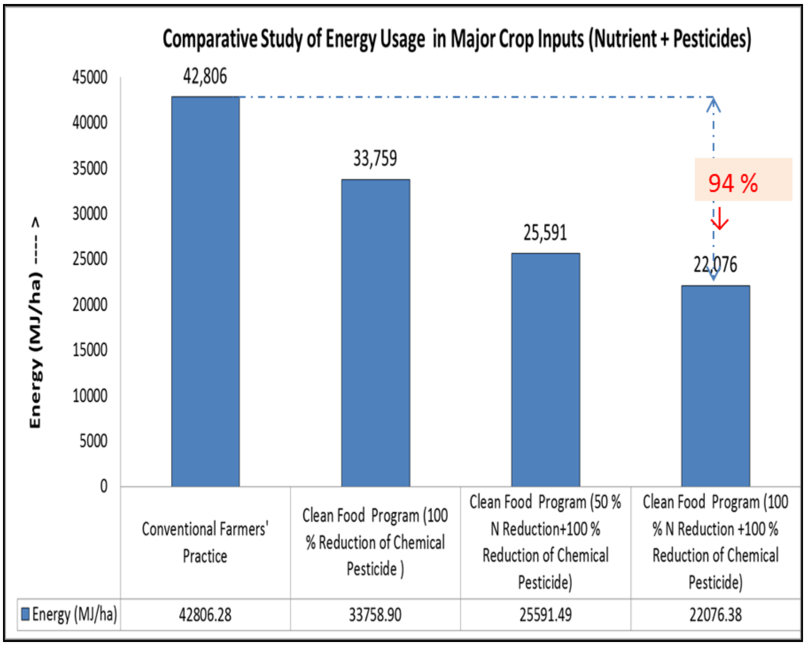
Contd. . .

MILESTONE NO. 7 - SUMMARY

27 to 57% higher Energy Output was recorded under the different levels of 'Clean Food' Program, which **indicates higher resilience of this Crop Production Model in terms of ensuring Crop and Economic Security** both in the present and future.

Especially the **highest Energy Output (57%)** under 'Clean Food' program with 100% Reduction of both Chemical Pesticides and N- fertilizers, indicates that these are the primary hands of unsustainability, and when eliminated **can reduce not only the adverse effects on climate, but also mitigate the economic vulnerability of the resource poor marginal and small farmers.**

Also, a **137 percent increase in Nutrient Energy Ratio recorded under the different cropping sequences under 'Clean Food' Model with 100% N- fertilizer Reduction + 100 % Reduction of Chemical Pesticides, highlighted better nutrient utilization efficiency and higher crop response per unit nutrient application, under IRF Technology.**



The **ENERGY INVESTMENT lowered by a remarkable 94%** when both chemical pesticides and N- fertilizers were completely eliminated through the interventional Soil Health Management and Plant Health Management under IRF Technology.

As well as **HIGHER INCORPORATION of RENEWABLE ENERGY SOURCES.**

These 'Clean food' Models demonstrated significant **ENERGY TRANSTITION**, **most importantly WHILE SUSTAINING CROP YIELDS & IMPROVING ENERGY PRODUCTIVITY –** which is a benchmark criteria for SUSTAINABLE AGRICULTURE.

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ESTIMATION OF CARBON SAVING AND GHG MITIGATION

MILESTONE NO. 8 - SUMMARY

The increasing risk of disruption in crop production due to climate change impact throws a major challenge towards mitigating global hunger. **The challenge is intensified by agriculture's extreme vulnerability to climate change. But agriculture is also the second largest contributor of greenhouse gases (GHG). At the same time this is the only sector that can enable both GHG mitigation and adaptation due to its potential to STORE A VAST AMOUNT OF SOIL CARBON -** up to 1 billion metric tons per year, which would offset around 10% of the annual GHG emissions of 8–10 billion metric tons/ year.

Increasing the amount of carbon in soil also makes it more productive for farmers which can only be through SUSTAINABLE FARMING APPROACHES. And for any sustainable farming, AMELIORATION OF SOIL is the most important criteria and QUALITY MANURE, rich in self-generated microflora is prerequisite for ensuring time bound effectiveness irrespective of agro-ecological settings.

EFFECTIVE TECHNOLOGY is the primary requirement towards effective bio-conversion of bio-resources, especially hard to biodegrade waste into quality manure and for GHG offsetting under the composting process, towards making meaningful contribution in respect of climate change mitigation. In this aspect, Analysis of GHG mitigation potential of agricultural ecosystems is a concrete approach to investigate and **assess carbon saving, and to evaluate the SUSTAINABILITY QUOTIENT of any Crop Production System**.

Assessment of GHG Mitigation under **Eleven different Cropping Sequences** was done in the Model Farm under different levels of 'Clean Food' Program which are as given below :

i) 'Clean Food' Program with 100% Reduction of Chemical Pesticides.

ii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **50% Reduction of N- fertilizer.**

iii) 'Clean Food' Program with 100% Reduction of Chemical Pesticides and **100% Reduction of N- fertilizer.**

The data obtained was compared with the GHG emission under Conventional Farming System.

Contd. . .

MILESTONE NO. 8 - SUMMARY

Assessment indicates that about 18-20 % reduction in GHG emission can be achieved with COMPLETE ELIMINATION OF CHEMICAL PESTICIDES. The finding substantiated the fact that N-FERTILIZERS ARE THE MAJOR GHG CONTRIBUTORS under the conventional farmers' practice.

The Average GHG emission was **(+) 0.12** kg CO_2-eq/kg produce under Conventionally Managed crop sequence.

In contrast, (-)0.05 kg CO_2-eq and (-)0.19 CO_2-eq per kg produce or a **NET MITIGATION of (-)0.17 to (-)0.31 kg CO_2-eq per kg produce**, was obtained under **CLEAN FOOD MODELS** with 50 % N-Fertilizer Reduction+ 100 % Reduction of Chemical Pesticides; and 100 % Reduction of both N-Fertilizer and Chemical Pesticides; respectively**.**

Comparative study of GHG Emission under Conventional Farmers' Practice *vs*. the GHG mitigation potential under the different 'Clean Food' Models under the Phase-II Project once again substantiated that, **a progression towards Safe and Sustainable Agriculture especially complete elimination of both the hands of unsustainability i.e. the N-fertilizers and Chemical Pesticides** can totally transform agriculture from a GHG Emitting Source to a CARBON Guzzling Sink.

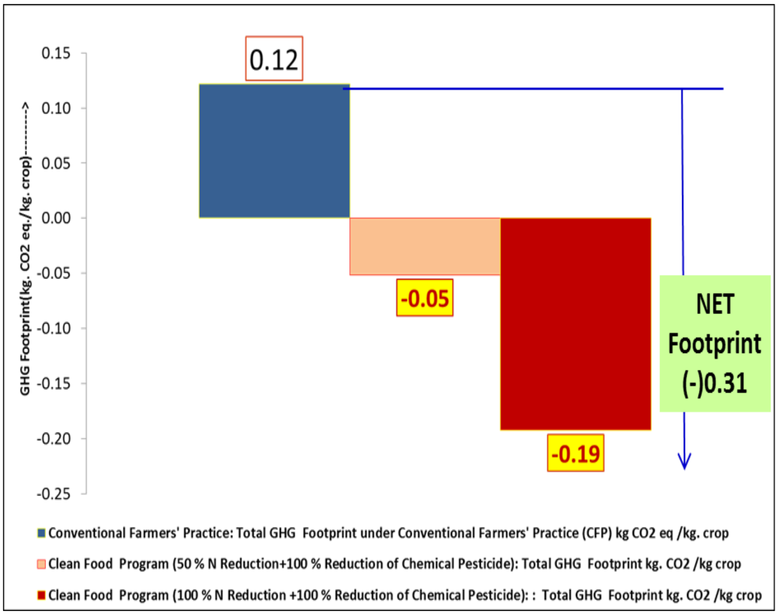


Fig. : Avg. GHG Footprint (kg CO_2 eq/ kg. crop) **under Conventional Farmers' Practice (CFP) vs. 'Clean Food' Models with 50% N Reduction + 100% Reduction of Chemical Pesticide vs. 100 % Reduction of both N- fertilizer and Chemical Pesticide.**

MILESTONE NO. 9

ANALYSIS OF SAFETY, QUALITY & SEED RESILIENCE OF CLEAN PADDY & VEGETABLE SEEDS

MILESTONE NO. 9 - SUMMARY

Climate change is threatening food security round the globe, where a large proportion of food is produced by the vulnerable smallholder farmers. The climate change impact has increased the relevance of using quality seeds by many folds; considering that seed quality plays significant role in success/ failure of any cropping system. Climate-resilient crops and crop varieties have been recommended as a way for farmers to cope with or adapt to climate change, but availability of climate resilient vegetable seeds are rare in India if not totally unavailable.

In the present study under IBM-IORF Sustainability Project, a program was initiated towards development of **CLIMATE RESILIENT- Net Zero Clean Vegetable Seeds** in farmers' field under Complete Organic Management with adoption of Inhana Rational Farming (IRF) Technology.

12 different open pollinated vegetable varieties viz. Brinjal, Chilli, Okra, Tomato, Green peas, Cauliflower, Carrot, Red amaranth, Cabbage, French bean, Spinach, Potato and one oilseed variety- Mustard; were selected for the seed developmental program.

Till the time of this report, complete documentation of the seed yield data has been done for eight vegetables varieties *viz.* Okra (1278 kg/ha), Tomato (214 kg/ha), Green peas (272 kg/ha), Red amaranth (1620 kg/ha), Spinach (3618 kg/ha), Bean (5255 kg/ha) and Potato (29.49 ton), as well as oilseed variety mustard (528 kg). Seed quality in terms of germination, seed vigour and climate resilience are in the process which will be documented in the 3rd year activity report.

Initiative was taken up to develop **'NET ZERO' Clean Paddy Seed, considering that Rice is both a Victim and a Cause of Climate Change.** The crop faces many **CHALLENGES** such as declining or stagnant yields, lack of water availability, contamination of natural resources due to excessive use of agrochemicals, biodiversity losses, greenhouse gas emissions and losses due to extreme climatic events.

Contd. . .

MILESTONE NO. 9 - SUMMARY

Quality evaluation of the Net Zero Clean Paddy (NZCP) Seeds paddy seeds was also undertaken to assess the impact of IRF Technology towards the Seed Quality attributes.

SEED QUALITY	Indian Seed Certification Standards for each Class		'Net Zero' Clean Paddy Seed developed under IRF Technology
	Foundation	Certified	Miniket (IET- 4786)
Pure seed (min.)	98.0%	98.0%	**99.85 %**
Inert matter (max.)	2.0%	2.0%	**0.15 %**
Huskless seeds (max.)	2.0%	2.0%	**No**
Other crop seeds (max.)	10/kg	20/kg	**No**
Total Weed seeds (max.)	10/kg	20/kg	**No**
Germination (min.)	80%	80%	**92 %**
Moisture (max.)	13.0%	13.0%	**9.32**

The germination rate of NZCP seeds was found to be 92% on an average, indicating a high seed viability. Germination Potential of NZCP Seeds was found to reduce considerably under water stress and salt stress, but the reduction was significantly lower as compared to conventional seeds; **which indicated their higher resilience to un-favourable conditions**. In terms of Germination under Accelerated Ageing **(G_{AA})**, the **'NZ' Clean Paddy Seeds showed superior performance as compared to the conventional seeds.**

Studies indicate that membrane lipid peroxidation is one of the major causes of seed ageing under accelerated ageing conditions (Oliveira et al., 2011a). However, **healthy plants contain numerous antioxidant compounds, both enzymatic and non-enzymatic, which act to prevent oxidative damage by the scavenging free radicals** before they attack membranes or other seed components (Bhaskaran and Panneerselvam, 2013). **The G_{AA} test values confirmed that the 'NZ' Clean Paddy Seeds embodied the potentials of a 'Healthy Plant'.**

IBM **Corporate Social Responsibility**

MILESTONE NO. 10

SAFETY AUTHENTICATION OF 'CLEAN FOOD' THROUGH 'FOOD SAFETY ASSESSMENT TOOL'

MILESTONE NO. 10 - SUMMARY

The **World Health Organization (WHO) states** "**If it is not safe, it is not food", as it does not serve its purpose to provide proper and safe nutrition**".

And now under the existential Climate Change, **the FAO indicates**, 'For the world's poor, adapting to climate change and ensuring food security go hand in hand and thus a paradigm shift towards agriculture and food systems that are more resilient, more productive, and more sustainable is required. **Food security requires SUFFICIENT, AFFORDABLE, NUTRITIOUS, & SAFE FOOD.**

According to the FSSAI report 2019 (Mittal, 2019), among the vegetable samples studied **brinjal showed the maximum number of pesticide residues; followed by the samples of tomato, okra, cabbage, cauliflower and cucumber.**

According to Food Safety and Standards (Contaminants, Toxins And Residues) Regulations, 2011; developed by Food Safety and Standards Authority of India, **lowest limits of pesticide residue in vegetables is 0.1 ppm except very few cases**. This was in accordance with Codex Alimentarius Maximum Residual Limit (0.1 ppm) in case of vegetables.

The Phase-1 of Project Demonstrated the 'CLEAN FOOD' MODEL- SAFE for Human Health @ Same Cost, Hence Sustainable for All - **aligned with SDG-2**, **that can be Adopted across Agro-ecological Zones and variable Farm Economies.**

Moreover, Clean Food means Safety Authentication NOT BY AUDIT but through ACTUAL ANALYSIS. The chromatographic technique for residue analysis however, is hugely expensive, complex, time-consuming and require specific resources and infrastructure which offer major hindrance towards regular analysis for monitoring of food safety. Especially for a country like India, with absolute dominance of marginal farmers in vegetable cultivation, lack of awareness, resource scarcity, inability to take economic risk and flaws in maintaining the standard practices w.r.t. chemical usage; enhances the availability of pesticides in food product.

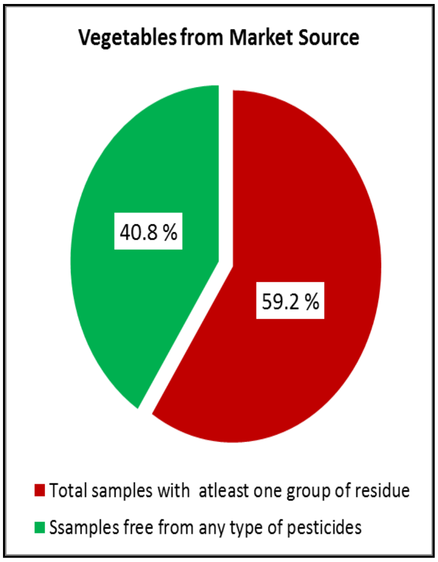
Moreover the short time gap between the field harvest of vegetables and consumption, limits the scope for safety analysis even if the infrastructure and economics is not considered.

Contd. . .

MILESTONE NO. 10 - SUMMARY

In this background an effective, speedy, yet an affordable method was needed to enable pesticide residue analysis in situations of limited resources, more so for safety authentication of Clean Food.

In this respect the **Colorimetric Assay Test** was identified as a solution that can tick off all the requirements. The Colorimetric Pesticide Assay Test can serve as the **MOST STRINGENT TEST** for Food Safety, due to the scope for detection of the Collective Presence/ Absence of the Pesticide Residues up to the Lowest- Group Specific Permissible Limits. **And Most Importantly at just 1/10th of the Conventional Cost of Residue Analysis.**



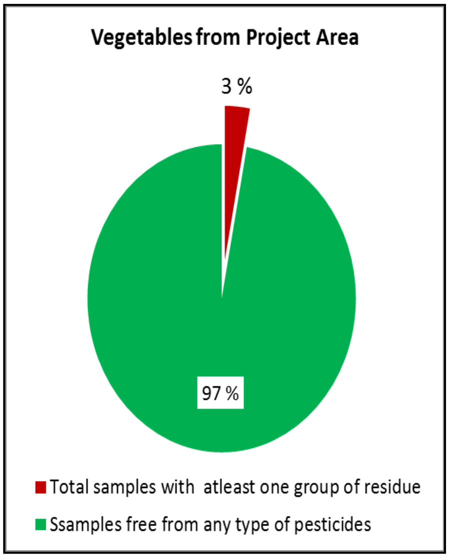


Fig. Showing Percent Vegetable Samples that exceeded Maximum Residue Limit (MRL) w.r.t. at least one pesticide group, as per CODEX ALIMENTARIUS FAO-WHO & FSSAI (>0.10 ppm) Standards

Pesticide Residue analysis of more than **140 vegetable samples** representing **18 different varieties of vegetables**, indicated **Residue Free Status in 97% of the samples collected from the 'Clean Food' Project Area.**

Another crucial finding was made in case of crops like **brinjal and pointed gourd**, which have a higher pesticide load **because of long duration (7-8 months) in field**. Under 'Clean Food' Program with adoption of IRF Technology, a **considerable reduction of pest pressure was observed even in case of these crops, which naturally lowered the requirement for pesticide application.**

Analysis also revealed **92.6% Reduction in the Risk of Pesticide Contamination in Food under 'Clean Food' Program, especially through the intervention of Plant Health Management under IRF Technology**.

Annexure - IV

Research Articles

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Recycling of Waste Utilizing Novcom Composting Technology towards GHG Abatement from Source

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Increased emission of greenhouse gases with enhanced industrialization, urbanization and conventional agriculture has accelerated the climate change which poses a fundamental threat to the environment, biodiversity and peoples' livelihoods. Moreover, targeting higher crop production, through conventional agriculture to feed a world population of 9.3 billion, by 2050; will entail higher GHG emission, considering that agriculture accounts for 17 percent of the global GHG emissions.

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But, agriculture is also the only sector, which can serve as a potential sink for GHG's, through regeneration of the Soil-C sequestration potentials. Application of stable and mature organic amendments is one of the effective ways, but for taking the program at scale, the raw material source for compost production has to be abundant and cost free. In this respect any type of biodegradable waste specially landfill/ legacy waste perfectly fits the bill, but the primary requirement is availability of effective and economic composting technology/ ies that can justify the dual premise of safe and effective waste bio-conversion as well as GHG abatement. The present study under IBM-IORF Sustainability Project was taken up to study waste bio-conversion as well as GHG mitigation potential under Novcom Composting Technology. The GHG's were measured using 'Closed Chamber Method' with daily reading for continuous 30 days.

Analysis of the Novcom compost samples confirmed their stability and maturity as depicted by the CO_2 evolution rate (2 mgCO_2–C/ g OM/ day) and the safety/ non- phytotoxic effect was confirmed by the germination index value of 1.12. The total NPK value of 4.18% indicated a high nutrient content and the C:N ratio of 13:1 indicated an effective nutrient mineralization potential, post soil application. However, the significant finding was made in respect of the soil microflora population which was found in the order of 19 – 56 x 10^{16} c.f.u., per gm or in other words 1 trillion billion c.f.u. per ton moist compost.

The study indicated a significantly low GHG emission (11.38 kg CO_2 equivalent/ ton treated waste) under Novcom Composting Technology, which was found to be 17 times lower in comparison to the reference values obtained in respect of the other biodegradation processes. Also, a very insignificant methane emission (0.67 kg CO_2 equivalent/ ton treated waste) was recorded under this technology. The generated database along with the initial and final data of moisture, carbon and nitrogen was utilized for development of empirical equations to predict GHG emission under Novcom Composting Technology. These empirical equations were consequently utilized to evaluate the GHG abatement potential of Novcom Composting Technology while recycling landfill materials, MSW, legacy waste, press mud, coir pith, vegetable market waste, refuse from food processing industry and wheat mill waste.

According to the assessment as per IPCC guideline, bioconversion of these wastes through Novcom Composing Technology can enable a GHG abatement of 5039 kg CO_2 eq per ton (*on an average*) of treated waste. Hence, this composting technology can facilitate an effective model towards attainment of the Net Zero objective along with significant social and economic impacts.

Keywords: Greenhouse gases; waste recycling; novcom composting technology; empirical equation; emission predictability.

1. INTRODUCTION

"Human-induced climate change is causing widespread disruption in nature and affecting the lives of billions of people around the world, despite efforts to reduce the risks" [1]. "A 2020 report found that nearly 690 million people or 8.9 percent of the global population are hungry, and 149 million children are stunted because of under-nutrition" [2]. "The 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" [3]. The challenge is intensified by agriculture's extreme vulnerability to climate change. Climate change's negative impacts are already being felt, in the form of increasing temperatures, weather variability, shifting agro-ecosystem boundaries, invasive pests, and more frequent extreme weather events [4]. On farms, climate change is reducing crop yields, the nutritional quality of major cereals, and lowering livestock productivity [5].

On the other hand, agriculture is the only sector, which acts as both a source and sink for the greenhouse gases [6]. Emission enhances with industrial agriculture, when use of fossil fuel, chemical fertilizers (especially N), synthetic chemicals and involvement of machinery increases [7]. According to an estimate by FAO, in 2018; global emissions due to agriculture was 9.3 billion tonnes of CO_2 equivalent (CO_2eqv.), which took a 14 percent growth since 2000 and accounted for 17 percent of global GHG emissions from all sectors [8]. However, agricultural ecosystems also have the potential to store a vast amount of soil carbon up to 1 billion metric tons per year, which would offset around 10% of the annual GHG emissions of 8–10 billion metric tons per year [9]. According to an estimate by Dr. Lal, the renowned Soil Scientist and the

2020 World Food Prize Winner, the carbon sink capacity of the world's agricultural and degraded soils is 50 to 66% of what it has been historically. This means our soil can hold 42 to 78 billion metric tons more carbon [10].

Increasing the amount of carbon in soil also makes it more productive for farmers which can only be through sustainable farming approaches. And for any sustainable farming, amelioration of soil is the most important criteria (AGRIVI, 2023) and quality manure, rich in self-generated microflora is prerequisite for ensuring time bound effectiveness irrespective of agro-ecological settings. Effective technology is the primary requirement towards effective bio-conversion of bio-resources, especially hard to biodegrade waste into quality manure [11] and for GHG offsetting under the composting process [12] towards making meaningful contribution in respect of climate change mitigation. However, there have been limited studies in this direction especially in the Indian agriculture sector.

In this background, bioconversion of waste was taken up under Novcom Composting Technology, which is a validated, aerobic biodegradation process developed by Dr. P. Das Biswas (pioneer of sustainable tea production in India) that can enable safe, stable and mature compost production within the shortest period of 21 days. The objective was to evaluate the effectiveness of Novcom Composting Technology in respect of waste recycling and abatement of greenhouse gases from source, as compared to the GHG emission potential of waste under landfill conditions.

2. MATERIALS AND METHODS

The study was done as part of developing Clean Food 'Net Zero' Model under IBM-IORF Sustainability Project at Nadia, West Bengal, India during 2021-22 by Inhana Organic Research Foundation in collaboration with Nadia Krishi Vigyan Kendra, BCKV, ICAR. Technical help specially in terms of studying the GHG emission under Novcom composting process was provided by experts from other institutes *viz*. Visva Bharati University, Energy Transition Commission, UK and i-No Carbon Limited, UK and Agricultural & Ecological Research Unit, Indian Statistical Institute, Giridih.

2.1 Preparation of Novcom Compost

For preparation of Novcom compost, different agro waste and cow dung was taken in 80: 20 ratio and the compost was prepared as per standard methodology [13].

2.2 Analysis of Compost Quality Parameters

Physicochemical properties of compost *viz.* moisture content, pH, electrical conductivity and organic carbon were analyzed according to the procedure of Trautmann and Krasny [14]. The total N, P and K in compost were determined using the acid digestion method [15,16]. Estimation of bacteria, fungi and actinomycetes was performed using Thornton's media, Martin's media and Jensen's media respectively, according to standard procedure [17,18]. Stability tests for the compost (CO_2 evolution rate, phytotoxicity bioassay test/germination index) were performed according to the procedure suggested by Trautmann and Krasny [14]. Cress (*Lepidiunsativum L*.) seeds were used for the phytotoxicity bioassay test.

2.3 Protocol for Greenhouse – Gas Measurement

For measurement of different greenhouse gas (GHG) *vis*. CO_2, N_2O, CH_4 and NH_3, eight Novcom compost heaps were made using different agro-waste *viz*. farm waste, banana stumps, water hyacinths, paddy straw, vegetable market waste, etc. during 2021 - 2022. To measure the GHGs, we inserted eight perforated tubes of 6.5' length, placed equidistance in the compost heap of dimension 10 ft. x 6 ft. x 6 ft. as per Pics. 1 and 2; in order to trap all the greenhouse gases (Pic. 1). We measured all the gases using 'Closed Chamber Method' with daily reading for continuous 30 days (compost matures in 21 days). This was done to estimate the total GHG on actual basis, not from any prediction model; as generally done in such case studies.

2.3.1 Nitrous oxide (N_2O)

Nitrous oxide (N_2O), more commonly known as "laughing gas," is a potent greenhouse gas, 273 times more powerful than carbon dioxide in terms of Global Warming Potential (GWP_{100}). Nitrous oxide has a strong affinity to get absorbed in acetic acid [19]. So we developed a chemical trapping mechanism using a closed chamber to measure Nitrous oxide emitted during compost biodegradation. However, the major difficulty is that CO_2 is also absorbed by acetic acid. So we used six different aqueous solution of acetic acid i.e., 0.05, 0.10, 0.30, 0.50, 1.0 and 2.0 percent.

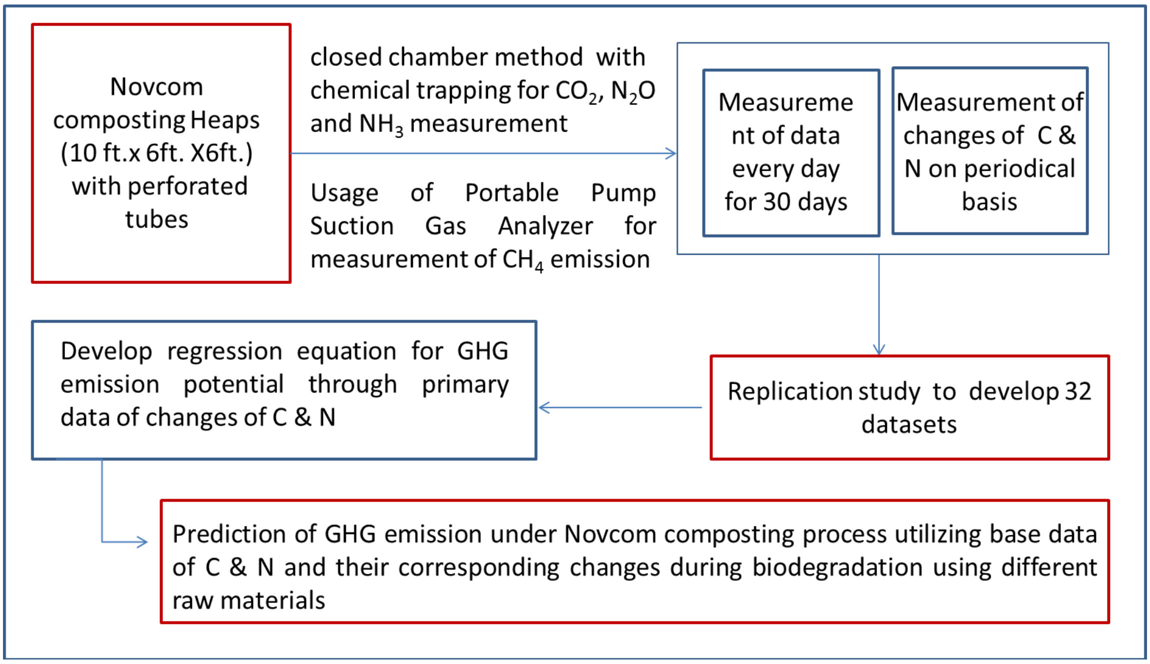
The solubility curve of carbon dioxide in aqueous acetic acid solution formed a parabola-like structure with maximum absorption in 1% acetic acid solution. Therefore, 1% acetic acid solution was used for the experiment.

2.3.2 Carbon-di-oxide (CO_2)

CO_2 gas is absorbed in 1N NaOH solution. Hence, 20 mL 1 N NaOH solution was taken in two beakers and placed on the heap under the specific jar selected for CO_2 absorption. These solutions each of 20 mL were taken in a 100 mL beaker and were placed according to requirement under a closed vessel. The head of the eight tubes were also covered by these vessels. Also four beakers, containing 1% acetic acid and 1N NaOH were kept at room temperature [20].

Pic. 1. Structure for C with special perforated pipes for GHG estimation under IBM-IORF sustainability project

Flowchart of the Methodology Adopted for GHG estimation under Novcom Composting Technology:



Pic. 2A. Measurement of GHG emission from novcom compost heap through 'closed chamber method' under IBM-IORF sustainability project

2.3.3 Methane (CH_4)

An open bottom chamber was used to measure gas fluxes as per standard method [21]. Due to the flux ($F_{\text{Flux chamber}}$) of methane through the top of the compost material, the concentration of methane (C_{methane}) increased linearly inside the flux chamber over time, and the change in concentration over time (dC_{methane}/dt) was calculated.

2.3.4 Ammonia gas (NH_3)

Ammonia gas is absorbed in 5% boric acid. So, two beakers containing 20 mL 5% boric acid in each were placed under each jar selected for ammonia absorption. After 24 hours the boric acid was titrated against 0.05 N H_2SO_4 using mixed indicator. This was done repetitively on each day for the entire period of composting.

3. RESULTS AND DISCUSSION

3.1 Variation in Temperature Generation during Composting Process

The temperature variation curve (Fig. 1) showed that there was steady rise of temperature within Novcom composting heap from day 2, which reached the peak (68^0 C) on 6th day. The steep rise of temperature indicated initiation of prolific microbial activity [22], which might be influenced by the energized Novcom solution. The average temperature between the successive turnings on 7th and 14th day gradually decreased went below 44^0C from the 19th day and from 21st day onwards the temperature curve was almost parallel to X axis, which confirmed the completion of composting process or simultaneously compost maturity Bera et al. [23]. Maintenance of a stable temperature of more than 145^0F (> 62.8^0C) within the compost heap for more than 3 consecutive days has been found to be effective towards destruction of most of the human pathogens, insect larvae and weed seeds within the compost heap [24], hence the temperature curve of compost heap suggests that the process could ensure a safe end product for application in soil as well as human handling.

3.2 Evaluation of end Product Quality

Study was also taken up to evaluate the end product quality developed under Novcom Composting Technology. Under this study, compost samples were collected from the heap on the 21st day and analyzed for physicochemical, microbial, stability and maturity/ phytotoxicity parameters.

Pic. 2B. Measurement of GHG emission from novcom compost heap from 0 – 30 days under IBM-IORF sustainability project

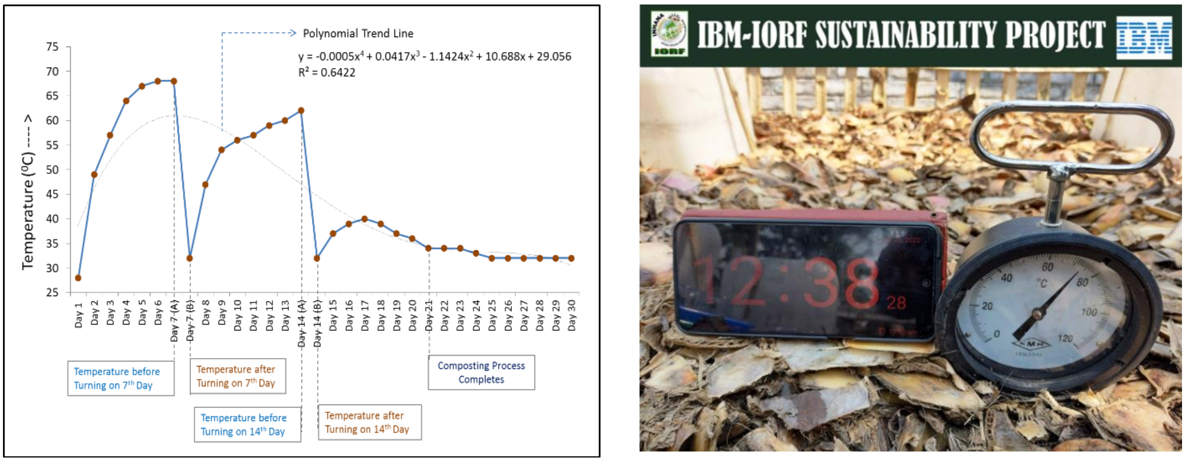


Fig. 1. Variation in temperature generation during novcom composting process under IBM-IORF sustainability project

3.2.1 Physicochemical parameters

All the compost samples appeared dark brown in colour with an earthy smell, deemed necessary for mature compost [25]. Average moisture varied from 60.24 to 65.4 percent (Table 1), which is slightly higher than the reference range (40 to 50) as suggested by Evanylo, [26]. pH of compost is an important criteria for consideration in respect of soil application, so that it can create a good growing medium for plants. pH value of Novcom compost samples ranged between 6.09 and 8.29 with mean of 7.70 (Table 1), which was well within the stipulated range for quality compost and indicated compost maturity [27]. Electrical conductivity value ranged between 1.24 and 3.30 with mean 1.70, indicating its high nutrient status. The organic matter of compost is a necessary parameter for determining the compost application rate to support sustainable agricultural production. Organic carbon content in compost samples ranged between 21.20 and 27.14 percent with mean value of 24.9, qualifying even the standard suggested value of >19.4 percent [28] for nursery application, with only few exceptions. Compost mineralization index (CMI) expressed as ash content/ oxidizable carbon indicated the ready nutrient supplying potential of compost for plant uptake [29]. The CMI values of the compost samples varied from 1.46 to 3.40 indicating that all the values complied the standard range of 0.79 to 4.38 [30].

3.2.2 Fertility and microbial parameters

Although 36 different nutrients are required for plant growth, but the macronutrient (N, P, and K) contribution of compost is usually of major interest. The total nitrogen content in the compost samples ranged between 1.69 and 2.01 percent (Table 2), which was well above the reference range suggested by Alexander [31] and Watson [32]. Mean value of total phosphate and total potash (0.86 and 1.10 percent respectively) were also higher than the minimum suggested standard. The ideal C/ N ratio of any mature compost should be about 10, as in humus; but it can be hardly achieved in composting [33]. However, of greater importance is its critical value (C/N ratio 20), below which further decomposition of compost in soil did not require soil nitrogen, rather released mineral nitrogen into the soil [34]. C/N ratio of the compost resembled the values obtained for any good quality compost.

Most organic substrates draw an indigenous population of microbes from the environment. In case of open-air composting processes, further colonization in compost material occurs naturally during heap construction as well as turning of heap. The microbial population, their biomass and activity, are key parameters that can also be used to elucidate the composting process [35]. At the same time the very high microbial population (in order of 10^{16} for total bacteria, fungi and actinomycetes count) in Novcom compost samples, corroborated the uniqueness of its production method which enables energy transfusion into the micro-environment within compost heap through application of potentized and energized Novcom solution. The process leads to generation of an ideal micro-atmosphere that facilitates self-generation of a high and diversified native microbial pool within the compost heap [29], which in turn influences fastest bio-conversion, high and balanced nutrient dynamics and desirable electrical conductivity, etc. [36].

Table 1. Physicochemical parameters of compost prepared under IBM-IORF sustainability project

Sl. No.	Parameter	Range Value	Mean value	(±) S.E.
Physicochemical Parameters				
1.	Moisture percent (%)	60.24 – 65.6	63.9	0.94
2.	pH_{water} (1 : 5)	6.09 – 8.29	7.7	0.41
3.	EC (1 :5) dSm^{-1}	1.24 – 3.30	1.86	0.37
4.	Total Ash Content (%)	49.56 – 65.50	55.1	2.69
5.	Total Volatile Solids (%)	34.5 - 50.44	44.9	2.69
6.	Organic Carbon (%)	19.2 - 28.0	24.9	1.52
7.	Compost Mineralization Index (CMI)	1.69 – 3.43	2.2	0.31

Table 2. Fertility and microbial parameters of compost prepared under IBM-IORF sustainability project

Sl. No.	Parameter	Range Value	Mean value	(±) S.E.
Fertility Parameters				
1.	Total Nitrogen (%)	1.69 – 2.01	1.89	0.04
2.	Total P_2O_5 (%)	0.86 – 1.10	0.97	0.03
3.	Total K_2O (%)	0.82 – 1.87	1.32	0.07
4.	C/N Ratio	12:1 – 17:1	13 : 1	0.52
Microbial Count (c.f.u. per gm moist compost)				
5.	Total Bacteria	(34–68) $x10^{16}$	56 $x10^{16}$	-
6.	Total Fungi	(29 – 37) $x10^{16}$	33 $x10^{16}$	-
7.	Total Actinomycetes	(15–28) $x10^{16}$	19 $x10^{16}$	-

3.3.3 Stability, maturity and phytotoxicity parameters

Compost maturity and phytotoxicity rating are the most important criteria for ensuring soil safety post compost application. Immature compost may contain high level of free ammonia, specific organic acids or other water soluble compounds which can limit seed germination and root development [37]. Many studies have shown that the application of immature compost in soil caused severe damage to plant growth [27]. Stability of compost sample indicates the status of organic matter decomposition and is a function of biological activity. Hence, microbial respiration forms an important parameter for determination of compost stability. Mean respiration or CO_2 evolution rate of all compost samples (1.98 to 3.92 mg/day) were more or less within the stipulated range (2.0 - 5.0) for stable compost [14]. The values obtained were in close conformity to the respirometry stability class rating of U.S Composting Council [38] for compost stability [37].

Assessment of phytotoxicity revealed that percent seed germination and root elongation over control ranged from 89 to 157 and 87 to 128 respectively (Table 3), which was well above the USCC guideline (> 90) for ‘very mature compost with no phytotoxic effect’. Germination index (phytotoxicity bioassay) value ranged between 0.78 and 1.60 (mean 1.12), which was well above the highest order of rating (1.0) and indicated not only the absence of phytotoxicity [35] in the compost samples but moreover, it confirmed that the compost enhanced rather than impaired germination and radical growth [14].

Table 3. Stability, maturity and phytotoxicity parameters of compost prepared under IBM - IORF sustainability project

Sl. No.	Parameter	Range Value	Mean value	(±) S.E.
Stability Parameters				
1.	CO_2 evolution rate ($mgCO_2$–C/g OM/day)	0.96 – 3.01	2.00	0.14
Maturity & Phytotoxicity Parameters				
2.	Seedling emergence (% of control)	89 – 157	104	4.21
3.	Root elongation (% of control)	87 – 128	123	3.05
4.	Germination index (phytotoxicity bioassay)	0.95 – 1.37	1.12	0.08

3.3 Measurement of Different Greenhouse Gas (GHG)

In the context of global warming, composting is one of the best waste management options that can offset GHG gases on one hand, while also contributing towards sustainable agriculture through the utilization of end product (compost) for soil health management; which in turn can enable the reduction of chemical fertilizers *vis-a vis* GHG mitigation from source. However, implementation of a reliable technology to deal with these wastes is considered as a pillar for sustainable development of any nation [39]. The amount of emitted gases under any composting process is highly influenced by the type of treated wastes and operational conditions, but most importantly the adopted composting technology, which would have a direct impact in reducing the rate of emissions, mainly N_2O and CH_4 [40,41]. At the same time apart from being environment friendly the technology needs to be cost- effective as well, in order to ensure large scale adoptability.

Emissions are formed due to inadequate aerobic conditions of composting [40]. Generally, the creation of anaerobic zones in compost mixtures results in CH_4 emissions, whereas nitrogen transformation and loss (NH_3 and N_2O) are linked to ammonification, nitrification, and de-nitrification during the composting process [42-44]. The rate of gaseous emissions generally vary as per the adopted composting method, but the emitted amount is still less than that recorded from the landfill sites and under waste-to-energy processes [45-47].

3.4 Global Warming Potential (GWP) Values of Green House Gases

Global Warming Potential (GWP) has been developed as a metric to compare (relative to another gas) the ability of each greenhouse gas to trap heat in the atmosphere. Specifically, it is a measure of how much energy the emission of 1ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2) [48]. CO_2 was chosen as the reference gas to be consistent with the guidelines of the Intergovernmental Panel on Climate Change [49]. Because CO_2 has a very long residence time in the atmosphere, its emissions cause increase in atmospheric concentrations of CO_2 that will last thousands of years [50]. The time period usually used for GWPs is 100 years. Nitrous Oxide (N_2O) has a GWP 273 times that of CO_2 for a 100-year timescale. N_2O emitted today remains in the atmosphere for more than 100 years, on an average [51]. Now in case of methane, there is an emerging debate whether, GWP of methane will be taken on 100 year's basis (as IPCC recommended) or on a shorter scale. Because, GWP hides trade-offs between short- and long-term policy objectives inside a single time scale of 100 or 20 years [52]. "The most common form, GWP_{100}, focuses on the climate impact of a pulse emission over 100 years, diluting near-term effects and misleadingly implying that short-lived climate pollutants exert forcing in the long-term, long after they are removed from the atmosphere" [53]. "Meanwhile, GWP_{20} ignores climate effects after 20 years" [54].

Now, the challenge is majorly related to methane, which is a powerful greenhouse gas with a 100-year global warming potential 28-34 times that of CO_2. But when m easured over a 20-year period, that ratio grows 84-86 times. Despite methane's short residence time, the fact that it has a much higher warming potential than CO_2 and that its atmospheric volumes are continuously replenished make effective methane management a potentially important element in countries' climate change mitigation strategies [55] .

According to J. Trancik, an MIT associate professor at the Institute for Data, Systems, and Society, more scientists are beginning to model the warming effects that today's methane emissions will have over the next 20 or 30 years, in order to predict more accurately whether humanity can avoid overshooting targets such as stopping global warming at 1.5 degrees Celsius [56].

Pérez-Domínguez et al. [57] also indicated that methane's short atmospheric life has important implications for the design of global climate change mitigation policies in agriculture. Results also showed that the choice of a particular metric for methane's warming potential is the key to determine optimal mitigation options, with metrics based on shorter-term impacts leading to greater overall emission reduction. Most importantly, when the ambition is to reduce warming in the next few decades, a shorter time horizon might be applied in comparing the effects of CO_2 and CH_4. Thus a two-value approach, which indicates the effect over two different time horizons, is suggested by a number of studies [54].

In the Sixth Assessment Report of IPCC (AR6) [58] , there is discussion regarding the use of a range of emission metrics, including GWP_{20} and GWP_{100} and how they perform, using methane as an example and explores how cumulative CO_2 equivalent emissions estimated for methane vary under different emission metric choices and how estimates of the global surface air temperature (GSAT) change deduced from these cumulative emissions compare to the actual temperature response computed with the two-layer emulator [59]. GSAT changes estimated with cumulative CO_2 equivalent emissions computed with GWP_{20} matches the warming trend for comparatively shorter time scale (a few decades) but quickly overestimates the response, whereas estimating emissions using GWP_{100} underestimate the warming potential [60]. So the moot point is we do not have another 100 years to achieve our 2050 climate neutrality and net zero targets and whatever we need to change, have to be done now.

Now, according to Abernethy and Jackson, emission metrics, a crucial tool in setting effective exchange rates between greenhouse gases, currently require an arbitrary choice of time horizon. So they propose a novel framework to calculate the time horizon that aligns with scenarios achieving a specific temperature goal and to best align emission metrics with the Paris Agreement 1.5 °C goal. They recommend a 24 year time horizon, using 2045 as the endpoint time, with its associated $GWP_{1.50\,C}$ = 75 [61].

In the study we used two different timescales for evaluating GHG emission in order to estimate the maximum impact of the GHG gases on environment. In case of N_2O, we considered the usual 100 years' time frame. But in the case of methane we took the 24 years' timeframe because CH_4 is short-lived in atmosphere, 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.

3.5 Emission of Carbon Dioxide (CO_2) under Novcom Composting Technology

The CO_2 released during composting is considered biogenic, not anthropogenic, so it is not considered in greenhouse gas calculation [62]. Good composting practices that balance the carbon: nitrogen ratio and provide adequate moisture will minimize GHG emissions [63] During biodegradation process the microbial communities' biodegrade the organic matter under aerobic condition and most of the carbon is lost as CO_2, such that a linear relation between carbon content and CO_2 emissions would be observed during the process [64]. CO_2 emission measured on day basis under Novcom Composting Technology showed intense values in the 1st week (Avg. 114.6 gm CO_2/ ton wet waste), which gradually decreased with progression in the composting period and became minimum after 21 days (22.79 gm CO_2/ ton raw material), indicating completion of the biodegradation process (Fig. 2).

In case of Novcom Composting Technology, the faster biodegradation (within 21 days) and presence of a very high, self- generated and diversified microbial pool in the order of 10^{16}cfu/ gm moist compost [65]; perhaps enabled higher carbon transformation from raw materials to the final end product leading to minimal CO_2 emissions. A case study from FAO-CFC-TBI Project (2009-11) relating to end product (compost) quality assessment (made using similar raw materials) under four different composting processes including Novcom Composting Technology, indicated the highest percent of organic carbon in Novcom compost as compared to the rest other studied compost samples [66]. The result further indicated that on an average 8 – 10 kg more organic carbon was saved from being lost in the environment as CO_2, per ton of compost; during the process of biodegradation under Novcom Composting Technology. Hence, Novcom Composting Technology demonstrated a higher GHG mitigation potential due to lower CO_2 emission during the process of biodegradation [67] as well as better opportunity towards regeneration of the soil carbon sink through Novcom compost application due to transformation/ preservation of the organic carbon as humus by the high, self-generated and diversified microbial pool within Novcom Compost.

3.6 Emission of Methane (CH_4) under Novcom Composting Technology

Methane is the major contributor to non-biogenic greenhouse gas emissions from composting, and the majority of that CH_4 is emitted early in the composting process. Generally, the creation of anaerobic pockets in compost mixtures results in CH_4 emissions which is probably due to increase of moisture due to structural breakdown of organic materials. In the absence of oxygen (O_2), a succession of microbes convert carbohydrates in the organic waste to CO_2 and CH_4 [12]. Once CH_4 is produced, it may be emitted to the atmosphere or oxidized to CO_2 within the pile. The balance between CH_4 production and oxidation is likely controlled by redox potential [68] and is affected by temperature and moisture, which control O_2 solubility and biological activity [69,70]. Methane emission under Novcom Composting Technology was found to be negligible in comparison to other processes, as also documented by several research workers [71-73].This might be attributed to the aerobic process [48] and the intense microbial activity within Novcom Composting heaps accelerated by the creation of favourable environment through the application of subtle energy forms in the form of Novcom solution.

Though the CH_4 emission was nominal under Novcom Composting Technology in comparison to average reference value of CH_4 emission (0.03 – 8.0 kg CH_4 per ton wet waste) measured under the different composting processes), it was measured on regular basis during the entire biodegradation period. The highest value was observed on the 7th day before demolition/ churning of the heap, which might be due to the increased formation of anaerobic pockets within the composting heap; attributed to excess moisture generation due to structural breakdown of organic materials under intense microbial activity. CH_4 generation was found to be negligible after 14 days of composting and ceased completely after 21 days (Fig. 3).

3.7 Emission of Nitrous Oxide (N_2O) under Novcom Composting Technology

Nitrification or the conversion of NH_4^+ to NO_3^-, and denitrification, the conversion of NO_3^- to nitrogen gas (N_2 and N_2O), are the major pathways leading to N_2O production and consumption [74]. Net emission of N_2O is dependent on the controls on both processes. As biodegradation proceeds, the mineralization of organic nitrogen leads to formation of ammonia (NH_3), which could react with H^+ ions to form NH_4^+. The NH_4^+ to NH_3 equilibrium is governed mainly by pH value and temperature within the compost heap [75,76] Ammonia-oxidizing bacteria or archaea and nitrite oxidizing bacteria convert part of the nitrogen to nitrate through the nitrification process which is used by the microbial community [77].

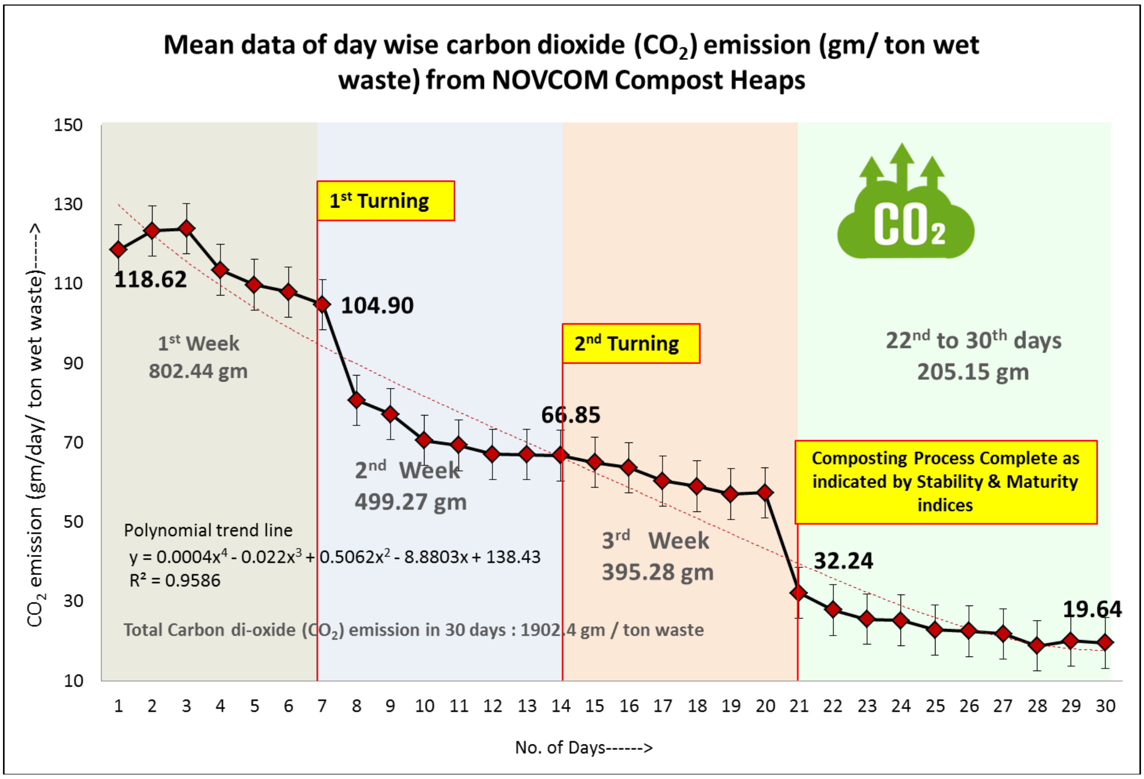


Fig. 2. Day wise carbon dioxide emission (gm/ton waste) during the biodegradation period under novcom composting technology

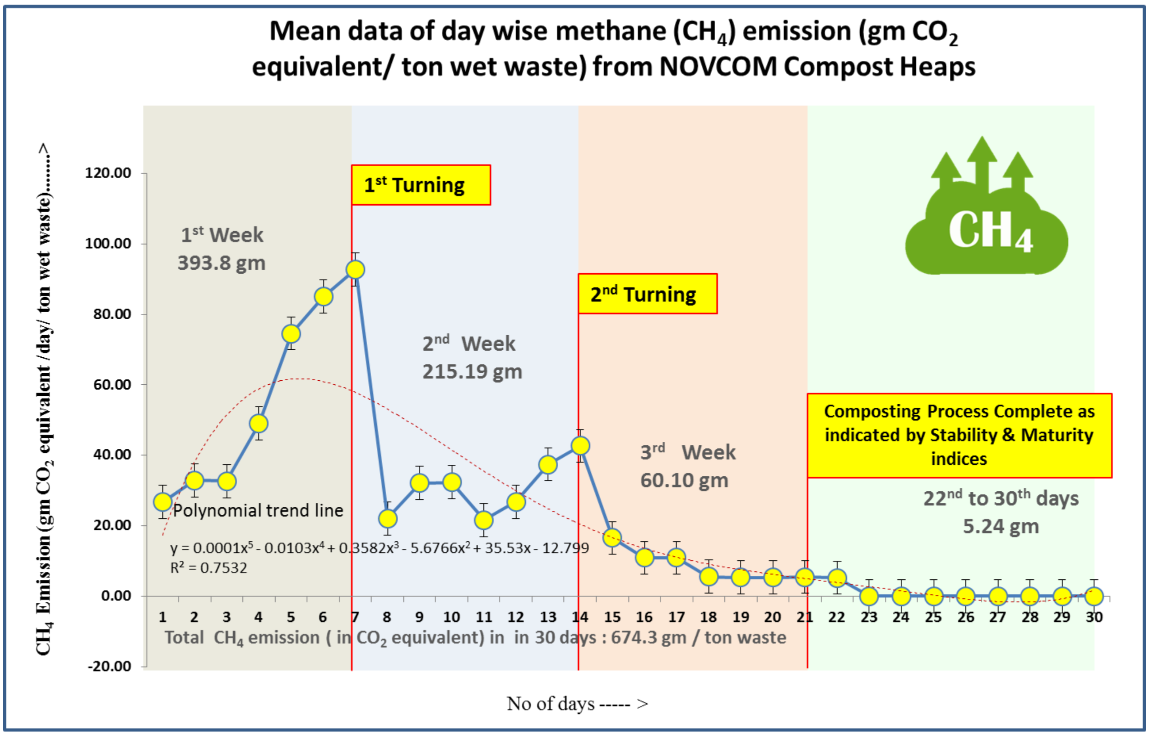


Fig. 3. Day wise methane emission (gm CO_2 equivalent /ton waste) during the biodegradation period under novcom composting technology

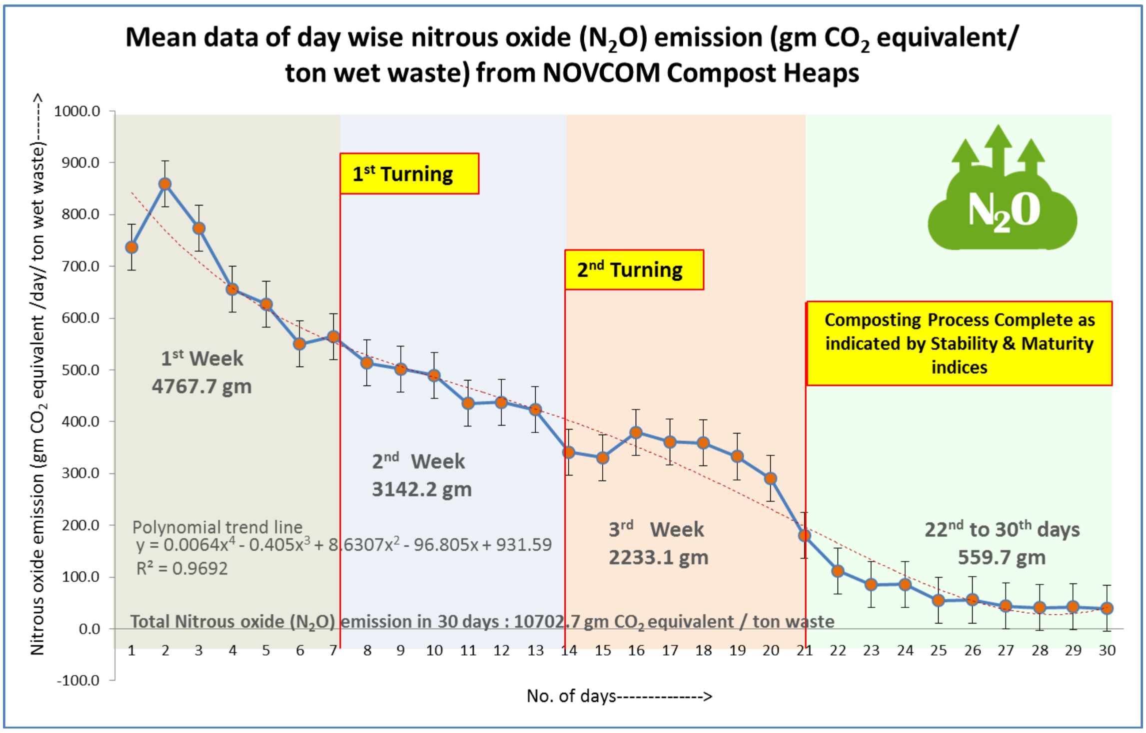


Fig. 4. Day wise nitrous oxide emission (gm CO_2 equivalent /ton waste) under Novcom composting method

In case of Novcom composting process, N_2O emission was highest in the 1st week of biodegradation (Average N_2O emission 679.8 gm CO_2 equivalent/ ton wet waste), it reduced gradually with the advancement of the composting period and became almost negligible post 21 days (Average N_2O emission 62.8 gm CO_2 equivalent/ day/ton wet waste) (Fig. 4). Since high temperature (over 40^0C) can hinder the activity of nitrifiers, the considerable N_2O emissions in the thermophilic stage was possibly due to NH_4^+ oxidization by methanotrophs [78,79]. Total N_2O emission under Novcom Composting Technology was about 1/10th of the average reference value (0.06 - 0.6 kg N_2O ton wet waste treated) documented in case of various composting piles by several research workers [80,72,73]. The lower values under Novcom Composting Technology might be due to the fact that the higher speed of biodegradation under this method was induced by the self- generated diversified microbial pool (in order of 10^{16}c.f.u. per gm moist compost) and not through any mechanization or artificial induction. The high microbial pool quickly immobilized the nitrogen released due to organic matter breakdown thereby reducing the escaping chances of N_2O during the process of organic matter breakdown.

3.8 Emission of Ammonia (NH_3) under Novcom Composting Technology

Key factors that control ammonia emission during composting are: pH, temperature, moisture content, aeration rate, carbon-to-nitrogen ratio and presence of microbial pool within the compost heap [81]. In case of Novcom Composting Technology, NH_3 emission decreased with progression of composting (Fig. 5) which indicated intense microbial activity within compost heap that reduced the escaping chances of NH_3 during the biodegradation process. However, due it's very low CO_2 equivalency, NH_3 is generally not considered under the GHG calculation methodology, though it has a negative impact on environment and reduces the nutrient quality of compost.

3.9 Development of Equation for Prediction of GHG Emission under Novcom Composting Technology

Regression equations were developed using the 32 generated data sets from the study of 8 Novcom Composting heaps, made with different agro waste, under IBM-IORF Sustainability Project, during the period 2021 – 22.

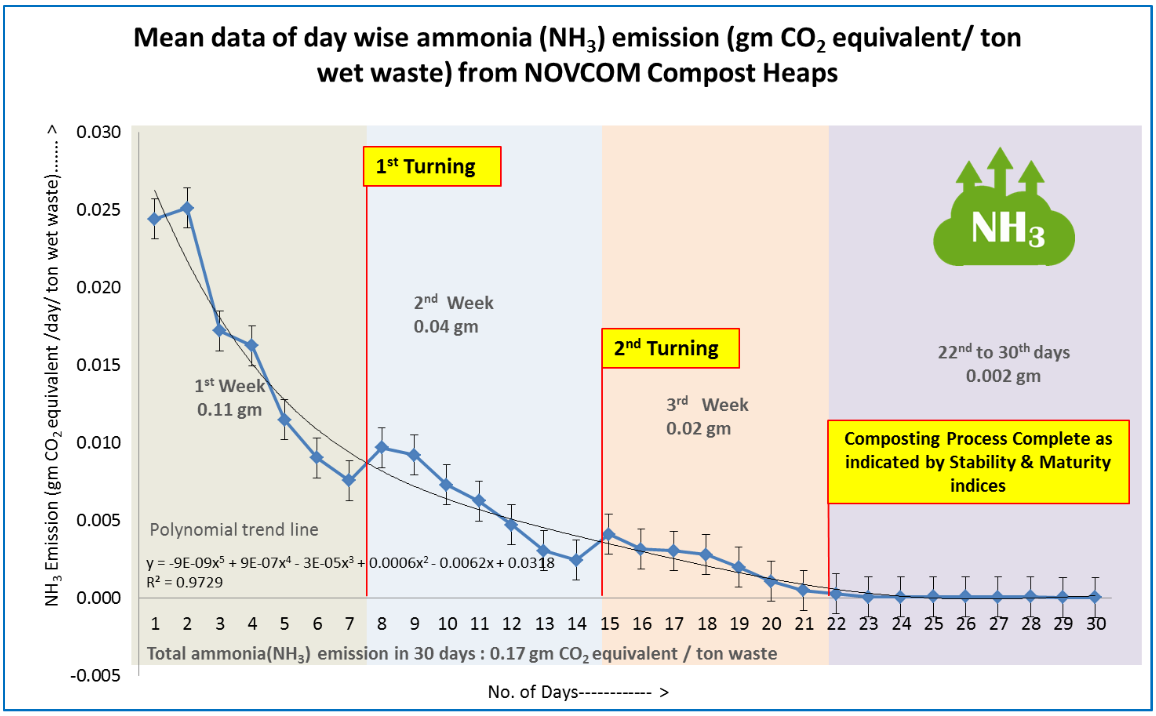


Fig. 5. Day wise ammonia emission (gm CO_2 equivalent /ton waste) under novcom composting technology

Pic. 3. Utilization of novcom compost for 'clean vegetable' production and development of 'clean food net zero' model under IBM-IORF sustainability project

3.9.1 Regression equation to predict CO_2 emission

The following Equation
$Y = 11.37*X + 14.61$
Where,
Y = Expected CO_2 Emission (gm)
X= Actual Carbon loss during composting process (kg)
$R^2 = 0.9228$
Note: R-squared (R^2) is a statistical measure that represents the proportion of the variance for a dependent variable and explains the strength of the relationship between an independent and dependent variable.

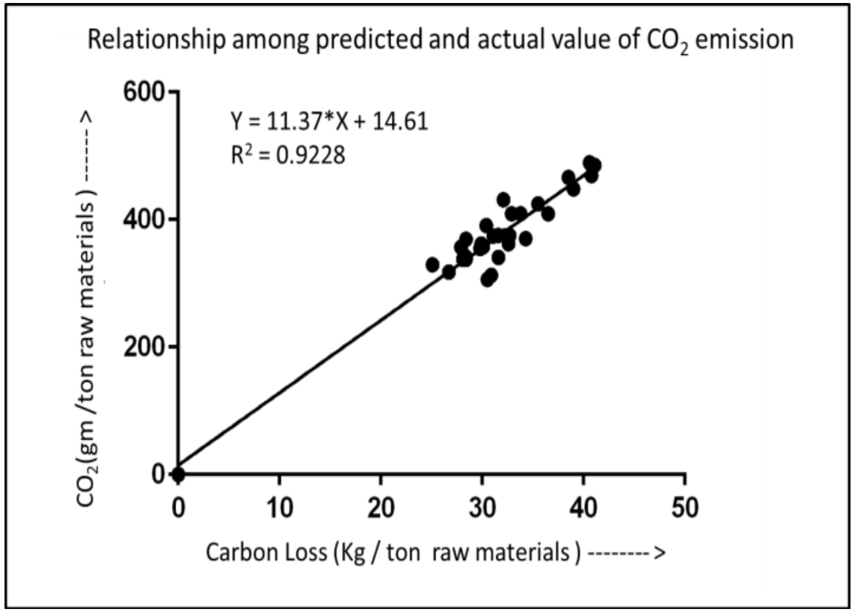


Fig. 6. Relationship among actual and predicted value of CO_2 emission

3.9.2 Regression equation to predict CH_4 emission

The following Equation
$Y = 0.06399*X - 0.2498$
Where,
Y = Expected CH_4 Emission (gm)
X = Actual Carbon loss during composting process (kg)
$R^2 = 0.8274$
Note: To find the expected emission in CO_2 equivalent, Y value should be multiplied with 75 (GWP of methane is 75 over a period of 24 years, meaning that one tonne of methane emission is equivalent to emitting 75tonnes of carbon dioxide.

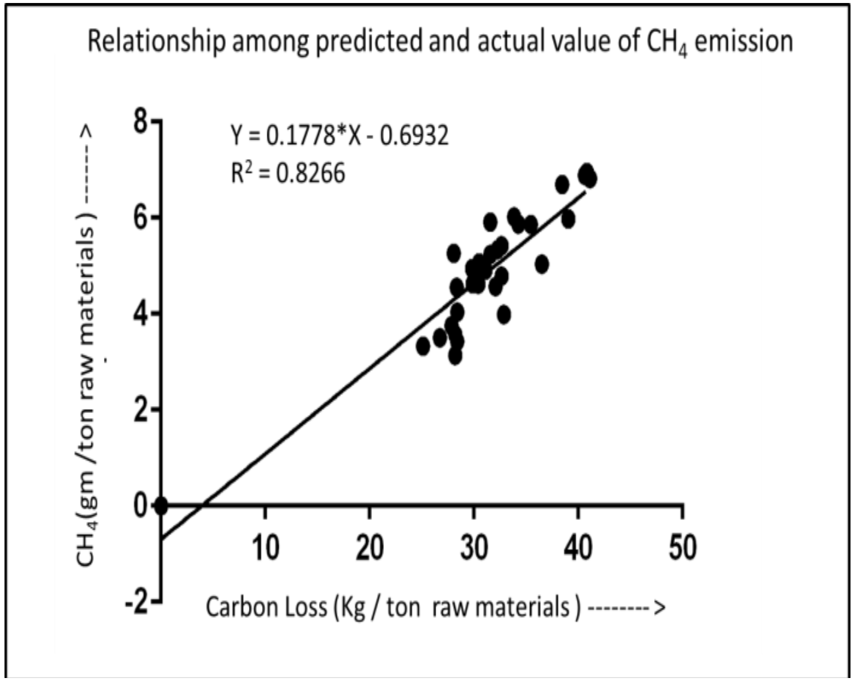


Fig. 7. Relationship among actual and predicted values of CH_4 emission

3.9.3 Regression equation to predict N_2O emission

The following Equation
$Y = 39.31*X + 0.6338$
Where,
Y = Expected N_2O Emission (gm)
X = Actual N loss in first 14 days during composting process (kg)
$R^2 = 0.9673$
Note : To find the expected emission in N_2O equivalent, Y value should by multiply with 273 (N_2O has GWP of 273over a 100 years period meaning that, one tonne of N_2O emission is equivalent to emitting 273tonnes of carbon dioxide)

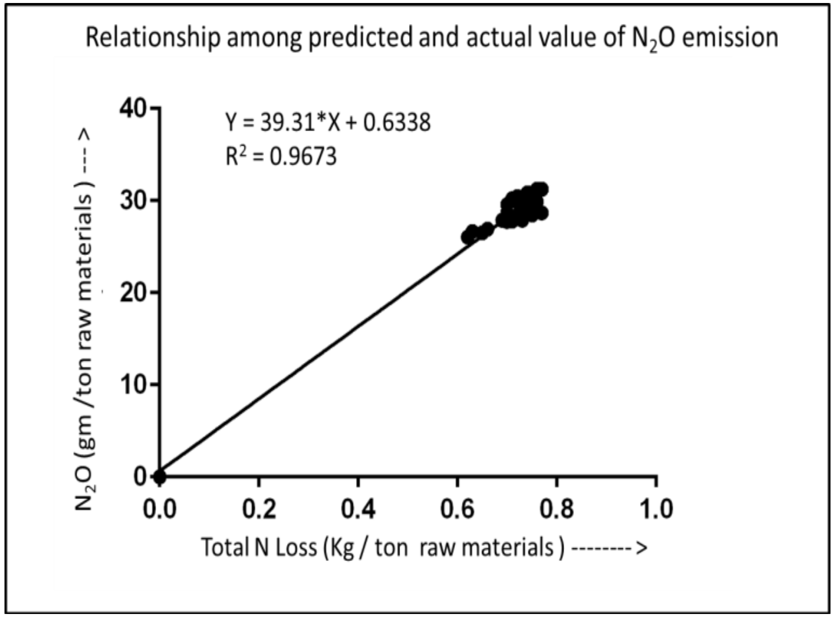


Fig. 8. Relationship among actual and predicted values of N_2O emission

3.9.4 Regression equation to predict NH_3 emission

The following Equation
Y = 0.07585*X - 0.003006
Where,
Y = Expected NH_3 Emission (gm)
X = Actual N loss in first 14 days during composting process (kg)
$R^2 = 0.734$
Note: Ammonia is generally not considered as GHG during any evaluation process as NH_3, has an Ozone Depletion Potential (ODP) rating of 0.

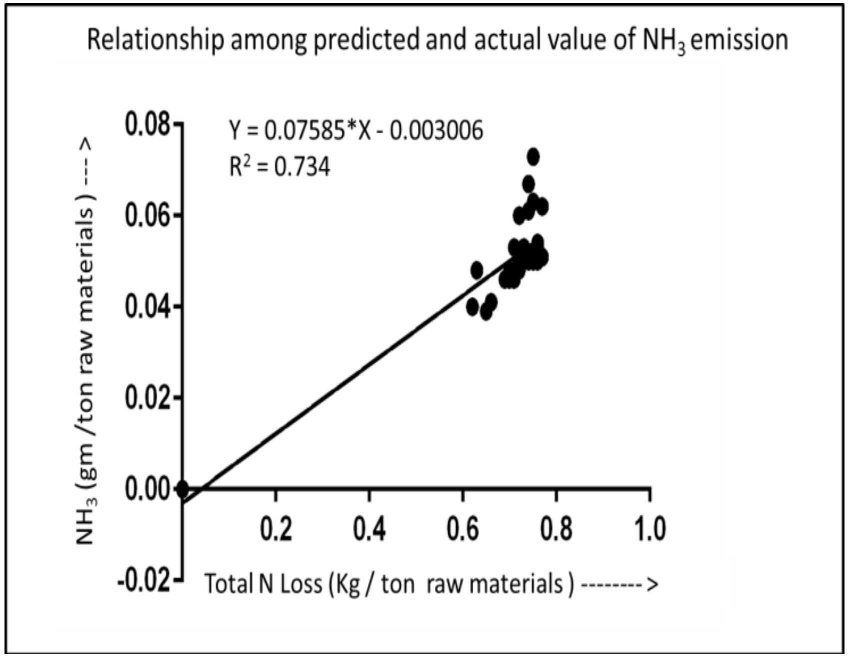


Fig. 9. Relationship among actual and predicted values of NH_3 emission

4. ASSESSMENT OF GHG ABATEMENT FROM LANDFILL MATERIALS UTILIZING NOVCOM COMPOSTING TECHNOLOGY AS PER IPCC GUIDELINE

Novcom Composting Technology can be utilized for bioconversion of any type of waste from (1) coir pith [82], (2) Press mud [83], (3) Water hyacinth [36], (4) Poultry litter [82], (5) Municipality solid waste [29], (6) Crop residues, (7) Banana stumps [84], (8) Refuse from food processing industries etc.; which in general are high GHG emitting sources especially under unplanned dumping at landfill sites. Estimation of the potential GHG emission from these waste materials was based on the document prepared by the IPCC National Greenhouse Gas Inventories Program to support the development of *Good Practice Guidelines* for estimation of greenhouse gas emissions from the waste sector and to manage the associated uncertainties. The document is a background paper for the IPCC expert meeting on Waste in Sao Paulo. The document concentrates on the anaerobic degradation process generating landfill gas (LFG). The existing *IPCC Guidelines* for national Greenhouse Gas Inventories have been reviewed, and an upgraded basis has been proposed for a worldwide good practice framework to carry out as accurately as possible national inventories of emissions of CH_4 [60]. We took the default IPCC methodology that is based on the theoretical gas yield (a mass balance equation) for calculating all potential methane released at a time.

4.1 Formula for Calculation of GHG Emission from Biowaste (Primarily Landfill Materials)

GHG emission (MT in CO_2 equivalent) =

$[(LM_T \times LF_F \times MC_F \times DOC \times DOC_F \times F \times 16/12 - R) \times (1 - OX)] * GWP_{CH4}$

LM_T: Total Landfill Material(MT)

LF_F: Fraction of Landfill Material disposed at Disposal Sites (if 100 % landfill material which is generated is deposited in Disposal sites, then LF_F value will be 1.0 (default value))

MC_F: Methane correction factor (fraction) (IPCC default value is 0.6, when there is no specific information)

DOC: Degradable organic carbon (fraction) (kg C/ kg landfill material)

DOC_F: fraction DOC dissimilated (IPCC default is 0.77)

F: fraction of CH_4 in landfill gas (IPCC default is 0.5) 16/12 : conversion of C to CH_4

R: Recovered CH_4 (MT) (in general value is 0 if not any specific treatment plants in disposal sites to recover methane

OX: oxidation factor (fraction – IPCC default is 0)

$GWP_{CH4\ (24\ years)}$: 75

Therefore, GHG Offset under Novcom Composting technology (credit calculation upto compost development, credit for compost application in soil is not included)

GHG Offset under Novcom Composting Technology	=	GHG Emission from untreated waste (Calculated as per IPCC Guideline)	-	GHG Emission during biodegradation under Novcom Composting Technology (Calculated as per emperical formula developed for GHG calculation under Novcom Composting Technology)

We used two different sets of emperical formula for calculation of GHG abatement under bioconversion of any landfill waste utilizing Novcom Composting Technology. First we calculated the GHG emission potential of the selected landfill waste through the emperical formula developed by IPCC. Then we used our formulation, developed from the extensive field experiments (as described in this article); to calculate the GHG emission potential of the same landfill waste when biodegraded under Novcom Composting Technology.

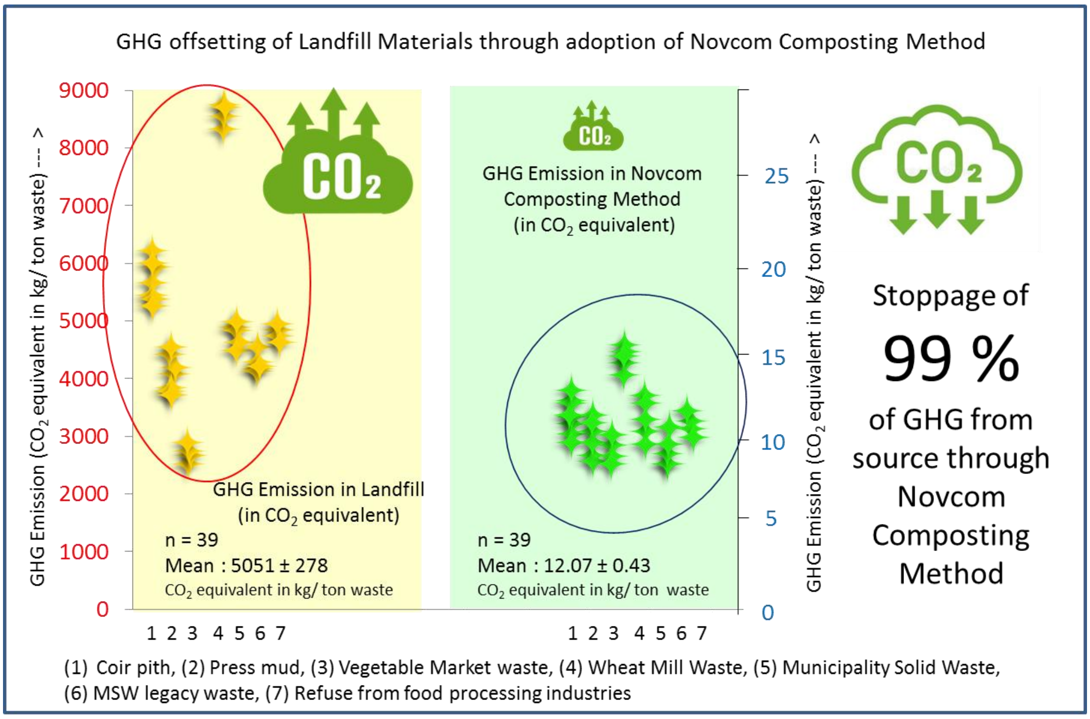


Fig. 10. GHG offset from landfill waste through its bioconversion utilizing novcom composting technology

We first calculated the GHG emission potentials of eight different kinds of biodegradable waste *viz*. coir pith, press mud, vegetable market waste, wheat mill waste, municipality solid waste, MSW legacy waste and refuse from food processing industries; under landfill conditions as per the IPCC methodology described above. GHG emission potential in terms of CO_2 equivalent in kg/ ton waste varied in between 2549 to 6187 kg CO_2 equivalent/ ton waste (Fig. 10). The highest GHG emission was in case of wheat mill waste (average 8828 kg CO_2 equivalent/ ton waste) followed by coir pith (average 6014 kg CO_2 equivalent/ ton waste) and municipality solid waste (average 4722 kg CO_2 equivalent/ ton waste). The GHG emission potentials of these eight different kinds of biodegradable waste when recyclced under Novcom Composting Technology was recalculated as per the developed emperical formula described above. The required database for calculating the probable GHG emission during biodegradation was sourced from our previous studies [85,86,23,29]. The Calculation using emperical equations indicated that biodegradation under Novcom Composting Technology leads to non significant GHG emission (average 12.07 kg CO_2 equivalent/ ton waste) and thus has the potential to offset 99% of GHG from source.

The phenomenal achievement under this aerobic composting process is primarily due to minimization of the escape potential of two major GHG's i.e. CH_4 and N_2O during the process of biodegradation; primarily attributed to the generation of high self- generated and diversified microbial pool within the Novcom composting heap [89,92]. Thus, Novcom Composting Technology not only stabilized the organic mater in the waste within a shortest period of 21 days, but did so with minimal emission, as indicated by $1/16^{th}$ of the average reference emission values (total averaging 200 kg CO_2-eq per tonne wet waste treated) as documented under various composting processes [80,45,71,87,88, 72,73].

5. CONCLUSIONS

Composting programs are one of the most effective and economic means of reducing, eliminating and reversing GHG emissions towards the objective of climate change mitigation. In this respect, Novcom Composting Technology–a technological innovation can serve as an effective tool for climate action (GHG abatement from source) due to 17 times lower GHG emission as compared to the reference values under other biodegradation processes.

The dual premise of speediest biodegradation as well as GHG abatement, especially methane mitigation, under this composting process is primarily attributed to the self- generated and very high population of microflora which minimized the generation and escaping chances of the GHG's resulting from organic matter breakdown and nitrogen mineralization. Hence, the very high climate action potential of this Technology is driven by it's dual action mode i.e., lower CO_2 emission during waste recycling as well as speedy regeneration of the soil- C sequestration potential [90,91]; through transformation/ preservation of organic carbon as humus by the very high, self- generated and diversified microbial pool within Novcom Compost.

Thus Novcom Composting Technology can, serve as an effective tool for bioconversion of waste especially the high GHG emitters like landfill materials. It provides a fresh perspective in respect of large scale waste management especially in a country like India which continues to be a ticking time bomb of waste. Moreover, generation of safe and quality compost from waste, a raw material source, which is both abundant and cost free; that too within the shortest time period, provides the choice especially for the resource poor marginal and small farmers to undertake sustainable soil health management that is essential for present as well as future crop security. Thus Novcom Composting Technology can, drive not only successful 'Waste to Wealth' programs but most importantly serve as an excellent tool for GHG Mitigation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Technological Breakthrough for Large Scale Bioconversion of Coir Pith towards Sustainable Soil Health Management and Development of Source Point Methane Abatement Model

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Coir pith, a byproduct of coir industry, continues to be dumped as a waste in India, because despite its utility being claimed in different applications, an efficient and adoptable technology for its safe utilization is yet unavailable. 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. But so far, there is no available composting technology in this respect which is practically feasible, economically viable and socially acceptable.

Under IBM-IORF Sustainability project (2022-23) at Mandya, Karnataka, an effort was initiated utilizing Novcom Composting Technology, towards bioconversion of coir pith into safe, mature and qualitative compost for sustainable soil management, especially looking at the stony red soils of the area which are erosion prone, and have a poor productive potential.

Periodical study of Novcom coir pith compost samples on 0, 10, 20 and 30 days confirmed effective degradation as demonstrated by the rapid decline of C:N ratio from 1:100 to < 1:25, appreciation of total nitrogen by 98 percent and 60 % degradation of lignin within a 30 days' time period. The facts are corroborated by the respective very high (*in the order of 10^{16} c.f.u. per gm or one Trillion Billion microflora per ton compost*) population of bacteria, fungi and actinomycetes. Phytotoxicity Bioassay test values confirmed not only the absence of phytotoxic elements in compost, but also indicated that this compost can actually accelerate seed germination and root growth process. Estimation of methane mitigation potential under this technology utilizing the carbon assessment tool - Agriculture Carbon Footprint Assessor (ACFA, version: 1.0) indicated that untreated coir pith can potentially emit methane in the range of 5897 – 6025 kg CO_2 equivalent (taking $GWP_{24\ years}$ of methane: 75).

GHG emission during biodegradation of coir pith utilizing Novcom Composting Technology, was found to be about 31 times lower (6.47 kg CO_2 equivalent/ ton treated waste) than the reference values recorded in respect of any other standard biodegradation process. Especially in terms of methane the negligible emission under this composting technology is the highlight, as corroborated by the documented value of 0.61 kg CO_2 equivalent/ ton treated waste. The evaluation confirmed that bioconversion of coir pith utilizing Novcom Composting Technology can enable methane mitigation of about 6000 ton CO_2 equivalent per 1000 ton waste, directly from the source point.

The study indicated that Novcom Composting Technology can transform not only a potential pollutant to a quality organic soil amendment, the process also etches out and effective pathway for methane abatement directly from the source point that has crucial impact not only in respect of Sustainable Development Goal (SDG) 13, but also SDG 15, SDG-3 and most importantly SDG-2. Hence, bioconversion of coir- pith utilizing this technology can also facilitate an effective model towards the Net Zero commitment with significant social and environmental impacts.

Keywords: Coir pith; lignin; Novcom Composting Technology; methane abatement; ACFA; (version: 1.0), Sustainable Developmental Goals (SDG).

1. INTRODUCTION

"Coir pith is a biomass residue generated during the extraction of coir fiber from coconut husk and is a byproduct of the coir manufacturing industry. It is a ligno-cellulosic material forming about 70% of the coconut husk" [1]. "When husk of 10,000 coconuts are utilized for coir extraction, 1.6 ton of coir pith is obtained as a byproduct. If all the coconut husks available in India are processed, it is estimated that about 2.25 million tons of coir pith could be obtained annually" [2].

"The coir pith is finding new applications, as a soil conditioner and is being used as a soil-less medium for agri-horticultural purposes. With its moisture retention qualities, the coir pith is ideal for growing anthuriums and orchids. Moreover, this lignin content can be utilized for high-value applications, but has remained a challenge" [3,4]. "The lignin part contains aromatic and aliphatic components and various functional groups, including phenolic, hydroxyl, carboxyl, benzyl alcohol, methoxy, and aldehyde groups [4], which can cause phytoxicity when applied untreated in agricultural soil. Moreover, the high salt content [5], and high lignin in coir pith cause very slow degradability, which offer little scope for its use in crop production".

"Hence, most of the coir pith is dumped as waste and accumulates as a waste product in the form of heaps of coarse and fine dust. The coir pith poses fire hazard, space problem, health hazard and disposal problem if an appropriate solution is not found"[6]. "Traditionally, these agricultural wastes are disposed off by burning, which results in various environmental problems, including carbon deposits as well as the warming of the atmosphere. During the rainy season, the tannins and phenols of the coir pith leach out into the soil and the irrigation canals, thereby making agricultural lands unproductive. Moreover, the water pollution caused by such leaching is harmful to the aquatic and soil biological life" [7]. "Present forms of management or utilization are not sufficient enough to totally consume the waste generated and it continues to be a perennial problem to the nearby aquatic and terrestrial environments" [8]. But most importantly as a result of dumping, methane, a potent greenhouse gas is generated which contributes to climate change.

Lack of effective technologies is a major challenge towards bio- conversion of coir pith considering that windrow composting requires relatively large areas, is extremely sensitive to ambient temperatures and weather conditions and odour control is a common problem. In-vessel reactors have limited flexibility to handle changing conditions and are maintenance intensive. Moreover, the long time period of composting under all the presently available methods, can form a potent source of greenhouse gases especially for a complex raw material like coir pith. Finally the safety and stability/ maturity of the end product from these composting processes are often questionable. Hence, people continue to face tough challenges towards bioconversion of coir pith into quality manure for soil application.

However, coir pith in the presence of an effective bioconversion technology, can serve as an excellent resource for compost generation considering its high water holding capacity, nutrient retention capacity as well as large scale availability. Such a 'Waste to Wealth Program can ensure economic sustainability of the coir industry as well, which is facing tough challenges in respect of labour productivity, finances, finished product marketing, etc. Hence, this environment polluting agent and a high GHG emitter can serve as an excellent resource for quality compost production looking at the existential requirement for sustainable agriculture, for reclamation of degraded soil as well as for sustenance of crop productivity.

Novcom Composting Technology developed by Dr. P Das Biswas, an Indian scientist and pioneer of Ecologically and Economically Sustainable Organic Tea Cultivation in India; has shown its potential as a speedy, effective and economic pathway for quality compost generation [9]. This technology was utilized for bioconversion of coir pith and the GHG offsetting potential under this composting method was evaluated using ACFA (Version 1.0) – Agriculture Carbon Assessment Tool developed by Inhana Organic Research Foundation (IORF) as per Intergovernmental Panel on Climate Change (IPCC) guidelines [10].

Pic. 1. Piling up of coconut husk in coir factory for extraction of coir fibre

Pic. 2. Coir factory for extracting coir fibre and coir husk

Pic. 3. Toxic leachate containing high salt and phenolic content from coir pith dumps in and around coir factories

2. MATERIALS AND METHODS

2.1 Study Area

Village: Kalenahalli, Hobli: Kikkeri, Taluk: Krishnarajpet, District: Mandya, Karnataka, India.

The study was initiated under IBM-IORF Sustainability Project during 2022-23 for establishment of the Clean Food 'Net Zero' Model. The quest for quality compost for towards sustainable soil health management led to coir-pith; a waste of coir industry, with an abundant supply of 5.0 – 6.0 lakh metric ton yearly in Karnataka alone and an economic source. 1000 ton coir pith was sourced and Novcom coir pith compost was produced towards attending the objective of eliminating N- fertilizer through sustainable soil health management.

2.2 Method of Compost Preparation

2.2.1 Raw materials used

Coir pith and cow dung in 80: 20 ratio was used for making compost.

2.2.2 Novcom solution

It is the biologically activated and potentized extract of Doob grass (*Cynodon dactylon*), Bel (*Sida cordifolia* L) and common Basil (*Ocimum bascilicum*). Detail of the solution is given by Seal et al. [11] who worked on the biodegradation pathway of Novcom Composting Technology.

2.2.3 Working Mechanism of Novcom Solution under Element Energy Activation (E.E.A.) Principle

Novcom Composting Technology is a unique biodegradation system that can convert any type of biodegradable material including toxic and hard to biodegrade materials into quality compost. Through the erection of Novcom composting heap, we tried to create an environment for self-generation of diversified microflora. The application of Novcom solution (Fig. 1) served to provide the desired energy sources in the most pure and subtle form for speedy multiplication of microflora and higher activity efficiency. This energy management is based on the 'Element Energy Activation' (E.E.A.) Principle, inspired by the Vedic philosophy.

An effective biodegradation process is usually guided by the mesophillic- thermophillic – mesophillic stages, where one stage comes only when the previous one completes. Novcom solution along with heap construction just speeds up this orchestra, especially the attainment of thermophillic stage in the initial phase of composting; in a very organized and synchronized manner. This method provides just the necessary environment for completion of each step so that the next step can take over ultimately culminating into a stable, mature and non- phytotoxic compost, within the shortest time period. Here no specific input or agent that is known to have influence in the breaking down of the organic material is added because these have their own limitations either singly or in combination.

If the mechanism of Novcom Composting Technology is interpreted under the Element Energy Activation Principle, it manifests as a unique, novel but the most convenient system for generation of quality compost. It is known that all objects of Earth are composed of five elements. Hence, in the first stage of degradation under Novcom Composting Technology, the elements are broken into their individual identity. Then, the temperature rises 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 thermophilic bacteria start growing up. After a span of time the actinomycete group of micro-organisms come and breaks the degraded material into 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 so rapid, intense and programmed that it finishes within the shortest period of three weeks.

The technology promises to provide solution irrespective of the type or nature of raw material or the agro climatic situations. The process does not require any microbial inoculation because the necessary microbes are generated naturally due to set up of an ideal environment. Moreover, microbial inoculation is an unscientific process because strains are first experimented individually but in the practice is given in combination. Since, each microbe has individual biological cycle and behavior that can never match when applied in combination with other microbes, hence, 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 pre-poning any stage will always make the process a complex one. The compost developed with Novcom Composting Technology provides the energized environment for regeneration of soil fauna. Hence, application of even a small quantity of the compost brings about a noticeable change in the soil in the shortest possible time. Finally, one thing is to be remembered that microbes also need an adequate environment to grow and function. Hence, to provide the environment is more necessary than to inoculate them directly into the soil. The effectiveness of Novcom Composting Technology is defined by its mechanism to create the required environment.

2.2.4 Preparation of Novcom coir pith compost

At a selected upland and flat area, a 10 ft. x 8ft. x 6ft. support structure was made with bamboo strips and coconut leaves for erecting the coir pith compost heap. A layer of cow dung slurry was put as the bottom layer and the same was sprayed on the inside walls of the support structure. Coir pith was mixed with cow dung slurry at 80:20 ratio (coir pith and cowdung on weight basis) and spread layer wise (each layer being approximately 0.5 ft. thick.) till it reached to the top of the structure. About 60 ml Novcom solution (diluted 25 ml in 5 liter water) was sprayed on each layer. Total 16 layers were required to reach a height of 6ft., because the heap height gradually reduced with compression and hence, total 2000 ml of Novcom solution was required for this heap.

The heap was covered with coconut leaves and left in this manner for 9 days. On 10th day, one side of the heap structure was opened and the material was altered and mixed properly with JCB. The material was put back in the structure, repeating the previous process. Once again 2000 ml of Novcom solution was used. The process was again repeated on 20th day and the compost was ready on 30th day.

2.3 Research Methodology

2.3.1 Analysis of compost samples

"Physicochemical properties of compost, *viz*. moisture content, pH, electrical conductivity and organic carbon were analyzed according to the procedure of Trautmann and Krasny" [12]. "The total N, P and K in the compost were determined using acid digestion method of Jackson" [13]. "Estimation of bacteria, fungi and actinomycetes was performed using Thornton's media, Martin's media and Jensen's media respectively, according to procedure outlined by Black" [14]." Stability tests for the compost (CO_2 evolution rate, phytotoxicity bioassay test/ germination index) were performed according to the procedure suggested by Trautmann and Krasny" [12]. Cucumber (*Cucumis sativus*) seeds were used for phytotoxicity bioassay test. Lignin percentage was analyzed as per methodology of Nandhini et al. [1]. Statistical Analysis in terms of standard error was performed with SPSS software.

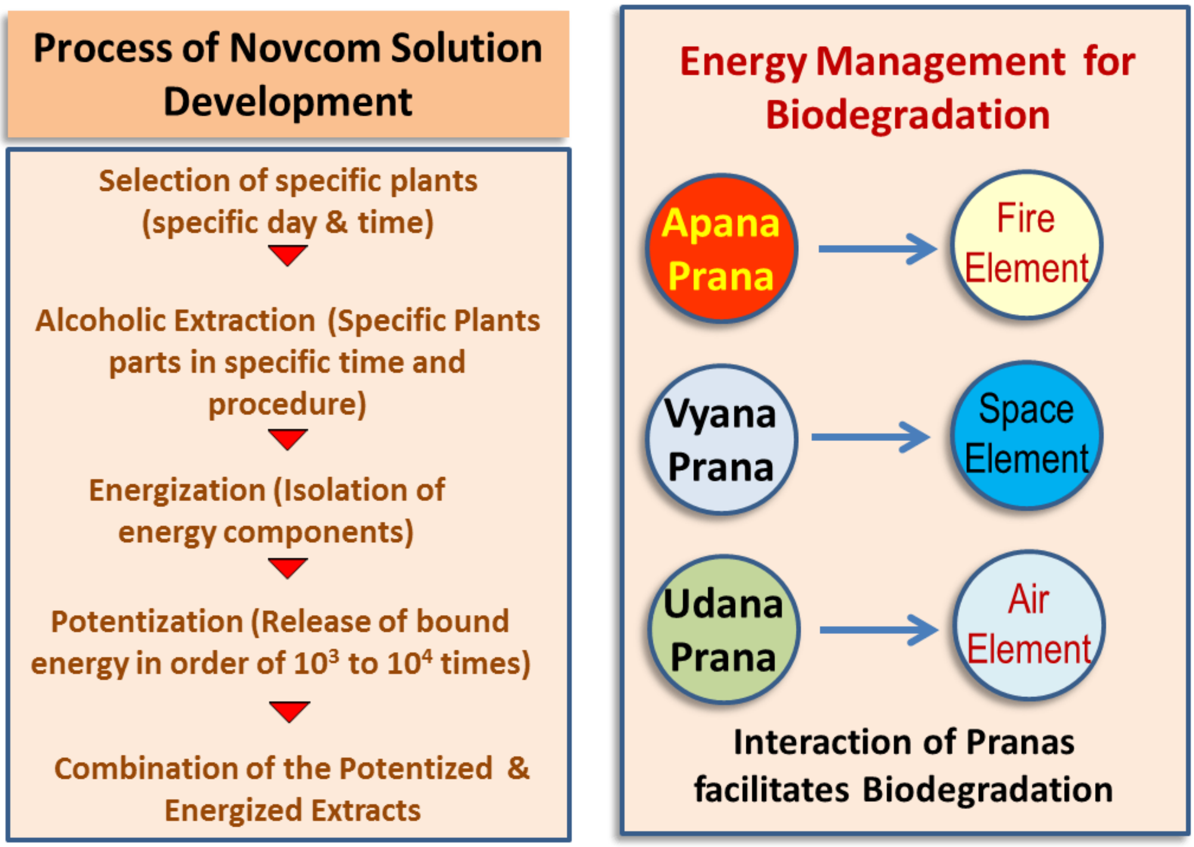


Fig. 1. Process of Novcom solution development and interaction of Pranas facilitates biodegradation

Pic. 4. Support structure for erecting Novcom coir pith compost heap at Mandya, Karnataka

Pic. 5. Transport of coir pith for making Novcom coir compost at Model Farm, Mandya, Karnataka

Pic. 6A & 6B. Preparation of cow dung slurry and mixing of cow dung slurry with raw coir pith in 80 : 20 ratio (coir pith and cow dung on weight basis) at Model Farm, Mandya, Karnataka under IBM-IORF Sustainability Project

Pic. 7. Mixing of raw coir pith with cow dung slurry at Mandya, Karnataka

Pic. 8. Transfer of cow dung slurry mixed Coir pith by JCB for erction of Novcm heap at Model Farm, Mandya, Karnataka

2.3.2 Protocol for greenhouse – gas measurement

For measurement of different greenhouse gas (GHG) *viz*. CO_2, N_2O, CH_4 and NH_3, five Novcom coir pith compost heaps were made during 2022 - 2023. Details of designing of compost heaps are described in the research work done by Bera et al [15]. Day wise evaluation of Nitrous oxide (N_2O), Carbon-di-oxide (CO_2) and Ammonia gas (NH_3) was done as per standard chemical trapping method [15] while methane (CH_4) was estimated using an open bottom chamber to measure gas fluxes as per standard method [16].

3. RESULTS AND DISCUSSION

3.1 Analysis of Compost Quality

To evaluate the composting process and end product quality under Novcom Composting Technology, raw coir pith, samples from 1st turning (10th day), 2nd turning (20th Day) and final Novcom coir pith compost (30th day) were evaluated for 19 different quality parameters as per National and International standards. The samples were analyzed for physicochemical properties, microbial population, maturity and phytotoxicity parameters (Table 1 and 2).

3.1.1 Changes of organic carbon, nitrogen and C:N ratio with transformation of coir pith to mature compost

"Changes of organic carbon and C:N ratio is the most important indicator of compost maturity and stability. Microorganisms break down the chemical bonds of organic materials in the presence of oxygen and moisture and the rate of decrease in carbon content of waste over time indicates the speed of biodegradation during composting" [17,18]. "In case of Novcom coir pith compost, organic carbon decreased from 52.10 % in raw material to 31.28 % in the final compost (i.e. on day 30 of composting), which indicated faster biodegradation and simultaneously compost maturity (as organic carbon varied within 16 to 38 % in mature compost) within a short time frame" [11]. "The change in C:N ratio of the composting material was also considered in terms of stability, because as the readily available- C in the organic matter is oxidized and released as carbon dioxide, there is a general reduction in carbon content over time" [19]. "The C:N ratio of 30 day compost sample was 24.9:1 indicating maturity as a ratio of 20–30 results in an equilibrium state between mineralization and immobilization [20] and is considered good for soil application. This is because, soil microorganisms have a C:N ratio of around 8.0 and they must acquire enough carbon and some nitrogen from the soil to maintain that ratio in their cells and have been found to do best on a "diet" having a C:N ratio of 24.0" [21,22]. According to USDA Natural Resources Conservation Services (NRCS) soil microorganisms use 16 units of carbon for energy and the other eight parts for maintenance [23]. "Under these optimum conditions, soil microbes can spur release of nutrients and this ratio influences the amount of soil-protecting residue cover that remains on the soil" [24]. Novcom coir pith compost also met the additional criteria for compost stability, i.e. $C{:}N_{final}/C{:}N_{initial}$ ratio <0.75 [25], confirming that it attained maturity within 30 days. So this compost might be proven as an ideal soil energy enhancer for soil microbial rejuvenation resulting in sustenance of soil productivity.

"The total nitrogen content in the compost sample increased from 0.59 to 0.76 % during the first phase of composting (days 0 to 20) which might be due to a concentration effect following a decrease in substrate carbon [26] during the degradation of non-nitrogenous organic matter" [27]. Evaluation of the graph showing the decrease in organic carbon and increase in total N value revealed that the trend lines (Fig. 2) of organic carbon degradation and lowering of C:N ratio gradually separated from each other over time (as the shaded area widen). This indicated that there was a relatively greater increase in total N compared with the decrease in the organic carbon content. The finding might provide an indirect indication of the fixation of atmospheric- N within the compost heap by the autotrophic microorganisms generated during the composting process. According to de Bertoldi et al. [28,29], "an increase in the population of N-fixing bacteria in the later phase of composting, can be attributed to the increase in the value of total- N in compost, despite volatilization (primarily) losses from compost heap during biodegradation" [11].

3.1.2 Degradation of lignin under Novcom Composting Technology

"Raw coir pith contains the highest percentage of lignin, hemicelluloses, and wax and the lowest percentage of α-cellulose. The percentage of α-cellulose, hemicelluloses, lignin, and wax present in raw coir pith is 27.41%, 14.63%, 42.0%, and 10.16% respectively" [30]. "Especially the degradation of lignin in coir pith is problematic due to its complex structures. According to studies in natural condition, when dumped in open environment, lignin content in coir pith takes decades to decompose. It only begins to break down when it is 10 years old as the pentosan/lignin ratio of pith is 1:0.30 while the minimum value required for moderately fast decomposition in the soil is 1:0.50" [30]. In the case of Novcom Composting Technology, >60% of lignin is degraded within 30 days of composting. This was primarily influenced through energy infusion, brought about by the application of Novcom solution that enabled self- generation of a huge population of microflora within Novcom heap during the process of composting (Fig. 3).

3.1.3 Quality of novcom coir- pith compost

Qualitative evaluation of Novcom coir pith compost (as per 19 different analytical parameters) was carried out to assess the potential of this composting method towards production of high-quality mature compost. In this study, samples collected on the 10^{th}, 20^{th} and 30^{th} day of composting were analyzed for physicochemical, microbial, stability and maturity/phytotoxicity parameters (Table 1 and 2).

3.1.4 Physicochemical parameters of Novcom coir pith compost

“The predominant use of compost is to mix it with soil to form a good growing medium for plants, for which pH forms an important criteria of consideration” [31]. “The pH value of the compost samples ranged between 6.29 and 7.35, with a mean of 7.32, which was well within the stipulated range for good quality and mature compost” [25]. Electrical conductivity of the compost samples ranged between 1.83 and 1.96 with a mean of 1.89 dSm^{-1}, indicating the absence of any saline toxicity effect [32].

Pic. 9A & 9B. Addition of Novcom solution in water and spraying of Novcom solution on coirpith at Model Farm, Mandya, Karnataka.

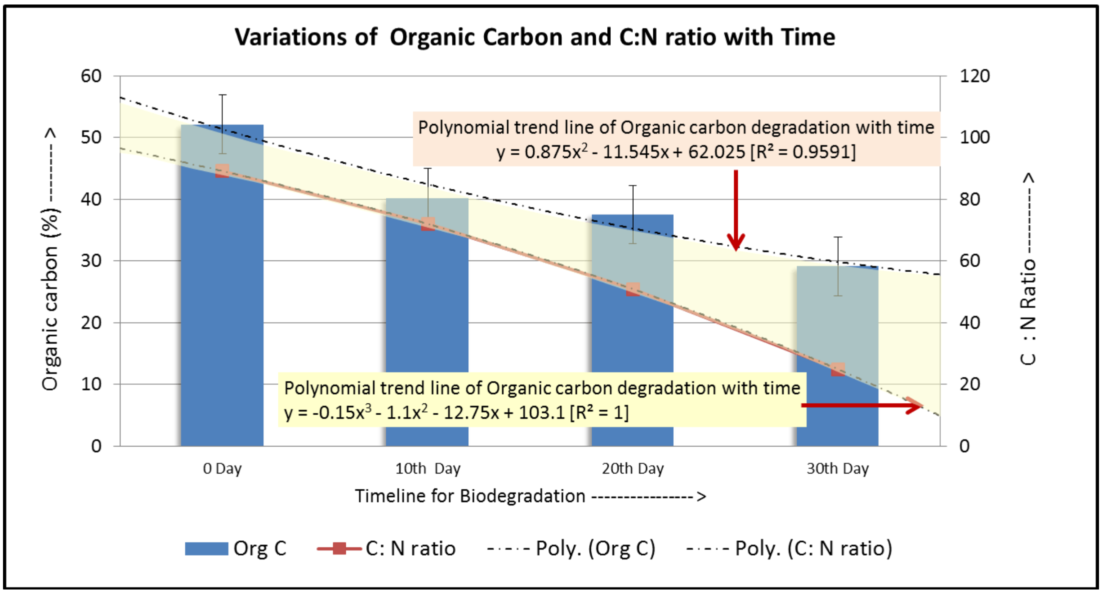


Fig. 2. Variations in the organic carbon content and C:N ratio of coir pith during biodegradation under Novcom Composting Technology

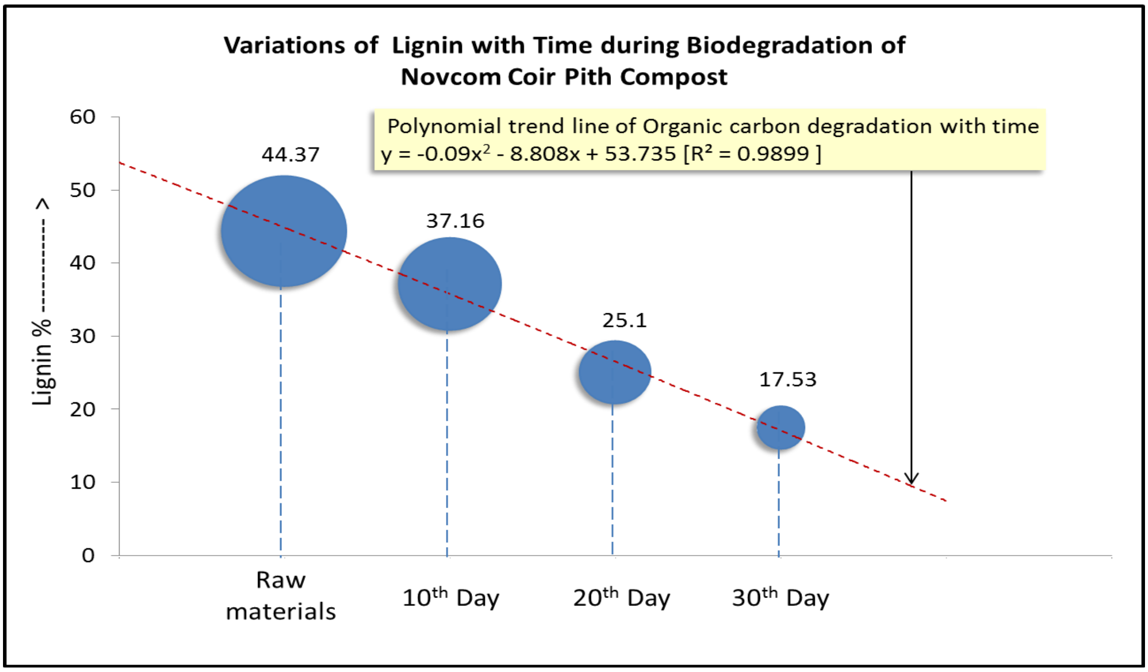


Fig. 3. Degradation of lignin content in coir pith under Novcom Composting Technology, at Mandya, Karnataka under IBM-IORF Sustainability Project

Pic. 10A & 10B. Inspection of the on-going large scale Novcom Composting program utilizing Coir pith by Dr. P Das Biswas, Developer of this Method; at Model Farm, Mandya, Karnataka under IBM-IORF Sustainability Project

Composting transforms raw organic residues into humus-like material through the activity of soil microorganisms. The organic matter content of compost is a necessity for determining the compost application rate to obtain sustainable agricultural production [33]. By increasing soil organic matter content, which fuels microbial activity and nutrient cycling, compost applications can increase the overall soil fertility. Organic carbon content in the compost samples ranged between 26.8 and 32.1%, with a mean value of 29.1%, which met the standard value of >19.4% suggested by Australian Standard 4454 [34] for nursery application.

3.1.5 Fertility and microbial parameters of Novcom coir pith compost

"Although 36 different nutrients are required for plant growth, the macronutrient (N, P, and K) contribution of compost is usually of major interest" [35]. "The total nitrogen content in the compost samples ranged between 1.12 and 1.20 %, which was well above the Indian standard [36] of 0.5% and the range of 1–2%" suggested by Alexander [37] and Watson [31]. Total phosphorus (0.18–0.20%) was around the minimum suggested standard of 0.22% [36], whereas the values obtained for total potassium (2.67–2.87%) were much higher than the range (0.2–0.5%) suggested by Alexander [37] and Watson [31], on dry matter basis.

Microbial Status of compost is one of the most important parameter for judging compost quality because microbes are the driving force behind soil rejuvenation and maintenance of soil – plant – nutrient dynamics that is crucial for crop sustenance [7]. The huge population of microflora (in the order of 10^{16} cfu/gram moist compost for total bacteria, fungi and actinomycetes) in Novcom compost, corroborated the uniqueness of this composting technology in respect of faster bio- conversion and high nutrient content, as also found by other research workers in respect of Novcom Composting Technology [38,39].

3.1.6 Evaluation of stability, maturity and phytotoxicity of Novcom coir pith compost

"Compost stability, maturity and phytotoxicity rating are the most important criteria because immature compost may contain high level of free ammonia, organic acids or other water-soluble compounds, which can limit seed germination and root development" [33]. "The stability of given compost is important in determining the potential impact of the material on nitrogen availability in soil or growth media, and maintaining consistent volume and porosity in container growth media. Most uses of compost require a stable to very stable product that will prevent nutrient tie up and maintain or enhance oxygen availability in soil or growth media" [40]. Hence, microbial respiration formed an important parameter for determination of compost stability [41]. Mean respiration or CO_2 evolution rate of all compost samples (1.74 to 1.89 $mgCO_2$–C/g OM/day) was more or less within the stipulated range (2.0 - 5.0 $mgCO_2$–C/g OM/day) for stable compost proposed by Trautmann and Krasny [12] and Bartha and Pramer [42].

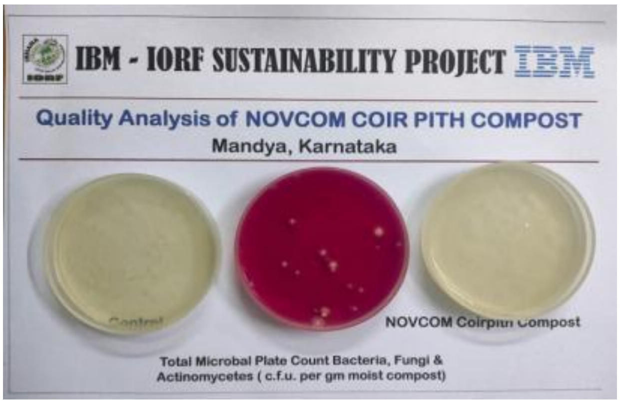
The phytotoxicity bioassay test, as represented by the germination index, provided a means of measuring the combined toxicity of whatever contaminants may be present [43]. Phytotoxicity is also a significant indicator of final compost product maturity and is assessed through germination bioassays using a variety of crop seeds [44]. It is known that immature compost introduce phytotoxic compounds such as heavy metals [45], phenolic compounds [46], ethylene and ammonia [45], excess accumulation of salts [45] and organic acids [47] which could retard seed germination and plant growth [48]. The mean germination index value (1.23) of Novcom compost was well above the highest order of rating (1.0). The value indicated the absence of phytotoxicity in the compost [49] and also confirmed that the compost enhanced rather than impaired germination and radicle growth [12].

3.2 Assessment of GHG Emission Potential of Coir Pith from Landfill

Coir pith is a lignocellulosic agro residue from coir industry of India. Though utility of coir pith has been claimed in different applications, an efficient and accepted technology for its maximum utilization is not yet available [8]. Coir pith is generally dumped in the environment

Pic. 11. Preparation of Novcom coir pith compost at Model Farm, Mandya, Karnataka under IBM-IORF Sustainability Project


Pic. 12A & 12B. Novcom Coir pith compost ready in 30 days, confirmed by stability, maturity and phytotoxicity test

Pic. 13 A & 13 B. Analysis of compost nutrient content and microbial properties in IORF laboratory, Kolkata; under IBM-IORF Sustainability Project

Pic. 14 A & 14 B. Phytotoxicity bioassay test of mature Novcom coir pith samples in IORF laboratory, Kolkata under IBM-IORF Sustainability Project

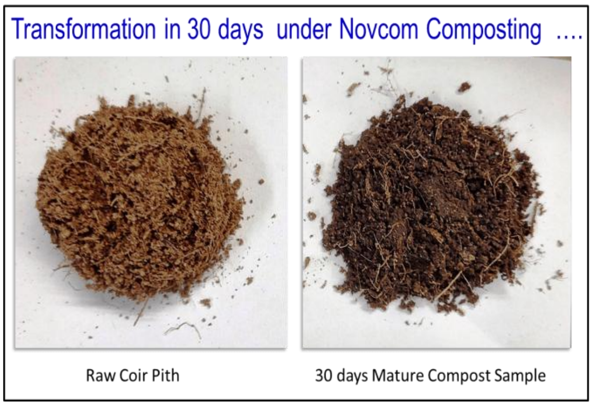
around the extraction units and form huge hillocks which occupy large land space, create pollution [2] and form potential source for GHG emission. As per scientific literature, whenever any biodegradable waste is disposed in waste dumps and landfills, most of the organic material will be degraded over a period and mostly CH_4 is produced and released to the atmosphere contributing to global warming [50].

Table 1. Variation of physicochemical properties, nutrient status and lignin content during bioconversion of coir pith utilizing Novcom Composting Technology

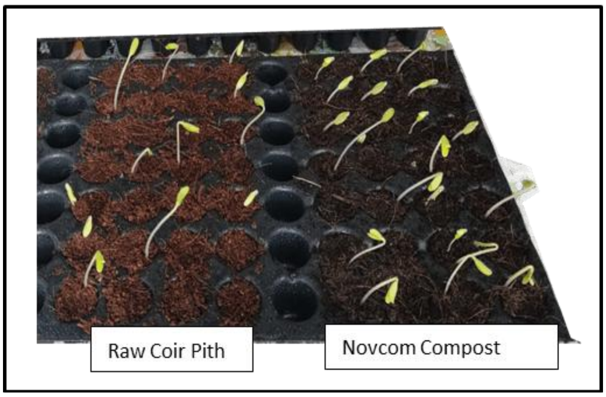
Sl. no	Quality parameters	Raw coir pith		10^{th} day Sample		20^{th} day Sample		30^{th} day Sample	
		Range value	Mean value	Range value	Mean value	Range value	Mean value	Range value	Mean value
1	Moisture (%)	47.00 – 55.4	50.76 ± 0.71	68.50 - 75.0	72.50 ± 0.69	64.96 - 72.50	69.2 ± 0.66	66.0 - 72.0	69.6 ± 0.45
2	pH	5.90 - 6.73	6.15 ± 0.07	6.53 - 6.86	6.70 ± 0.03	6.13 - 6.85	6.60 ± 0.07	7.29 - 7.35	7.32 ± 0.01
3	EC (dSm^{-1})	2.69 - 3.24	3.11 ± 0.05	1.95 - 2.65	2.43 ± 0.08	1.96 - 2.30	2.14 ± 0.04	1.83 - 1.96	1.89 ± 0.01
4	Ash Content (%)	3.00 - 11.11	4.83 ± 0.73	21.09 - 41.09	27.65 ± 2.17	19.2 - 39.7	32.4 ± 2.17	42.11 – 51.75	47.6 ± 0.81
5	Total Vol. Solids (%)	88.89 - 97.00	95.17 ± 0.73	58.91 - 78.96	72.35 ± 2.17	60.3 - 80.8	67.6 ± 2.17	50.4 – 57.89	52.4 ± 0.81
6	Org. Carbon (%)	49.38 - 53.89	52.87 ± 0.41	32.73 - 43.87	40.20 ± 1.20	33.5 - 44.9	37.5 ± 1.21	26.81 – 32.16	29.11 ±0.45
7	Total N (%)	0.53 - 0.67	0.59 ± 0.01	0.47 - 0.62	0.56 ± 0.01	0.58 - 1.18	0.76 ± 0.06	1.12 - 1.20	1.17 ± 0.01
8	Total P_2O_5 (%)	0.08 - 0.21	0.16 ± 0.01	0.12 - 0.26	0.17 ± 0.01	0.12 – 0.24	0.17 ± 0.01	0.18 - 0.22	0.20 ± 0.01
9	Total K_2O (%)	1.38 - 1.61	1.48 ± 0.02	1.60 - 1.81	1.72 ± 0.02	2.10 - 2.74	2.48 ± 0.06	2.67 - 2.87	2.80 ± 0.02
10	C:N ratio	89:1 - 99:1	89.9 :1	69 : 1 – 81 : 1	72 : 1	38:1 - 62:1	50.9 : 1	23 : 1 - 27 : 1	24.9 : 1
11	CMI	–	–	0.48 – 1.26	0.71 ± 0.08	0.43 - 1.19	0.89 ± 0.08	1.31 - 1.93	1.64 ± 0.05
12	Total lignin %	40.2 – 47.4	44.37± 0.79	33.6 - 41.9	37.16 ± 0.81	18.7 - 30.5	25.1 ± 1.11	15.40 - 20.5	17.53 ± 0.54

Table 2. Variation of microbial, stability, maturity and phytotoxicity parameters during bioconversion of coir pith utilizing Novcom Composting Technology

Sl No	Quality parameters	Raw coir pith		10th day Sample		20th day Sample		30th day Sample	
		Range value	Mean value	Range value	Mean value	Range value	Mean value	Range value	Mean value
13	Bacteria (c.f.u. per gm moist compost)	–	–	(22-51) x 10^{14}	38 x 10^{14}	(67-176) x 10^{16}	115 x 10^{16}	(127-168) x 10^{16}	142 x 10^{16}
14	Fungi (c.f.u. per gm moist compost)	–	–	(2-7) x 10^{12}	5 x 10^{12}	(4-11) x 10^{14}	6x 10^{14}	(12-22) x 10^{16}	17 x 10^{16}
15	Actinomycetes (c.f.u. per gm moist compost)	–	–	(9-15) x 10^{10}	11 x 10^{10}	(1-5) x 10^{14}	3x10^{14}	(9-18) x 10^{16}	12 x 10^{16}
16	CO_2 evolution rate (mg CO2-C/g/OM/day)	–	–	2.68 - 3.70	3.1 ± 0.13	1.96 - 3.60	2.63 ±0.14	1.74 -1.89	1.82 ±
17	Seedling emergence (% over control)	–	–	79.1 - 87.1	81.2 ± 0.95	78.6 - 102.7	92.85 ± 2.09	92.4 -102.0	98.3 ±0.8
18	Root elongation (% over control)	–	–	73.1 - 85.8	82.6 ± 1.21	82.5 -102.8	94.32 ± 1.85	119.5 - 138.5	130.5 ±1.84
19	Germination Index	–	–	0.58 - 0.75	0.67 ± 0.02	0.68 – 0.96	0.88 ± 0.03	1.18 - 1.37	1.28 ±0.02



Pic. 15. Transformation of raw coir pith to mature compost in 30 days under Novcom Composting Technology.



Pic. 16. Comparative evaluation of seed germination under raw coir pith and Novcom Coir pith Compost

Pic. 17. Utilization of coir pith to develop quality compost using Novcom Composting Technology and application of Novcom Coir pith Compost in soil for development of Clean Food 'Net Zero' – a practical demonstration of GHG Mitigation in the Agriculture Sector under IBM-IORF Sustainability Project at Model Farm, Mandya, Karnataka

Scientists used satellite data from four major cities worldwide — Delhi and Mumbai in India, Lahore in Pakistan and Buenos Aires in Argentina — and found that emissions from landfills in 2018 and 2019 were 1.4 to 2.6 times higher than earlier estimates. Although methane only accounts for about 11% of greenhouse gas emissions and lasts about a dozen years in the air, it traps 80 times more heat in the atmosphere than carbon dioxide does [51] over the first 20 years after it reaches the atmosphere. And most importantly though CO_2 has a longer-lasting effect, methane sets the pace for warming in the near term [52] as methane has a radiative forcing approximately 120 times more than CO_2 immediately after it is emitted [53]. At the same time, methane is an important precursor for tropospheric ozone contributing in both global warming and causing damage to human health and plants [54].

3.3 Methane Abatement: The Most Effective Pathway for Climate Action

There has been a worldwide focus on curtailing carbon dioxide emission resultant from burning of fossil fuels, but it is also critical to cut methane emissions—not least because methane has a more powerful near-term warming effect than CO_2, but also because cutting methane emissions would have a more immediate impact on the climate [55]. A recent assessment from the United Nations Environment Programme (UNEP) and the Climate and Clean Air Coalition found that cutting farming-related methane emissions would be the key in the battle against climate change [56].

Methane mitigation is most important as it is the primary contributor to the formation of ground-level ozone, a hazardous air pollutant and greenhouse gas, exposure to which causes 1 million premature deaths every year. Methane has accounted for roughly 30 per cent of global warming since pre-industrial times and is proliferating faster than at any other time since record keeping began in the 1980s. According to data from the United States National Oceanic and Atmospheric Administration, even as carbon dioxide emissions decelerated during the pandemic-related lockdowns of 2020, atmospheric methane shot up [56].

Methane mitigation is more important because carbon dioxide remains in the atmosphere for hundreds to thousands of years. This means that even if emissions were immediately and dramatically reduced it would not have an effect on the climate until later in the century. But it takes only about a decade for methane to break down. So, reducing methane emissions now would have an impact in the near term and is critical for helping keep the world on a path to 1.5°C. Thus, methane anthropogenic reduction goals are between 44% and 67% to the 2010 level to achieve the maximum 1.5^{o}C global temperature increase by 2050 whereas anthropogenic CO_2 reduction goals are nearer 100% (IPCC 1.5^{o} target) [57].

3.4 Debate on GWP of Methane on 100 Years Basis or on a Shorter Scale

For many years, methane was overlooked in the climate change conversation. But scientists and policymakers are increasingly recognizing that methane reductions are crucial [15]. Atmospheric concentration of methane is increasing faster now than at any time since the 1980s. At the same time though, annual emissions are only 3% w/w of those associated with CO_2 (0.56 $GtCH_4$/year *vs.* 14.5 $GtCO_2$/year for methane and CO_2 respectively) [58,59] but methane has a radiative forcing approximately 120 times more than CO_2 immediately after it is emitted [53], which means that now is the methane moment.

Acting now to reduce methane emissions will have immediate benefits to the climate that reductions in carbon dioxide cannot provide on their own [52]. But there is an emerging debate whether, GWP of methane will be taken on 100 years basis (as IPCC recommended) or on a shorter scale. Because, GWP hides trade-offs between short- and long-term policy objectives inside a single time scale of 100 or 20 years [60]. Increasingly there are calls for the use of different time horizons (*e.g.* 20 years) or even different metrics that better reflect climate change or align with climate targets (*e.g.* the global temperature change potential as described in the IPPC AR5 [53,61].

The most common form, GWP_{100}, focuses on the climate impact of a pulse emission over 100 years, diluting near-term effects and misleadingly implying that short-lived climate pollutants exert forcing in the long-term, long after they are removed from the atmosphere [62]. Meanwhile, GWP_{20} ignores climate effects after 20 years [63]. Now, the challenge is majorly related to methane, which is a powerful greenhouse gas with a 100-year global warming potential 28-34 times that of CO_2. Measured over a 20-year period, that ratio grows 84-86 times. Despite methane's short residence time, the fact that it has a much higher warming potential than CO_2 and that its atmospheric volumes are continuously replenished make effective methane management a potentially important element in countries' climate change mitigation strategies [64].

According to J. Trancik, an MIT associate professor at the Institute for Data, Systems, and Society, more scientists are beginning to model the warming effects that today's methane emissions will have over the next 20 or 30 years, in order to predict more accurately whether humanity can avoid overshooting targets such as stopping global warming at 1.5 degrees Celsius [65].

Pérez-Domínguez et al. [66] also indicated that methane's short atmospheric life has important implications for the design of global climate change mitigation policies in agriculture. Results also showed that the choice of a particular metric for methane's warming potential is the key to determine optimal mitigation options, with metrics based on shorter-term impacts leading to greater overall emission reduction. Most importantly, when the ambition is to reduce warming in the next few decades, a shorter time horizon might be applied in comparing the effects of CO_2 and CH_4. Thus a two-value approach, which indicates the effect over two different time horizons, is suggested by a number of studies [63].

Pic. 18. Field visit of IBM Representatives Mr. Manoj Balachandran, Mrs. Shobha V. Mani, Ms. Nisha Anil & Ms. Usha in the Project Area at Mandya, Karnataka

In the Sixth Assessment Report of IPCC (AR6) [67], there is discussion regarding the use of a range of emission metrics, including GWP_{20} and GWP_{100} and how they perform, using methane as an example and explores how cumulative CO_2 equivalent emissions estimated for methane vary under different emission metric choices and how estimates of the global surface air temperature (GSAT) change deduced from these cumulative emissions compare to the actual temperature response computed with the two-layer emulator [68]. GSAT changes estimated with cumulative CO_2 equivalent emissions computed with GWP_{20} matches the warming trend for comparatively shorter time scale (a few decades) but quickly overestimates the response, whereas estimating emissions using GWP_{100} underestimate the warming potential [67].

Hence, the moot point is that we do not have another 100 years to achieve our 2050 climate neutrality and net zero targets and whatever we need to change, have to be done now. So though under UNFCCC, GWP_{100} remains the standard: according to the Paris "rulebook," [69] people can use other metrics to provide information; this comes with the requirement to provide supporting documentation [70].

Howarth [71] suggested that the 20-year period is more appropriate for evaluation of GHG emissions since there is an urgent need to mitigate them in the next 15–35 years. Additionally, AR6, published in 2021, raised the GWP of methane to 29.8 over a 100-year horizon but seems to have reduced the 20-year horizon factor to 82.5.16 With the adoption of COP 21 (Paris), and particularly of net zero targets for 2050 there is a convincing case for taking a 20–30-year, rather than a 100-year horizon [72].

In the latest IPCC report [73], it has been clearly maintained that, IPCC does not recommend an emissions metric because the appropriateness of the choice depends on the purposes for which gases or forcing agents are being compared. Emissions metrics can facilitate the comparison of effects of emissions in support of policy goals. They do not define policy goals or targets but can support the evaluation and implementation of choices within multi-component policies (e.g., they can help prioritize which emissions to abate). The choice of metric will depend on which aspects of climate change are most important to a particular application or stakeholder and over which time horizons. Different international and national climate policy goals may lead to different conclusions about what is the most suitable emissions metric [74].

Now, according to Abernethy and Jackson, Emission metrics, a crucial tool in setting effective exchange rates between greenhouse gases, currently require an arbitrary choice of time horizon. So they propose a novel framework to calculate the time horizon that aligns with scenarios achieving a specific temperature goal and to best align emission metrics with the Paris Agreement 1.5 ◦C goal. They recommend a 24 year time horizon, using 2045 as the endpoint time, with its associated $GWP_{1.50\,C}$ = 75 [75].

In this study, assessment was done through Carbon assessment Tool (ACFA- Version 1.0) which is based on guideline prepared for the IPCC National Greenhouse Gas Inventories Program to support the development of *Good Practice Guidelines* for estimation of greenhouse gas emissions from the waste sector and to manage the associated uncertainties [76]. Under this evaluation the default IPCC methodology that is based on the theoretical gas yield (a mass balance equation) was followed, to calculate total methane emission (at a time), assuming that all potential methane is released in the same year when the solid waste is disposed.

3.5 Calculation of GHG Emission Potential from Biowaste (Primarily Landfill Materials) as per IPCC Guideline (Utilizing Carbon Assessment Tool: ACFA- Version 1.0)

GHG emission (MT in CO_2 equivalent) =
$$[(LM_T \times LF_F \times MC_F \times DOC \times DOC_F \times F \times 16/12 - R) \times (1 - OX)] \times GWP_{CH4}$$

LM_T : Total Landfill Material(MT)
LF_F : Fraction of Landfill Material disposed at site (if 100 % landfill material which is generated is deposited at site, then LF_F value will be 1.0, default value)
MC_F : Methane correction factor (fraction) (IPCC default value is 0.6, when there is no specific information)
DOC : Degradable organic carbon (fraction) (kg C/ kg landfill material)
DOC_F: Fraction DOC dissimilated (IPCC default is 0.77)
F : Fraction of CH_4 in landfill gas (IPCC default is 0.5)
16/12 : conversion of C to CH_4
R: Recovered CH_4 (MT) (in general value is 0 if not any specific treatment plants in disposal sites to recover methane
OX: oxidation factor (fraction – IPCC default is 0)
GWP_{CH4}: 75 (based on 24 year time horizon)

Thirty samples of raw coir pith were collected from different coir factories at Karnataka and analyzed to generate the required database for calculation of the methane emission potential (kg CO_2-eq) per ton moist raw coir pith waste, as per IPCC guideline**.** The GHG emission (kg CO_2-eq) per ton moist raw coir pith based on 24 years' time horizon varied from 5446 to 6963 kg CO_2-eq with a mean value of 6013.7 kg CO_2-eq. The histogram represents the distribution of numerical data in specific range, which showed that GHG emission potential of raw coir pith is mostly in the range of 6000 – 6500 kg CO_2-eq/ ton wet raw coir pith followed by 5500 – 6000 kg CO_2 eq/ ton wet raw coir pith (Fig. 4).

3.6 Study of GHG Emission in Novcom Coir Pith Compost

Ten Novcom coir pith compost heaps were selected to study the emission of CO_2, CH_4, N_2O and NH_3 during biodegradation period under IBM-IORF Sustainability project.

3.6.1 Study of carbon dioxide (CO_2) emission under Novcom coir pith composting process

The CO_2 released during composting is considered biogenic, not anthropogenic, so it is not considered in greenhouse gas calculation [76]. CO_2 emission measured on day basis during the Novcom composting process showed higher values in the 1st week which gradually decreased with progression in the composting period and became minimum after 30 days indicating completion of the biodegradation process. Total CO_2 emission during entire biodegradation period was 1.848 kg CO_2/ ton raw material.

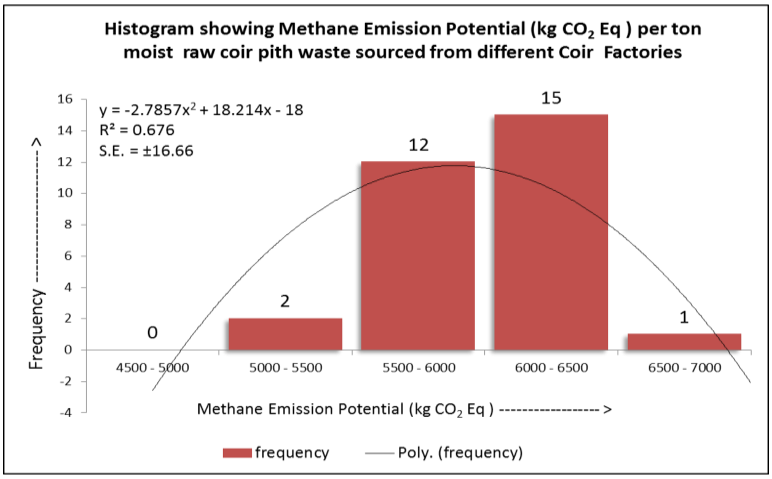


Fig. 5. Histogram showing methane emission potential (kgCO_2 eq) per ton moist raw coir pith, as per IPCC guideline

Pic. 18. Utilization of coir pith as organic manure post bioconversion under Novcom Composting Technology for developing Clean Food 'Net Zero' Model, under IBM-IORF sustainability project

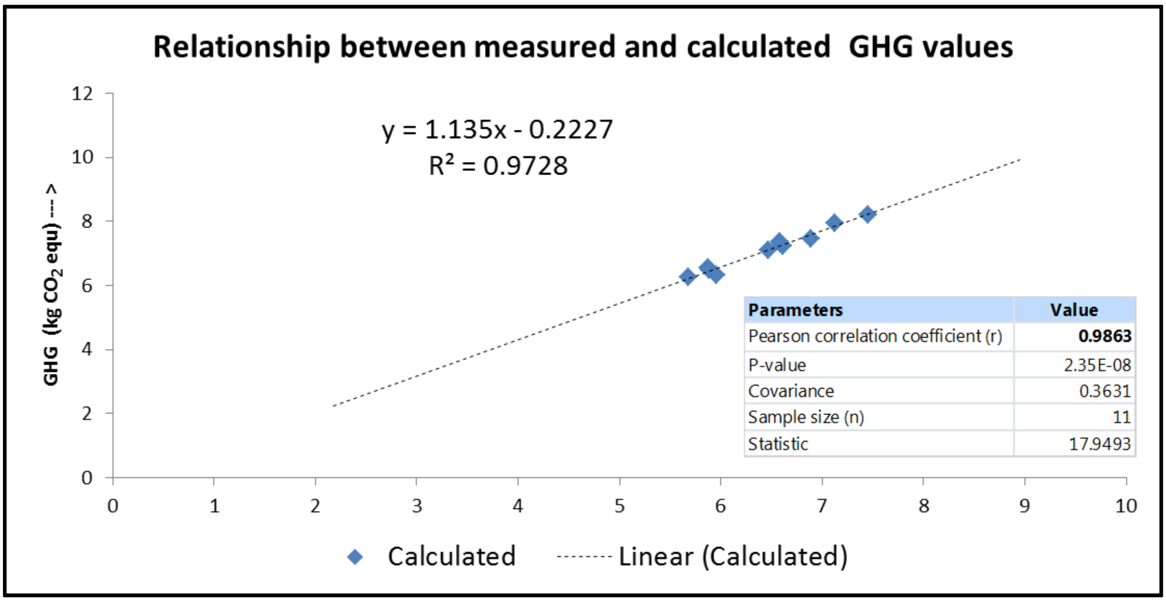


Fig. 6. Relationship between the measured and calculated GHG values (kg CO_2 euivalent / MT wet raw coir pith) under IBM-IORF Sustainability Project at Mandya, Karnataka

3.6.2 Emission of Methane (CH_4) under Novcom Composting Technology

Methane is one of the contributors to non-biogenic greenhouse gas emissions from composting, and the majority of that CH_4 is emitted early in the composting process [77]. In the case of Novcom coir pith composting process methane emission was found to be negligible (0.61 kg CO_2 equivalent per ton wet coir pith) as compared to that documented by several research workers [78,79,80] in respect of other standard biodegradation processes (2.25 – 600 kg CO_2 equivalent per ton wet waste, considering $GWP_{24years}$ of CH_4 : 75) [81]. The primary reason behind negligible methane emission under Novcom Composting process is the aerobic process of composting that minimize the anaerobic pockets (which nullifies the proliferation of methane producing bacteria), controls the O_2 solubility and balances the redox potential. Moreover the enhanced microbiological activity in the composting also means higher storage of the carbon from the decomposed organic matter into the microbial biomass, which lowers the escape potential of C as a potent GHG from the composting heap. This intense microbial activity within the Novcom Composting heap on the other hand is accelerated by the creation of favourable environment due to the application of subtle energy forms through Novcom solution [15].

3.6.3 Emission of Nitrous oxide (N_2O) under Novcom Composting Technology

Nitrous oxide (N_2O) emission during composting is an important issue. It not only leads to nitrogen (N) loss from compost, but also exacerbates the greenhouse effect [82,83]. In case of Novcom coir pith composting, emission of nitrous oxide (N_2O) was about 5.86 kg CO_2 equivalent/ ton wet coir pith w.r.to reference range of 16.38 – 163.8 kg CO_2 equivalent/ ton wet waste (considering $GWP_{100years}$ of N_2O : 273) [82]. The lower values under Novcom coir pith composting might be due to initial lower value of N in the raw material as well as higher speed of biodegradation under this method that is induced by the self- generated diversified microbial pool (in order of 10^{16} c.f.u. per gm moist compost) and not through any mechanization or artificial induction. The speedy nitrification process as well as faster immobilization of the nitrogen released due to organic matter breakdown by the high microbial pool; reduces the escaping chances of N_2O from Novcom Composting heap during the process of organic matter breakdown [15].

3.6.4 Emission of Ammonia (NH_3) under Novcom Composting Technology

Ammonia is one of the main compounds responsible for generation of offensive odours and atmospheric pollution when composting organic wastes with high nitrogen content [83]. In case of Novcom coir pith composting, NH_3 emission (0.03g CO_2 equivalent/ ton wet coir pith) decreased with progression of composting indicating intense microbial activity within compost heap that reduced the escaping chances of NH_3 during the biodegradation process [15]. However, due its very low CO_2 equivalency, NH_3 is generally not considered under the GHG calculation methodology, though it has a negative impact on environment and reduces the nutrient quality of compost.

3.6.5 Total GHG emission during biodegradation of Novcom coir pith compost

To calculate the total GHG emission during biodegradation of Novcom coir pith compost we took the total emission value of methane (CH_4) and nitrous oxide (N_2O) in terms of CO_2 equivalent as per IPCC guideline. It was found that a total 6.47 kg CO_2 eq was emitted per ton of raw coir pith during the entire biodegradation period of 30 days. Now, considering the reference value of 200 kg GHG emission per tonne treated wet waste during composting [78,79,80,84,85,86], Novcom coir pith composting would be about 31 times more efficient in terms of GHG mitigation; which might be due to the prolific self- generated population of native microflora within the compost heap, that speeded up the biodegradation process and alternately shortened the biodegradation period to under 30 days.

3.7 Case Study of GHG Emission from 1000 ton Landfill Material (Coir Pith) Bio- Converted Utilizing Novcom Composting Technology under IBM–IORF Sustainability Project at Mandya, Karnataka; during 2022 – 23

Clean Food ‘Net Zero’ program was taken up under the IBM-IORF Sustainability Project, to establish the ‘Net Zero’ Model in Agriculture towards impactful climate action (especially in respect of methane mitigation), degraded soil reclamation as well as to showcase the relevance of safe and sustainable agriculture in respect of crop yield improvement *vis-à-vis* farmers’ empowerment. About 1000 ton of coir pith was bio-converted utilizing Novcom Composting Technology. The total GHG emission/ mitigation was evaluated through ACFA (version 1.0) – a carbon assessment tool for agriculture, developed by IORF as per IPCC guideline; which uses an empirical equation to calculate total GHG emission from raw material under Novcom Composting Technology with inputs of moisture, carbon and nitrogen value from initial and final stages.

As per ACFA (version 1.0), calculation of GHG emission from composting activity (E_{CA}) is as follows:

$$E_{CA} \text{ (Kg } CO_2 \text{ equivalent/ MT Raw Materials)} = E_T + E_{CM} + E_{CB}$$

Where,

E_T : Total GHG Emission from Raw Material Transport (kg CO_2 equivalent/MT Raw materials)
E_{CM} : Total GHG Emission from Composting Activity (kg CO_2 equivalent/MT Raw materials)
E_{CB} : Total GHG Emission during Compost Biodegradation

Total GHG Emission from Raw Material Transport (E_T)

E_T : $[2 \times D_{LS} \times FE_V \times E_F] / V_{CC} + (E_{E1} \times V_w \times T_O) / V_{CC}$
$=[2 \times 10 \times 0.224 \times 2.644]/5 + [0.0975 \times 12 \times 2.5]/5$ kg CO_2 Equivalent / MT Raw material
= 2.954 kg CO_2 Equivalent MT Raw material
So, GHG emission for 1000 MT coir pith transport = 2954 kg CO_2 equivalent

Where,

D_{LS} : Total distance (in km) from composting unit to disposal site from where raw materials are collected (Default value 10 km up to 5,000 ton and 0.003 km / ton when value is > 5000 ton)
FE_V : Fuel Efficiency of the vehicle carrying the landfill material (i.e. litre of diesel / petrol / gasoline used to carry the vehicle 1 km) (Default value 0.224 litre diesel/km) [87]
E_F : Reference GHG emission value of the fuel used by the vehicle (Default value 2.653 kg CO_2equ / litre).
V_{CC} : Carrying Capacity of the vehicle carrying the landfill material (i.e. total amount of landfill material can be carried (in MT) in single trip). (Default value 5 MT).
E_{E1} : Embodied emissions factor for the vehicle per hour (Default value 0.0975 kg CO_2equ / hour/ ton) [88]
V_W : Total weight of the empty vehicle (Default value 12 MT)
T_O : Total Time of Operation (i.e. time (in hour) required to carry single trip landfill material from disposal site to composting unit) (Default value 2.5 hour upto 5000 ton and (1.5 +0.1 x Km) hour for < 5000 ton)

Total GHG Emission from Composting Activity (E_{CM})

$=[(T_{CM} \times F_M \times E_F)+(T_{ECM} \times E_M \times EC_E)] +[(E_{E2} \times M_w \times T_{CM}) +(E_{E2} \times M_{Ew} \times T_{ECM})]$

$= [(0.2 \times 5 \times 2.644)+(0 \times 0.0 \times 0.236)] +[(0.0975 \times 10 \times 0.2)+(0.0975 \times 0 \times 0)]$ kg CO_2 equ
=2.839 kg CO_2 equivalent

So, GHG emission for 1000 MT coir pith preparation = 2839 kg CO_2 equivalent

Where,

T_{CM} : Total machine operating time for compost making (in hour) (Default value 0.2 hour / MT raw materials).
T_{ECM} : Total electric machine operating time for compost making (in hour) (Default value 0.0 hour / MT raw materials).
F_M : Total Fuel used per hour (in ltr) for compost making (Default value 5 ltr / hr)
E_F : Emission factor (kg CO_2 equivalent) per liter Fuel used (Default value 2.653 kg CO_2equ / litre)
E_M : Total Electricity used by machinery (in MJ) per hour for compost making (Default value 0 MJ)
EC_E : Emission factor (kg CO_2 equivalent) per MJ electricity used. (Default value 0.236 kg CO_2/ MJ)
E_{E2} : Embodied emissions factor per hour for the machinery used (Default value 0.0975 kg CO_2equ/ hour/ ton). (for both electric and diesel operated machinery) [89]
M_w : Total Weight of the general machines used for compost preparation (Default value 10).
M_{Ew} : Total Weight of the electric machines used for compost preparation (Default value 0).
TL_C : Total Raw material used for compost making

Total GHG Emission during Compost Biodegradation (E_{CB})

To evaluate the total GHG emission during biodegradation of Novcom coir pith composting, we took the help of hypothetical equation developed by Bera et al [15] which was used by the carbon assessment toll ACFA (version 1.0).

Now total GHG emission during biodegradation of Novcom coir pith composting

$= E_{N_2O}$ (kg CO_2 equivalent / MT waste) + E_{CH_4} (kg CO_2 equivalent / MT waste)
Now in case of Novcom compost

E_{N_2O} (kg CO_2 Equivalent / MT waste) = [39.31 x $TNL_{20\ Days}$ (kg/ton waste) + 0.6338] x 1/1000 x 273 ----- (i) (Where $TNL_{20\ Days}$: Total Nitrogen Loss in first 20 days)

Calculation of $TNL_{20\ Days}$ from the analytical value

$TNL_{20\ Days}$ (kg/ton waste) = [(100– $M_{0\ Day}$) x ($TN_{0\ Day}$/100)-(100 – $M_{20\ Day}$) x ($TN_{20\ Day}$/100)]x10
=[(100 -50.76) x(0.59/100) –(100-69.20) x (0.76/100)] x 10 kg/ton waste
=0.6 kg/ton waste
So, E_{N_2O} = [39.31 x 0.6 + 0.6338] x 1/1000 x 273 kg CO_2 Equivalent / MT waste
=6.44 kg CO_2 Equivalent / MT waste

E_{CH_4} (kg CO_2 Equivalent / MT waste) = [0.06399x $TCL_{30\ days}$ (kg/ton waste) - 0.2498] x 1/1000 x 75 (Where $TCL_{30\ days}$: Total Carbon Loss in first 30 days)

Calculation of $TCL_{30\ days}$ from the analytical value

$TCL_{30\ days}$ (kg/ton waste) = [(100 – $M_{0\ Day}$) x ($TOC_{0\ Day}$/100) - (100 – $M_{30\ Day}$) x ($TOC_{30\ Day}$/100)] x 10 =[(100-50.76) x(52.87/100) – (100-69.6) x (37.53/100)] x 10 kg/ton waste
=146.2 kg/ton waste

So, E_{CH_4} (kg CO_2 Equivalent / MT waste) = [0.06399x 146.2 - 0.2498] x 1/1000 x 75

=[9.355 – 0.2498] x 1/1000 x 75 kg CO_2 Equivalent / MT waste (Considering GWP_{24} of Methane = 75 for which detail discussion was done in earlier part of the paper)
=0.68 kg CO_2 Equivalent / MT waste
So, GHG emission during biodegradation for 1000 MT coir pith was 7120 kg CO_2 equivalent

So total GHG emission from 1000 ton Novcom coir pith composting is as follows

$E_{CA} = E_T + E_{CM} + E_{CB}$ (kg CO_2 equivalent/ 1000 MT raw coir pith)
=2954 +2839 + 7120 kg CO_2 equivalent / 1000 MT raw coir pith
==12.913 ton CO_2 Equivalent /1000 MT coir pith

Total GHG Offsetting with bio-conversion of coir pith into Novcom coir pith compost

GHG Offsetting with bio-conversion of coir pith to Novcom coir pith compost

GHG Offsetting with conversion of landfill materials to compost = GHG Emission from untreated waste - GHG Emission during composting
=(6013.7 -12.91) MT CO_2 euivalent /1000 MT coir pith
=6000.79 ton CO_2 euivalent /1000 MT coir pith

3.8 Comparision of the Measured GHG Emission from Actual Sudy with the Calculated Value Utilizating the Empirical Equation from AFCA (version 1.0)

In the following study we compared GHG emission from actual study and from emperical equation under AFCA (version 1.0) to evaluate how much the data sets are correlated and whether this tool can be used in any practical projects; as actual field study for every case might not be practically feasible and economically viable. Pearson correlation coefficient (r) value (r = 0.9863) indicated that there was high degree of positive correlation between the measured and calculated GHG values and thus AFCA (version 1.0) can be utilized for GHG evaluation specially where Novcom composting technology is adopted.

4. CONCLUSION

Study of the biodegradation pathway under Novcom Composting Technology, and evaluation of the end product (Novcom Coir- pith Compost) quality, indicated that the process can provide an excellent solution towards production of stable, mature and non-phytotoxic compost using any type of biodegradable material, especially toxic, hard to biodegrade and methane emitting waste, including landfill materials.

The results indicated that, this Composting Technology can help out not only in transforming coir pith – a high GHG emitter, toxic and hard to biodegrade waste, with no effective technology for effective bio-conversion, into a safe, mature and qualitative amendment for soil health management. Moreover, the bio-conversion actually demonstrates a First of a Kind Model in Agriculture for Methane abatement, directly from Source Point.

In respect of climate action, composting activity has been referred as one of the most effective and economic option towards GHG abatement. And this study specifically indicates the very high

GHG offsetting potential under Novcom Composting Technology; as reflected by more than 99% Omission of GHG from source point during the process of coir pith bioconversion.

Finally, the safe, quality and microflora rich (one trillion billion c.f.u. of self- generated microflora per ton moist compost) coir pith compost, generated through Novcom Composting Technology within a short time frame of 30 days validates its potential as an effective tool that can successfully drive the Net Zero Goal, enable successful reclamation of degraded lands and improve crop productivity; while also generating additional mandays and options for income generation; that can empower farmers' livelihood.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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