PROJECT REPORT

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

Project Site : Haringhata Block, Nadia district, West Bengal, India.

Project Duration : 2021 – 2022

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

IBM - IORF SUSTAINABILITY PROJECT

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

PROJECT TEAM

Inhana Organic Research Foundation (IORF)

Dr. Ranjan Bera

Dr. Antara Seal

Dr. Anupam Datta

Mrs. Susmita Saha

Mr. Somesh Dutta

Mr. Atanu Das

TECHNICAL ASSOCIATION

Dr. Koushik Mukhopadhyay,
Nadia Krishi Vigyan Kendra, ICAR

Dr. Arun Kumar Barik
Visvabharati University, Santiniketan

Dr. Rambilash Mallick
Calcutta University, Kolkata

Dr. Pradip Bhattacharya
Indian Statistical Institute, Giridih

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Website : www.inhana.in

ORGANIZATIONAL SUPPORT

Manobjomin Agro producers Company Limited , Kolkata

SafeU Agricultural Pathways Limited, Kolkata

IBM - IORF SUSTAINABILITY PROJECT

IBM India Private Limited
12, Subramanya Arcade - 1
Bannerghatta Main Road
Bangalore - 560 029, India
Tel : 91-80-40683000
Fax : 91-80-26787218
www.ibm.com/in
CIN Number: U72200KA1997PTC022382

October 26, 2021

Dr. P Das Biswas
Founder Director
Inhana Organic Research Foundation (IORF)
168, Jodhpur Park (1st Floor),
Kolkata – 700068, India

Re: IBM Cash Grant

Dear Dr. P Das Biswas,

The IBM Sustainability Accelerator was established to propel the world to a more sustainable future. It does so by directly supporting initiatives benefiting people most vulnerable to environmental threats. IBM provides the organizations implementing these programs with access to advanced technology and expertise that are otherwise out of their reach but needed to expedite urgently needed capabilities.

The purpose of this letter (this "Letter Agreement") is to inform Inhana Organic Research Foundation (IORF) ("Grantee") that it has been selected to receive a grant ("the Grant," as further described herein) from IBM India Private Limited ("IBM").

This Letter Agreement consists of (a) this Letter Agreement; (b) the Statement of Work attached hereto as Appendix A; (c) the General Terms and Conditions for the grant attached hereto as Appendix B, (d) the Grant Budget attached hereto as Appendix C. The parties agree this Letter Agreement (with all appendices) constitute the sole agreement of the parties relating to its subject matter and supersedes all other agreements and communications relating to this subject matter. By signing below, Grantee agrees to the following terms of this Letter Agreement and all Appendices hereto.

Please sign below, scan, and return this Letter Agreement and enclosed appendices to Shobha V Mani, (shobhamani@ibm.com). IBM looks forward to working with Grantee on this Grant.

Sincerely,

e-Signed by Manoj Balachandran
on 2021-10-26 14:19:51 GMT

Manoj Balachandran
Head – Corporate Social Responsibility
IBM India & South Asia

Attachments: Appendix A – Statement of Work
Appendix B – General Terms & Conditions
Appendix C – Grant Budget

ACCEPTED AND AGREED TO BY:

Inhana Organic Research Foundation (IORF)

e-Signed by Dr. P Das Biswas
By: on 2021-10-27 12:47:00 GMT
Authorized Signature
P. Das Biswas
Founder Director
Inhana Organic Research Foundation

Date: 2021-10-27 12:47:00 GMT

IBM India Private Limited (IBM)

e-Signed by Manoj Balachandran
By: on 2021-10-26 14:19:56 GMT
Authorized Signature
Manoj Balachandran
Head – Corporate Social Responsibility
IBM India & South Asia

Date: 2021-10-26 14:19:56 GMT

Foreword

I am pleased to note that IORF has successfully initiated 'Clean Food' production- A True Demonstration of Safe & Sustainable Agriculture that ensures Safety to Human Health while ensuring Economic Sustainability for both the Producers and the Consumers. And appreciation goes to the IBM Sustainability Project that has provided the impetus that was crucial towards stepping up the momentum of the initiative.

I have also noted that this first phase of the IBM-IORF Sustainability Project has provided few deliverables that can be of global significance, especially in respect of SDG 2- End Hunger, Achieve food security, and Promote Sustainable Agriculture and SDG- 13- Climate Action. A number of Sustainability Tools, which I believe are First of their Kind in respect of Indian Agriculture have also been developed by IORF; and I am of the opinion that these will play a crucial role towards adjudging the effectiveness of any Sustainable Agriculture Initiative especially considering the Statement of UN "It is currently not clear or well defined what constitutes productive and sustainable agricultural practice". Moreover, the Project on Clean Food gave an insight to work on the Model of Clean Food 'Net Zero' – Most significant intervention against Climate Change.

Two unique findings have been deducted from Clean Food 100% N- Reduction Model from Model Farm area of this Project, which are GHG Footprint of (-) 37553 kg CO_2 eq /ha./year and Energy Footprint of 63,423 MJ/ha. from Clean Food 100% N- Reduction Model, compared to (+) 5,675 kg CO_2 eq /ha./year and 84527 MJ/ha. in the Conventional Practice respectively.

Such Energy Footprint in Clean Food Net Zero is indeed a significant achievement and land mark when agriculture could not be included in the Energy Transition Commission.

These data have inspired me to take the Clean Food –NZ Model to a higher scale in the coming year in a New 100 ha Project and if possible in another relevant agro-ecological condition.

Foreword

I am sure this First Phase Project Report will serve as a Benchmark study and the Guide Map towards progression of the farmers especially the resource poor small and marginal farm holders towards Safe and Sustainable Agriculture, which is perhaps the only solution for Climate Resilient Crop production and Sustained Livelihoods.

I wish to place on record my sincere appreciations to IBM for their support for the cause of sustainability and IORF Team for the execution of this project with over compliance and bringing out this Report. While ten important Milestones have been covered from a single project, it has also developed Prototypes of important Sustainability Tools in the name of Soil Health Proximity Tools and Colorimetric Assay Test. I am thankful to IBM for their stimulus to move ahead. I believe that these Prototypes can be transformed into Tools with the amalgamation of IBM knowledge system. I am extremely hopeful that Inhana Team and IBM Knowledge System will work together to accomplish these unique opportunities.

Dr. P. Das Biswas
Founder Director

Message

When IBM launched its Sustainability Initiatives in India, we wanted to start working with the right people and on the right areas to create impact. Sustainable Agriculture was a no brainer considering the repercussions of not doing it. **Sustainable agriculture is an approach to farming that emphasizes environmental stewardship, economic viability, and social responsibility.**

There are several reasons why we thought that sustainable agriculture is important:

Environmental Conservation: Sustainable agriculture practices aim to **minimize the negative impact of farming on the environment by reducing greenhouse gas emissions, soil erosion, and water pollution.** By conserving the environment, we can protect the health of ecosystems and biodiversity.

Food Security: Sustainable agriculture can help **ensure food security by providing a stable and reliable supply of food.** By diversifying crops and using practices that promote soil health and biodiversity, farmers can help ensure that their crops are resistant to pests and diseases, and can also withstand extreme weather events such as droughts and floods.

Economic Viability: Sustainable agriculture **can provide economic benefits to farmers by reducing input costs and improving yields.** By adopting practices such as conservation tillage, integrated pest management, and crop rotation, farmers can reduce their reliance on expensive inputs such as fertilizers and pesticides, while also improving the health and productivity of their soil.

Message

Social Responsibility: Sustainable agriculture can also have positive social impacts, by promoting rural development, supporting local economies, and ensuring that farmers are able to make a decent living. **By adopting sustainable farming practices, farmers can create more resilient and equitable communities, and ensure that future generations have access to healthy and nutritious food.**

Our partnership with IORF has yielded some outstanding outcomes and results and expecting the same to be scaled over a period of time to contribute to the National agendas around sustainable agriculture. This team has been outstanding in meeting and over achieving its milestones consistently. This has also resulted in this program winning us 3 CSR Awards in 2022-23. Looking forward to our third year of collaboration and partnerships.

Manoj Balachandran

Head - CSR, IBM India & South Asia

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Summary

Modern agriculture has changed dramatically since the end of World War II and the development helped to increase food production. **However, this new found surplus food came at a significant ecological cost** resulting in threats to food security as well as to human health and safety due to increasing risk of food chain toxicity. Looking back; India, being primarily an agrarian country, the problem became complex considering that more than **80% of the farming community belonged to small and marginal categories, that are more vulnerable to climate change** due to livelihood dependency on tiny farm lands and lesser risk taking abilities w.r.t. newer sustainable initiatives.

In this background, IORF conceived the Safe & Sustainable 'Clean Food' initiative in the early part of 2020 in collaboration with Nadia KVK (ICAR) with introduction of Inhana Rational Farming (IRF) Technology, an exclusive innovation of IORF. IRF Technology is a Comprehensive Crop- Technology which facilitates Safe & Sustainable Agriculture through its unique Energy Management Approach towards Plant Health Management along with Rejuvenation of Soil Health – meaning, utilization of **'Clean Energy to Produce Clean Food'.**

The initiative transformed into a Comprehensive

Safe and Sustainable

'Clean Food Program'

(Elimination of Chemical Pesticides & Nitrate Fertilizers)

with Impetus from

IBM Sustainability Project

Clean Food Movement is probably the first initiative toward Healthy Life & Farmers' Empowerment; through the development of Safe & Sustainable 'Clean Food' (Elimination of Chemical Pesticides & Nitrate Fertilizers), i.e. crop sustainability without raising the cost of production, and establishment of a transparent supply mechanism from farmers' field to consumers in order to ensure affordable safe food for all.

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

This innovative Farmers'-Participatory Program is based on a Scientific- Nature Friendly Sustainable Agricultural Practice and a Transparent/ analytically backed Evaluation System with an objective to develop a Self-sustainable Consumer Connect Agriculture Model; which can fuel livelihood upliftment of the farming community. 'Clean Food' is the first & only offer in the direction of Safe & Sustainable food - enable large scale production of safe food, ensure producers' profitability & enable value added product at affordable pricing.

Summary.....

The project was initiated in the indo-gangetic alluvium soils of Nadia district, West Bengal. The area belongs to hot, moist subhumid ecological sub region (15.1) (Sehgal, 1992). The climate of the study area is characterized by oppressively hot summer, high humidity and high rainfall during the monsoon. The program started with Farmers' Meeting and Awareness program along with field survey for gathering information regarding the land demography, land use, agrochemical usage, farming activities, etc.

We developed a comprehensive Soil Test Protocol with 26 Parameters Study that encompassed Physical, Fertility and Biological Parameters. We also developed **5 Soil Quality Indices with Colour Coding** to facilitate better understanding of Soil Health by the farmers through the **Improved Soil Health Card**.

The average land holding size of the small and marginal farmers in India is about 0.38 hec., which is less than 80% of the classified range of 2.0 hec. (< 1.0 hec. for marginal & 1-2 hec. for Small farmers). **With the Sustainability Stimulus from IBM India, IORF took up the mandate for Resource Mapping of 100 hec. Project Area comprising about 350 to 400 farmers. For this about 350-400 soil samples were to be analyzed. But actual field evaluation revealed the critical land fragmentation with land holding size even <0.26 ha and they were not contiguous but scattered in two or more locations. Hence for appraisal of land specific Soil Quality Status (SQS); IORF had to go down to the micro grid size of 0.16 hec. So IORF took up an exhaustive Soil Analysis Program, considering four different Sampling Grids : 10 hec., 2.5 hec., 0.6 hec. & 0.16 hec. – which led to about 1200 Soil Samples**.

A Comprehensive Soil Analysis of about **1200 Sample pool was undertaken as per 26 Quality Parameters.** Gradually we also developed comprehensive Soil Health Cards for the project farmers towards facilitating soil test based Soil Health Management.

Soil Textural Analysis in the project area showed dominance of medium textured soil with highest presence of silt loam in 42.80 % area. Majority of area had slightly acidic pH (5.5-6.5), while assessment of the soil organic carbon indicated it to be as one of the major limitations; as more than half of the area had low (0.5 to 0.75%) to very low (<0.5%) status. Analysis showed low (200-280 kg/ ha) to moderate (280-360 kg/ ha) Soil available- N in about 72% area, while available phosphate was in the relatively higher range (>90.0 kg/ ha) in close to 86% of the area. Available Potash content was moderate (250-340 kg/ ha) to moderately high (340-450 kg/ ha) in most of the area. High to very high value of soil available nitrate in majority of the area indicate higher usage of N-fertilizers in the project area.

The major soil limitation in the project area is the microbial population and its dynamics considering that both microbial biomass (indicator of microbial pollutions) and Soil Fluorescein Diacetate Hydrolysis (FDAH) values (indicator of working efficiency of microbial population) were low to very low in majority of the area.

95 Soil Resource Maps of 5 Project Villages to benefit more than 1000 farmers in respect of Soil Test Based Soil Health Management

Also the comparatively lower value of soil Microbial Quotient ($_{q}$MBC) and corresponding high Soil Microbial Metabolic Quotient (qCO_2) indicate stressful conditions of the residing microbial population leading to depleted soil health. And thus despite no major limitation in soil physical and physicochemical characteristics, Soil Quality Index (SQI) of the soil in the Project Area is moderate (0.46 – 0.60) in majority of area (72.4 % area) followed by poor status in 22.2 % area and moderately high status only in about 5.4 % area.

Crop specific Soil and Plant Health Management Schedule was developed under IRF Technology after consideration of the soil analytical data and pesticide footprint study, to propel the objectives of Reduction of Pest/ Disease Pressure *vis-à-vis* Reduction of External Chemical Inputs while enabling Crop Sustenance/ Improvement. IORF's classroom and on-field training regarding development of different organic concoctions, organic alternatives for pest control along with Plant Health Management; helped the farmers to eliminate chemical pesticides in majority of the vegetables (with few exceptions), without incurring any crop loss or increasing the cost of production.

1600 – 2000 ton of Safe and Sustainable 'Clean Food' was produced encompassing a wide variety of vegetable crops. About 400 farmers were benefited in terms of access to Sustainable Crop Technology that facilitates Reduction of Unsustainable Inputs while enabling Crop Sustainability, especially under the existential climate change impact.

The problem of pesticide residue is very high in India. And the situation is no different in the project area where the critical land fragmentation and the contrasting High Cropping intensity, leads to High Dependence on land and therefore extreme reliance on the unsustainable inputs like fertilizers and pesticides. Hence, the ecological footprint of pesticides have increased significantly over time. In this context reliable pesticide risk indicators are pivotal to assess the potential risk associated with the pesticide use, particularly in the case of limited data availability and before undertaking any Safe & Sustainable Agricultural Initiative. **This was the Background behind the development of Pesticide Pollution Indices by IORF**

The **IBM Sustainability Project** provided the opportunity to IORF to Standardize its **Crop & Soil Pesticide Footprint Assessment Tool** (*originally developed and used in Plantation crops*) **for the Field Crops** (Vegetables) as no such evaluation Pathway is presently available in this sector.

Summary.....

Two Pesticide Pollution Indices : i) Crop Pesticide Pollution Index (CPPI) & ii) Soil Pesticide Pollution Index (SPPI) were used to assess the Risk Potential related to Crop Sustainability, Soil Quality Degradation, Pesticide Residue in the End Product and Future vulnerability of crop sustainability under climate change impact.

Among the different vegetable families evaluated, a higher consumption was documented in case of solanaceae, and cucurbitaceae, with the highest in case of malvaceae family. Higher SPPI value noted under solanaceae, cucurbitaceae and malvaceae families, indicated a high toxicity load on the soil, especially in relation to the microbial population and their functional dynamics. **And the lack of sustainable soil management, raises a big question mark on the future sustainability of these vegetable farm lands.** Evaluation of the Pesticide Load on Crop (AI/kg) *vis-à-vis* Crop Pesticide Pollution Index (CPPI) under different vegetable cultivation indicated higher values for Brinjal , Chilli, Okra and Pointed Gourd, which are also the higher revenue generating crops. The finding indicated that **farmers need to reduce the pesticide use and migrate toward Safe & Sustainable Agriculture in order to save themselves from future economic distress**.

'Clean Food' means Safety authentication through actual analysis. And here a major challenge arose, considering that the present chromatographic techniques are hugely expensive, complex and time-taking process. So batch wise testing of Vegetables for Consumer Safety Compliance is out of question especially considering that the majority of the vegetable producers are small and marginal farmers. These farmers need a scientific pathway that can provide an economic solution for Safety Compliance.

Colorimetric Pesticide Assay Test can be a Game Changer in Food Safety Analysis

&

Global Applicability for Speedy (1/10th of Conventional Time), Effective & Economic Analysis of Food Safety for Consumer Compliance at

1/10th to 1/15th of the Cost under present HPLC testing methods.

The search for a sustainable alternative led us to the Colorimetric Assay Test for pesticide residues. This test method although utilized round the globe to identify the pesticides residues, lacked Standard Protocol towards Safety Evaluation of Vegetables. **Hence, IORF took up the massive task of process Standardization for which more than 1200 samples comprising 30 Major Vegetables** (*produced in India*) **were tested in IORF laboratory**. **The newly standardized protocol can enable both Qualitative & Quantitative Estimation of the Major Pesticide Groups in Vegetables, detect Heavy Metals as well as Other Toxic Substances of known/unknown origin related to human health and safety.**

The Colorimetric Pesticide Assay Test can serve as a Real Game Changer in the Food Safety Arena & a 'Sustainability Tool' for Safe & Sustainable Agriculture

Summary.....

Vegetables are the source of Nutrition for Human Health, but only when this Nutrition comes from a Safe Source- it can Sustain Life & Promote Good Health. And Only Safe and Sustainable Agriculture can Produce Safe Vegetables for its Nutrition to provide Actual Health Benefits and Immunity. Quality evaluation of 'Clean Food' was done in terms of three parameters *viz*. Vitamin – C content, Protein Richness and Antioxidant Richness; which have crucial relevance towards human health. **Twelve major vegetables grown in the project area were taken for the assessment; i.e., Potato, Tomato, Brinjal, Carrot, Cauliflower, Cabbage, French Beans, Green Peas, Spinach, Okra, Green- Chilli and Red Onion.**

There was an indication of comparatively higher value of nutrition in the vegetables grown under Clean Food Program as compared to their conventional counterparts. **This might be primarily attributed to the Plant Health Management, which forms an integral part of IRF Technology.** The findings suggested that adoption of Inhana Rational Farming Technology not only helped to sustain crop yield, it also demonstrated the potential towards enhancement of the qualitative components of the vegetables.

Following the development of 'Clean Food' we assessed its sustainability quotient in terms of GHG Mitigation and Energy Use Efficiency.

In the 1st phase of the IBM Sustainability Project, we calculated the GHG offsetting potential under 'Clean Food' production. Primarily we used the Cool Farm Tool developed by 'Soil & More' (Hamburg, Germany) for calculation of GHG offsetting / carbon saving under 'Clean Food' production. But the stimulus from IBM Sustainability, enabled the generation of data base that will be used for the **development of Advanced GHG Calculator; considering all aspects, including 'Plant Efficiency' following the induction of Sustainable Clean Energy.**

The developed database and its interpretation provided insights towards development of **'Agriculture Carbon Footprint Assessor (ACFA)'** which could become a crucial Sustainability Tool to assess the impact of any **Agriculture Initiative towards the objective of Net Zero** – the Ultimate Goal of Safe & Sustainable Agriculture

As per the primary estimate, this 100 ha 'Clean Food' Project showed a **GHG Offsetting Potential of upto 750 ton CO_2 Equivalent.** But if Soil Health Management undertaking Bioconversion of Waste (*landfill material*) through Novcom Composting Method is taken up, then **the same 100 ha 'Clean Food' Program can enable '57% ENERGY TRANSTITION and a GHG MITIGATION POTENTIAL of up to 10,000 MT CO_2 eq.** (*case specific*); **which can be the most meaningful way to accomplish the Net Zero Carbon Objective**.

Thus the IBM Sustainability Program not only spearheaded the '**Clean Food Movement**' by giving a comprehensive shape to the program, but most importantly facilitated the generation of **unique Tools which could help to remove the bottleneck in the pathway of successful Safe and Sustainable Agricultural initiative on a global scale.**

Summary.....

PROJECT INNOVATIONS & IMPACTS – *a Recap*

- **Safe & Sustainable** '**CLEAN FOOD**'- **First ever endeavor to comply the requirement of SDG-2,** more meaningfully **Target 2.4** (*Sustainable food production and resilient agricultural practices*) – hugely relevant considering UN's statement, "It is currently not clear or well defined what constitutes productive and sustainable agricultural practice".

- **SOIL HEALTH PROXIMITY MODEL -** Knowledge regarding Soil Health w.r.t. individual farm land is the first step in the progression towards Sustainable Agriculture, but is next to impossible in the Indian perspective considering the critical land fragmentation; which not only entails a huge cost but also a huge time. The Soil Health Proximity Model developed under this project **can generate up to 20 accurate and comprehensive Soil Health Card from a single soil sample analysis – can enable Soil Health Card for 'Every land' at 1/10th of Conventional Cost**.

- '**COLORIMETRIC PESTICIDE ASSAY TEST**' - Pesticide monitoring in food has always been a difficult proposition for the Indian Farmers, especially for multiple harvest crops considering that the chromatographic techniques are hugely expensive and time-consuming. The '**Colorimetric Pesticide Assay Test'** developed under this project is **a scientific, speedy yet an economical alternative that enables complete residue analysis at 1/10th Cost and Time**– access of an adoptable solution especially for small and marginal growers.

- **PESTICIDE FOOTPRINT ASSESSMENT (PFA) TOOL-** The average consumption of pesticide in India is lower than many other developed economies, but the problem of pesticide residue is very high in India. 'Pesticide Risk Indicators' can provide a crucial support in the assessment of the potential environmental and health risks from pesticide use, especially useful under conditions of limited data availability and resources, such as in Less Developed Countries. **But reliable pesticide risk indicators are extremely scarce.** The PFA Tool developed under this project **fulfills the requirement of a Simple yet Scientific Audit System for Risk Analysis** in terms of Overall Toxicity Impact of the applied Pesticide on Crop & Soil.

- **CLEAN FOOD 'NET ZERO' (CFNZ) MODEL – SAFEST FOOD** for Human Health , Soil & Environment - **SINGLE MODEL MULTIPLE IMPACTS**

  Impacts SEVEN CRUCIAL SDG's – 1, 2, 3, 11, 12, 13 and 15. This Model with a **GHG Mitigation Potential of upto 540 MT CO_2 eq. (approx.) per ha** can totally transform the present GHG Emitting agriculture to a GHG Sink Agriculture. CFNZ Model can potentially enable **57% ENERGY TRANSTITION and 87% HIGHER ENERGY PRODUCTIVITY.** CFNZ is perhaps a First Ever **DARAS Model** - **DELIVERABLE, ADOPTABLE, REPLICABLE, AFFORDABLE & SCALABLE.**

CHAPTER 1 : INTRODUCTION

Modern agriculture has changed dramatically since the end of World War II and food productivity has increased with new agro-technologies, farm mechanization, increased chemical inputs in terms of chemical fertilizer and pesticides, development of irrigation systems to bring more land under irrigation and government policies that favored maximizing production. **Although these developments have had many positive effects and reduced many risks in farming, they came at a significant cost. Prominent among these are topsoil depletion, groundwater contamination, air pollution, greenhouse gas emissions, new threats to human health and safety due to food chain toxicity, etc**. (Brodt *et al*, 2011).

The FAO emphasizes 'A profound change of the global food and agriculture is needed if we are to nourish todays' 815 million hungry and the additional 2 billion people expected by 2050'. The United Nations further explains 'It is time to rethink how we grow, share and consume our food. If done right agriculture can provide nutrition for all and generate income while supporting people- centered rural development and protecting the environment' (SDG2). At the same time, the UN recognizes that "**there is no food security without food safety** and that in a world where the food supply chain has become more complex, any adverse food safety incident may have global negative effects on public health, trade and the economy". The issue of food security and food safety is more critical in India's context as India ranks 94th among 107 countries in Global Hunger Index; 14% population estimated to be undernourished (PTI, 2020).

Food safety is also a serious concern as scientific evidence has shown that contamination of food is a serious issue in India due to unchecked microbial activity and the use of pesticides (The Hindu, 2015). Surveys carried out by institutions spread throughout the country indicate that **50-70% of vegetables are contaminated with insecticide residues** (Karanth, 2000). According to published report by Food Safety and Standards Authority of India (FSSAI) 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 (Sood, 2012) and the 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 use in vegetable farming. Still, their residues were found in the samples of different vegetables (Nishant & Upadhyay, 2016)

Thus the situation demands a paradigm shift in farming practices to ensure a sufficient supply of safe food at a global level while mitigating climate change and minimizing environmental impacts. Sustainable agriculture that integrates three main goals – environmental health, economic profitability, and social equity, is the only required solution. But the reality is vividly depicted in the **statement of the United Nation**, "**It is currently not clear or well defined what constitutes productive and sustainable agricultural practice**". That means, we need novel solutions for our future food security and sustainability without compromising food safety to achieve the United Nations sustainable development goals (Vågsholm et al, 2020).

It is well recognized that adopting sustainable agricultural technologies that utilize ecology based management strategies can increase productivity; reduce ecological harm through higher resource efficiency- greater agricultural output while using lesser land, water, energy and unsustainable inputs like fertilizers and pesticides; ultimately go on to ensure safe and sustainable food production. The importance of Safe and Sustainable Food Production has increased manifold in the backdrop of the Covid-19 pandemic, where immunity has become the pre-condition for survival. 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'.

The relevance of Sustainable Agriculture increases manifold **in the Indian context considering that >90% farmers are marginal and resource poor, with a land holding even < 0.38 hec., are therefore highly unsustainable, more vulnerable to climate change**, require compulsory usage of a large quantity of synthetic agrochemicals but receive very poor and inconsistent revenue. At the same time, because of increasing use, insufficient regulation, and poor knowledge about proper application procedures, pesticide exposure hazards are the greatest (Bera et al, 2022).

This was the background behind the development of the 'Clean Food' Program. It is a program to develop Safe & Sustainable Food through Elimination of Chemical Pesticides & Nitrate Fertilizers; towards empowerment of small and marginal farming Community, but above all; it is an initiative that will provide Safe and Sustainable Food – at Affordable Cost; through the adoption of a scientific - nature friendly farming practice called Inhana Rational Farming (IRF) Technology developed by Dr. P. Das Biswas.

The 'CLEAN FOOD' Concept was developed by IORF in concurrence with the Global Call "**No Food Security without Food Safety**". Thus 'Clean Food' is the End product of Safe & Sustainable Agriculture towards Empowerment of the Small and Marginal farmers and Preservation of our Environment in the back drop of Climate Change. And the IBM- IORF Sustainability Project is a program for development of a Model for Safe and Sustainable Agriculture; especially for the small and marginal farmers who have least access to Sustainable Agriculture Technologies.

- To make available an effective, economically viable and a conveniently adoptable Crop Technology that can ensure smooth migration from Conventional (*chemicalized/ Industrial*) Farming to **Safe & Sustainable (*pesticide free, low fertilizer input*) Agriculture**.
- To formulate a demonstrative Model for Safe & Sustainable Agriculture, higher revenue generation for the food producers and availability of **Safe Food to the consumers at affordable price** – A definite Model towards SDG-2.
- Production of Safe & Sustainable- 'Clean Food (Vegetables)' with **Lower Carbon Foot Print.**
- Establishment of 'Clean Food' Safety through batch-wise residue analysis utilizing the **Colorimetric Assay Test – a 1st time approach in the Indian agriculture scenario.**
- Ensure self- sustainability of the resource poor marginal and small crop producers through tangible **value addition of their crop end products, no crop loss, and no increase in the cost of production**.
- Enable 'Clean Food' to the consumers at an Affordable Price through establishment of a **Direct & Transparent Supply Line between the Producers and the Consumers.**

'SMART' Objectives-

- **Specific**
- **Measurable**
- **Achievable**
- **Relevant**
- **Time Bound**

IORF had started a pilot scale endeavor for Safe & Sustainable Food Production in the Nadia District of West Bengal in 2020 with an aim to introduce Sustainable Crop Management techniques, enable elimination of chemical pesticides and reduction of nitrate fertilizers with an aim to develop pesticide free end product – value addition that can enable livelihood sustenance of the farming community especially the small and marginal farmers. Krishi Vigyan Kendra (KVK) of Nadia District (ICAR) collaborated as Field Partner in this endeavor.

The Sponsorship from **IBM Sustainability Project provided the stimulus to spearhead the Program in 100 ha area with Multifarious Objectives that were set as Milestones**, all of which were achieved within the Project Period, some over accomplished; which would ultimately lead to **Outcomes that are Unique & Exclusive w.r.t. Indian Agriculture.**

What were the issues or concern that led to the Project ?

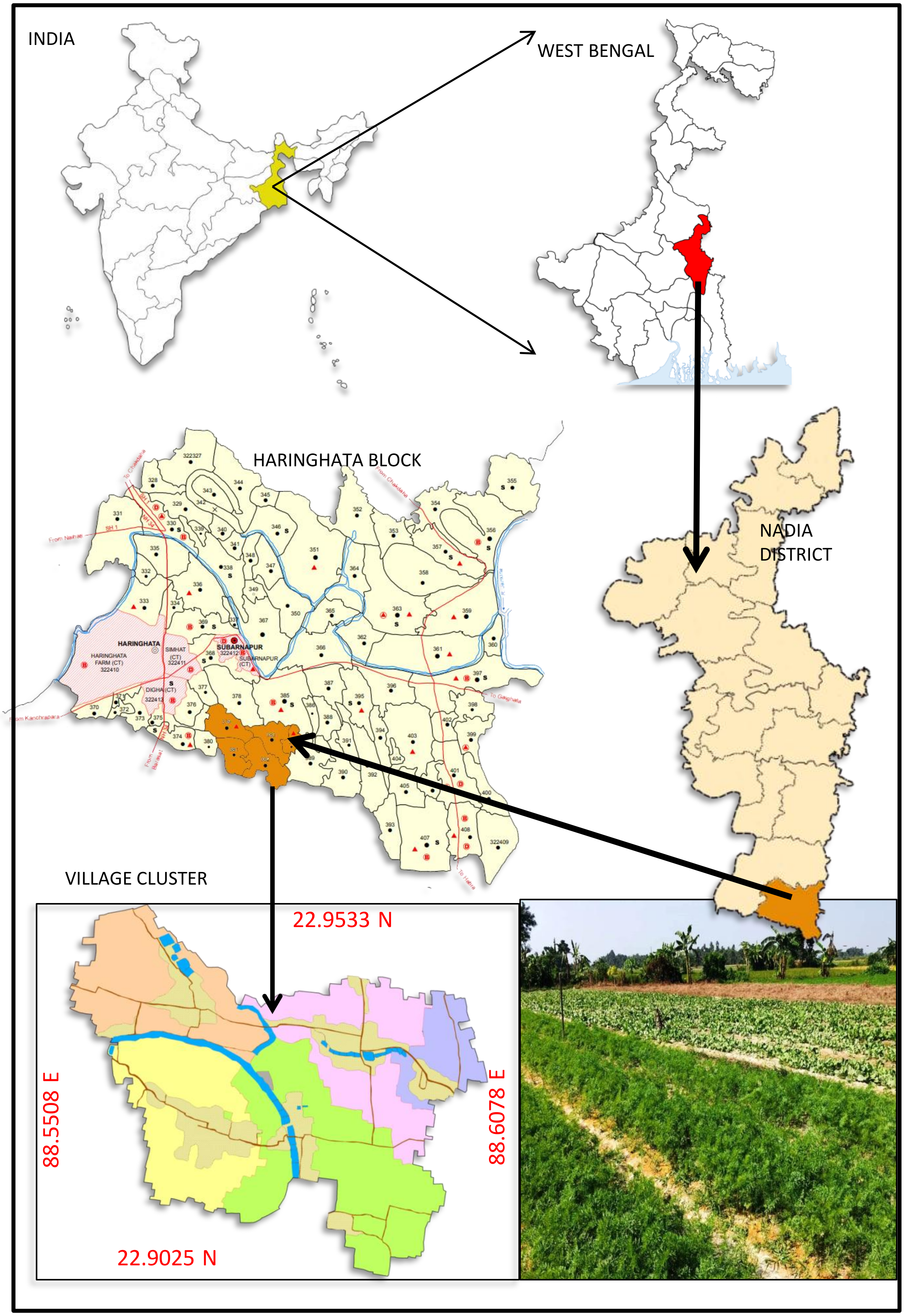
The Indo gangetic zone forms the major food basket of India and therefore is a major contributor of food for meeting the increasing hunger. Green revolution necessitated HYV crops, synthetic crop nutrients and synthetic crop protectants that helped to increase crop production. But abundant use of the synthetic inputs decreased the soil biological diversity, degraded the soils, and increased the dependency on irrigation, leading to considerable groundwater depletion in many areas.

Moreover, within a few years of green revolution the declining soil health, increasing cost of the chemical inputs, higher number of crop failures and increasing dependency on irrigation have made farming an unsustainable proposition for the marginal and resource poor farmers who comprise about 96% of the total farming population of West Bengal. Furthermore the climate change impact is predicted to have larger effect in this area in the near future.

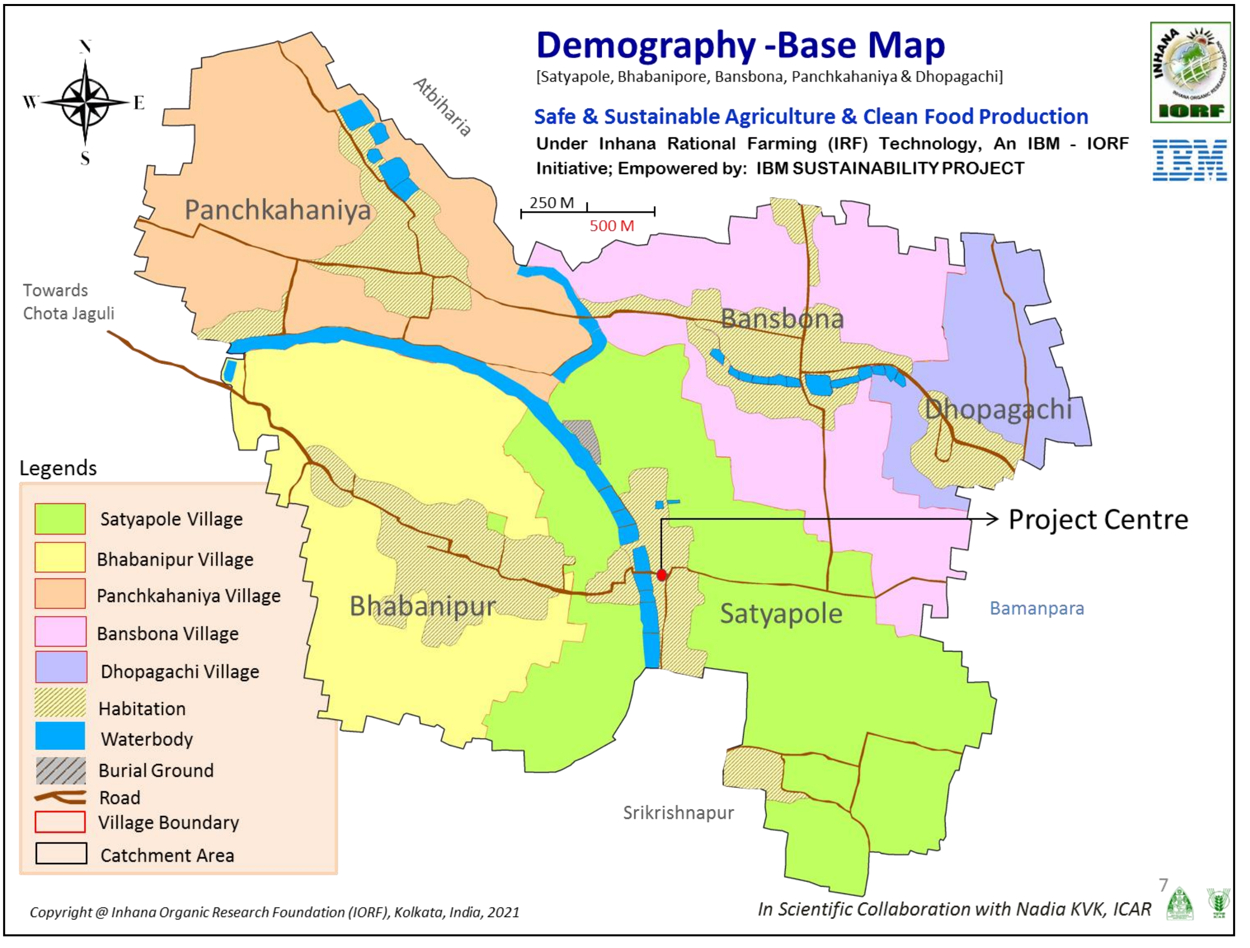
The indo-gangetic zone share a major part West Bengal - a state which **comprise 2.4% of the country's geographical area but provides food for 8% of the country's population**. However, the inherent vulnerability of the marginal farmers, along with critical land fragmentation, lack of adaptable technology/s and inaccessibility to modern and scientific agriculture; pose major limitation towards adaptation of sustainable agriculture, which is crucial for sustenance/ improvement of crop productivity, mitigation of the negative effects of chemical agriculture and resilience towards the climate change impact. In terms of vegetable production, West Bengal occupies the top position in the country but not so in terms of the yields of major crops. Meaning crop productivity is much lesser as compared to the actual potential but the pressure for food supply remains high – which indicates major exploitation of the land resources.

Hence, to meet the increasing food demand and maintain the supply line, that too with lesser resources and using sustainable inputs; it is **essential to adopt a Sustainable Technology especially in the background of the marginal and small farmers' adoption capability**.

PROJECT SITE : Block– Haringhata, **District-** Nadia , **State-** West Bengal, India



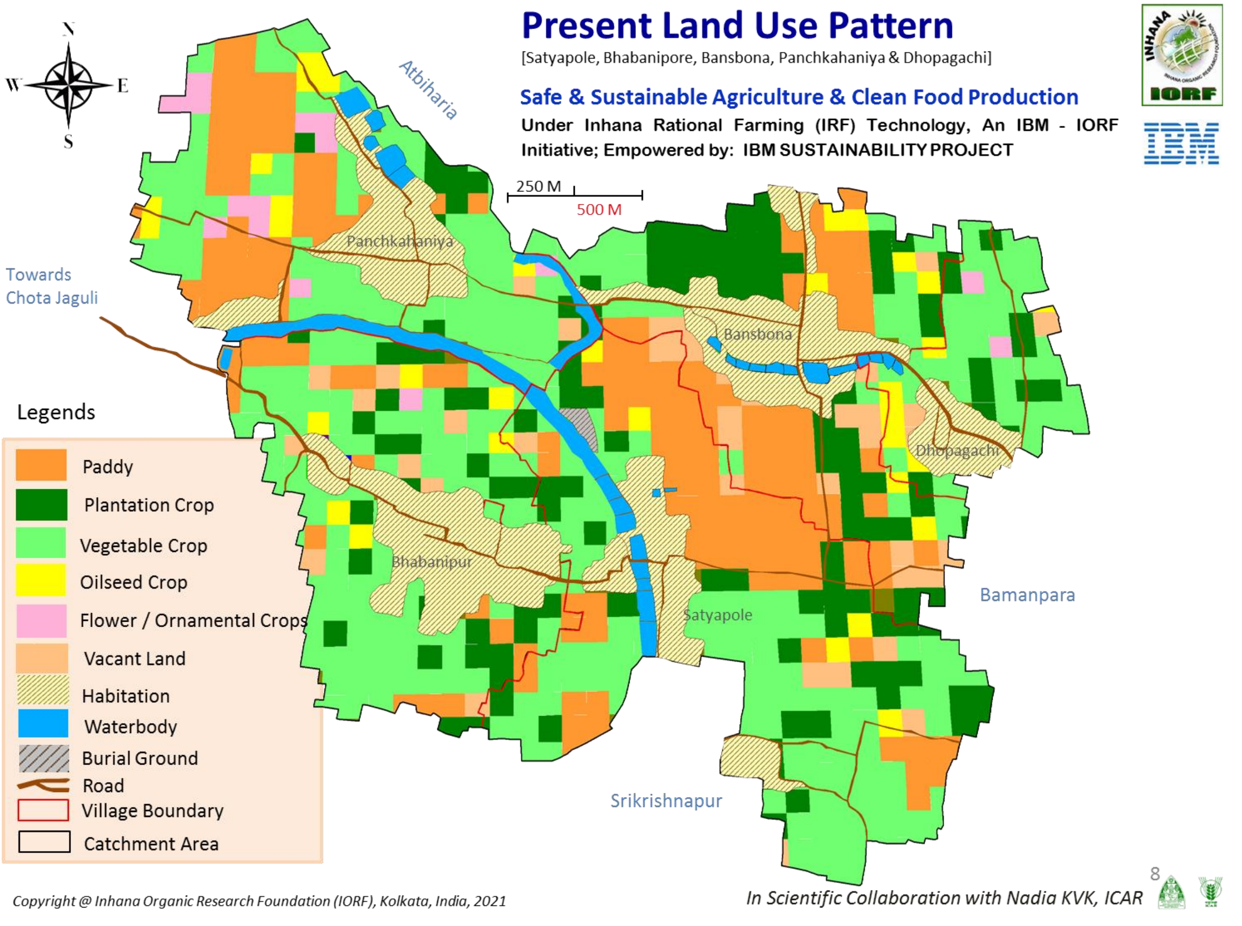
Demography Map of the Study Area



The Map shows the Village Boundary along with the other prominent areas like habitation, water bodies, major roads etc.

The relevance of this map can be clearly judged from the fact that it provides further insight of the study area and clearly depicts the Village Topography *vis-à-vis* distribution and positioning of the Agriculture Farm Area.

Land Use Map of the Study Area



Land use refers to the purpose a land serves, and for sustainable development, in the agriculture scenario it is necessary to assess the land use/land cover pattern over a period of time.

Present land use of the Study Area was mapped under 0.6 hec. or 1.5 acre grid and the Dominant Land Use was incorporated to develop the Land Use Base Map

Important Facets of land Use in the Project Area:

- The Project Area is an **Agriculture Intensive Zone** with about 200% to up to 300% Cropping Intensity.
- The Project Area has a **Rich Agricultural Diversity** with Paddy, oilseeds, vegetables (at least 10 – 15 different types) and plantation crops (4 to 5 types) being grown.
- As opposed to the general scenario in West Bengal (State) Agriculture; in the Project Area; plantation and vegetable crop dominates over paddy even in the rainy season.
- Only a small fraction of the land was found vacant, which reflects the intensity and land coverage of the area (in the entire cropping year).

CHAPTER 5 : ADOPTION OF SUSTAINABLE 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 the chemical way of crop cultivation. Miles away in India, Dr. P. Das Biswas, an Indian Scientist; re-searched to re-establish two lost qualities of the plant kingdom i.e., Sense of Self-Nourishment & Sense of Self- Protection.

Both the visionary men thought about development of 'HEALTHY PLANTS' for amelioration of causative factors behind plant signaling system w.r.t. 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); to 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 Project 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 a 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)

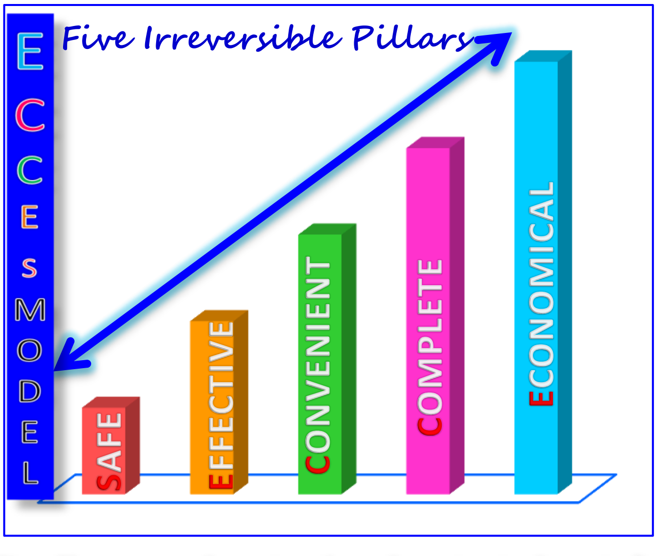
IORF was formed to disseminate the Research Findings of Inhana Biosciences among the Farming Communities (*especially the resource poor small and marginal farm holders*) to enable Safe & Sustainable Food Production and Economic Prosperity, under the existential Climate Change Impact. The organization 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.

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 the 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 has been documented by the workers who have followed this technology for organic crop production (Chatterjee *et al*., 2014 and Barik *et al*., 2014).

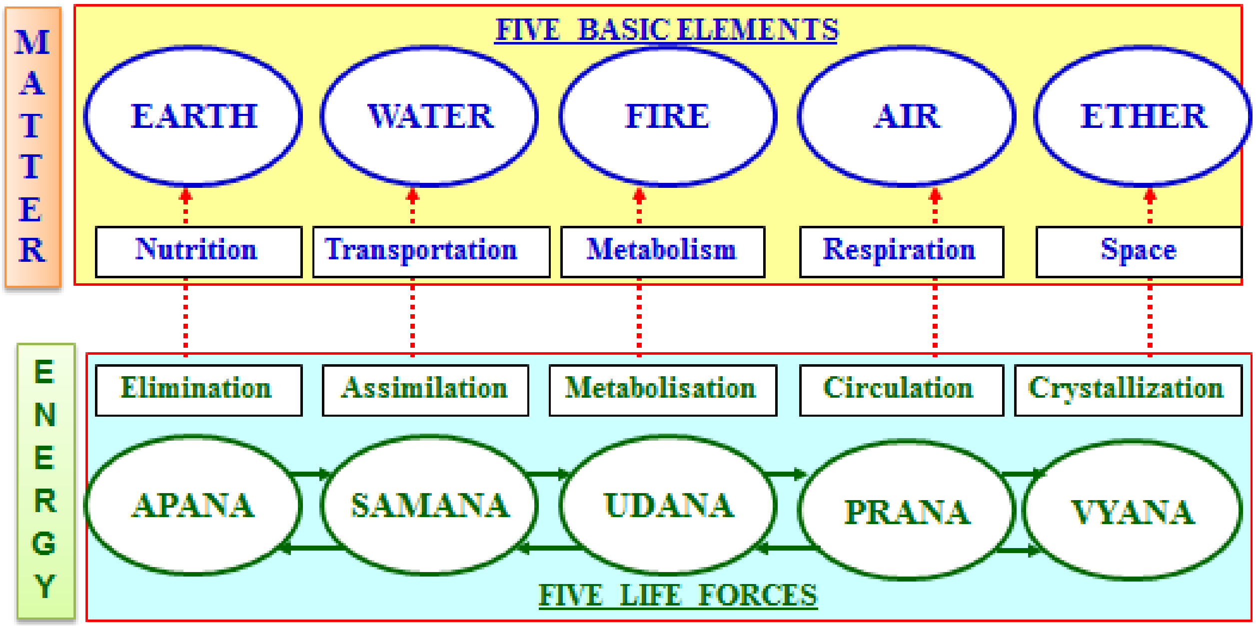
The uniqueness of this Crop Technology is that it is based on the **ECCES Model; i.e., Effective, Complete, Convenient, Economical and Safe;** that ensures Ecologically and Economically Sustainable and Safe crop production for the marginal and resource poor farmers which should be a prime criteria for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

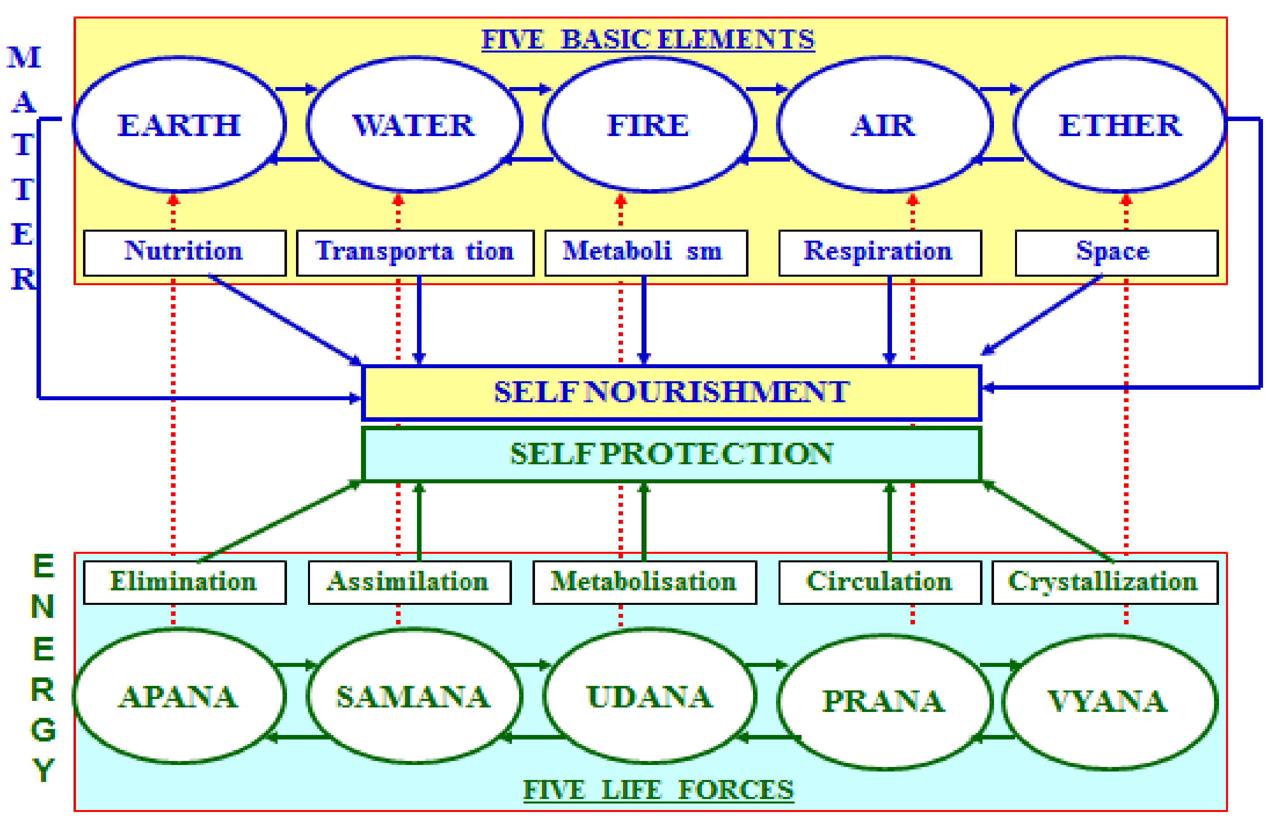
These five basic elements take care of **Self-Nourishment**.

Working Mechanism of E.E.A Principle



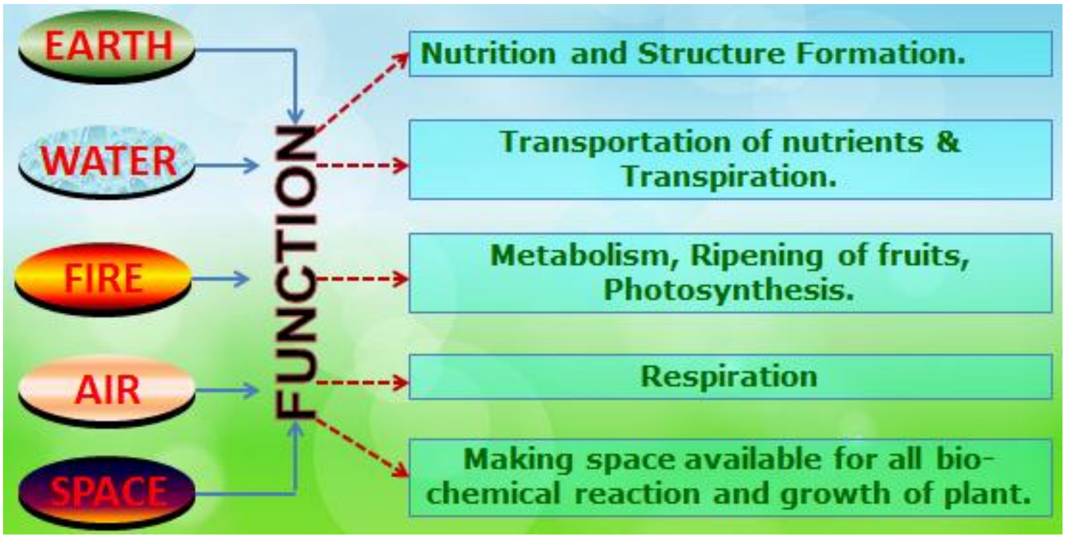
LIFE FORCES/ ENERGY	PREDOMINANT AREAS	BASIC ELEMENTS
APANA	ROOTS	EARTH
SAMANA	AERIAL PARTS	WATER
UDANA	LEAVES	FIRE
VYANA	WHOLE PLANT BODY	AIR
PRANA	CELLS	ETHER

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



Plant Health Management under IRF Technology

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

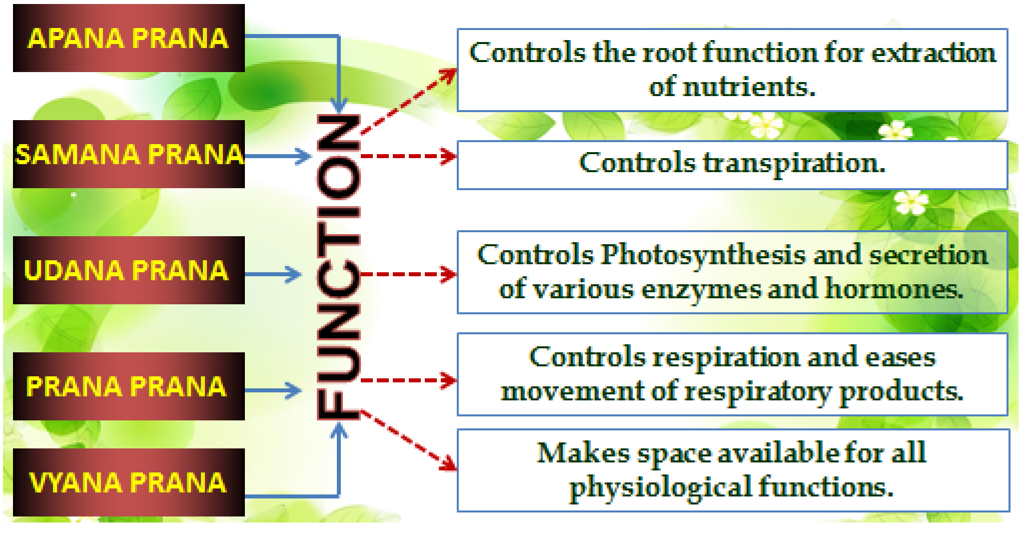


There are five different life forces or energies in all living bodies as well as in the plant system originated from the Basic Life Force i.e. Solar Energy. The **Self-Protection** mechanism is controlled by the Life Forces and they are also the vehicles of the basic elements and movement of nutrients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

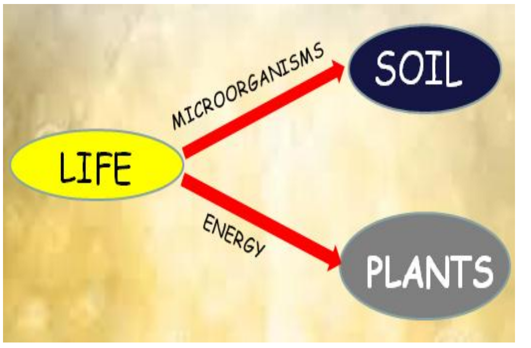
In plant system being 'PURE NATURE', energies directly activates on the matter or elements. Here Life Forces or Energies work as the power of expressing the former and moving the latter.

The Basic Life Force is the Solar Energy. The Five Life Forces or Prana Shakti originated from Basic Life Force controls Self - defense mechanism. LIFE FORCES ARE ACTUALLY VEHICLES 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**, for **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?

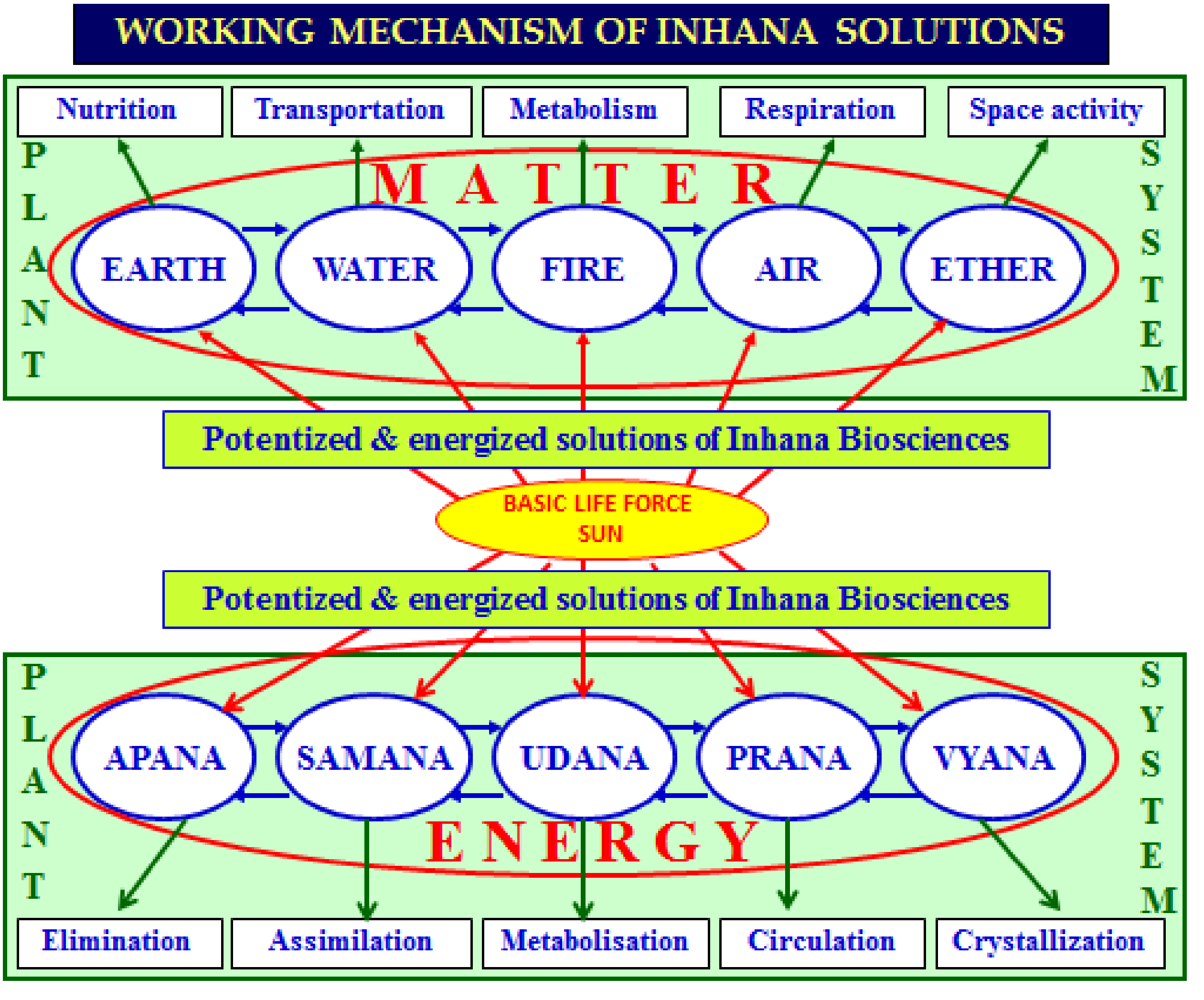
i. When Inhana Solutions are sprayed on the plants they just provide the necessary energy components that invigorate the various biochemical reactions.

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 USING NOVCOM COMPOST

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

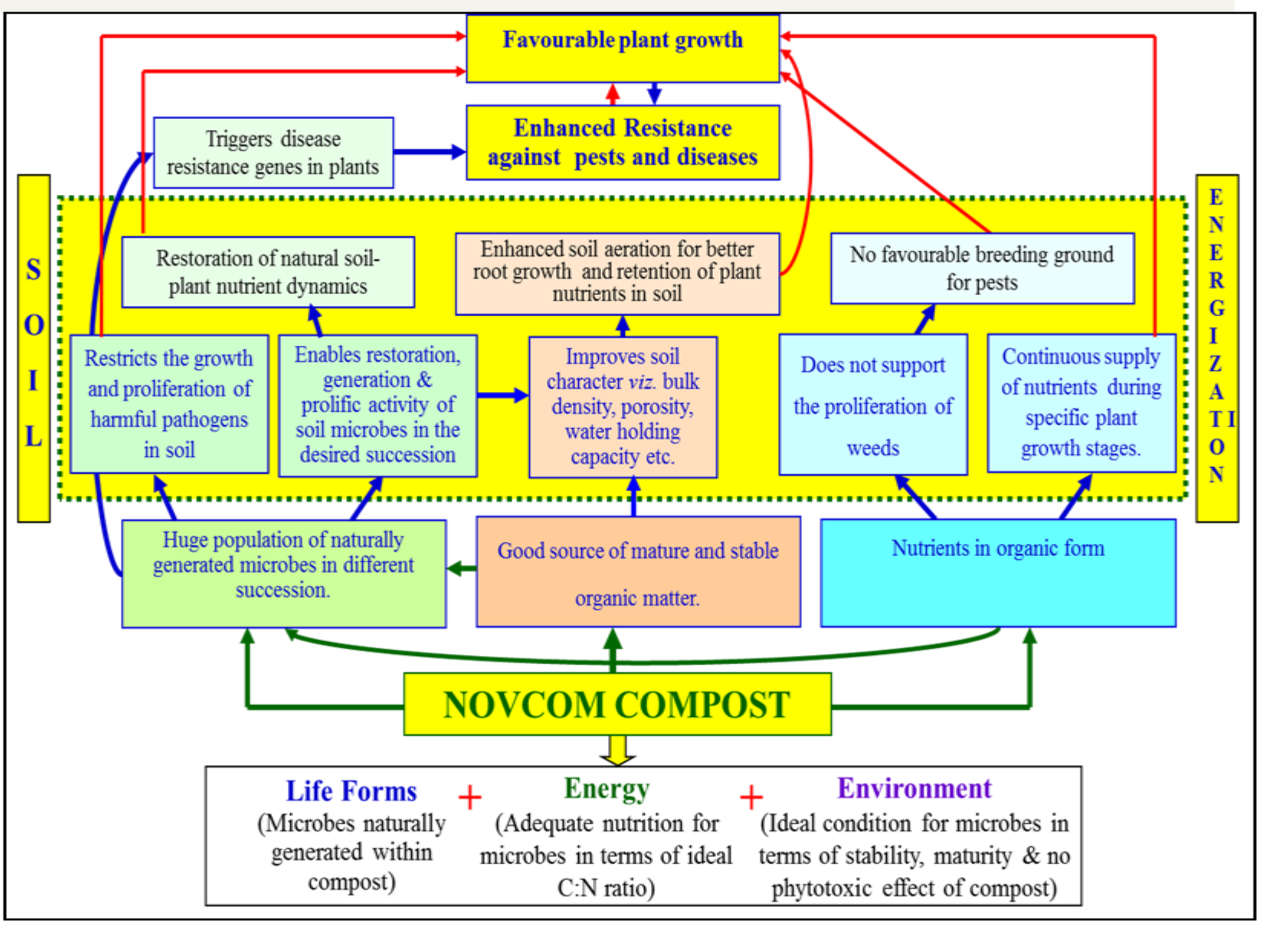
FACETS OF NOVCOM COMPOSTING TECHNOLOGY

- **Fastest composting method, quality compost gets ready in just 21 days.**
- **No specificity, any type of biodegradable material can be used 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 on this aspect have been published in different National & International Journals/ Seminars/ Workshops.

SOIL ENERGIZATION by NOVCOM COMPOST & Its Effect On Plant System

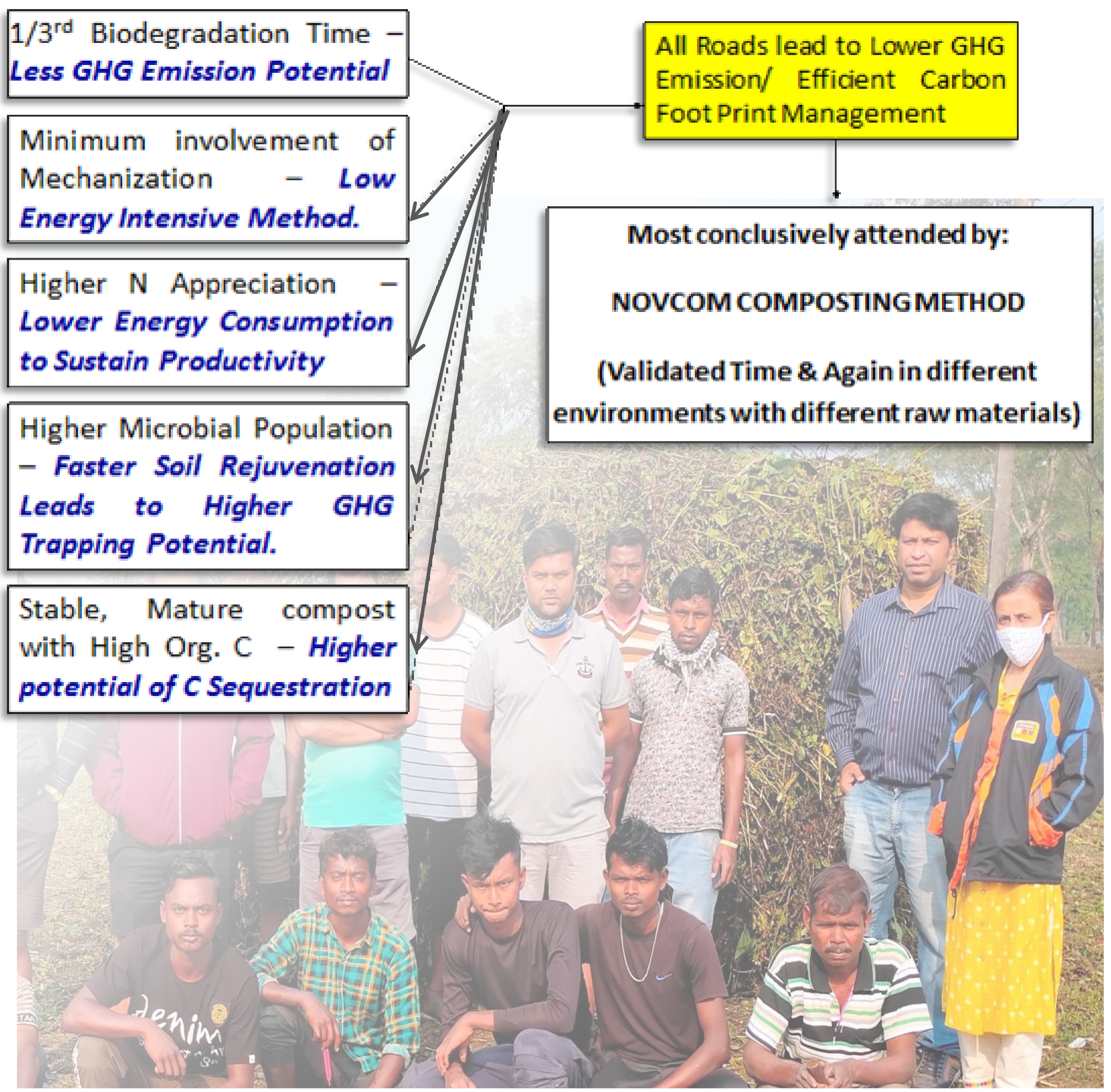


THREE WAY ACTION of NOVCOM Compost

- 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 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

CHAPTER 6 : CLIMATIC DATA OF THE STUDY AREA

The area belongs to hot, moist subhumid ecological sub region (15.1) (Sehgal, 1992). The climate of the study area is characterized by oppressively hot summer, high humidity and high rainfall during the monsoon. Winter starts from the middle of November which continues up to the end of February (Bera et al, 2021). As per the last 12 years climatic data base, it received about 1962 mm annual rainfall with highest rainfall (475.7 mm) in the month of July . The maximum rainfall i.e. 1800 mm is received during May to October which is about 92% of annual rainfall.

However, according to some study, in recent years the annual rainfall in the study area is showing a decreasing trend. There is a shifting pattern of monsoonal rain towards October and the onset of monsoon is also delayed by almost a week. The necessary adjustments in cultural practices should be done keeping this view in mind (Samanta et al, 2012).

The highest mean monthly temperature is observed in the month of April (40°C) and the lowest (17°C) in the month of January (**Table 1**) The difference between mean summer temperature (MSST) and mean winter temperature (MWST) is more than 5°C. Thus the soil temperature regime qualifies for 'hyperthermic'. The mean monthly relative humidity ranges from 40.6 to 78.6 percent. Highest number of rainy days was in July (29.2 days) closely followed by August (28.6 days) which means it rained almost every day during these months (Bera et al, 2021). Average sunshine hour was highest in the month of December (12.06) whereas highest number of Sunny Days was in December and January (29 days) (**Fig. 2**).

The UVI is a measure of the level of UV radiation and the higher the UVI, the greater the potential for damage to the skin and eye, and the less time it takes for harm to occur. The index predicts the risk of UV overexposure using a scale that ranges from 0 (minimal risk) to 11+ (very high risk). The maximum UV level on any given day occurs during the four-hour period between 10 a.m. and 2 p.m., a timeframe scientists refer to as 'solar noon.' The UV index in the study area ranged from high to very high with highest value (8.0) was in the month of March and April.

Table 1 : Five Years Average Climatic Data (2016 -2021) of the study area

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

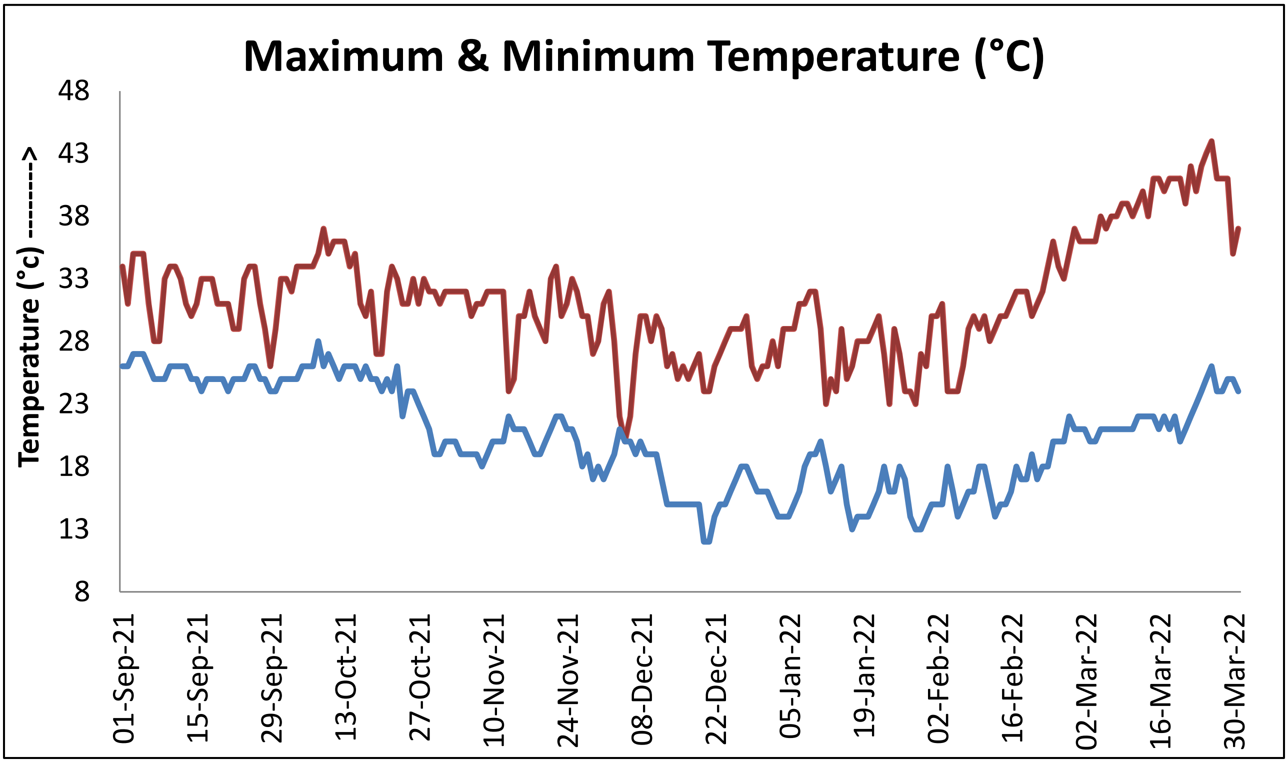


Fig. 1 : Climatic Data of the Study Area during the project period

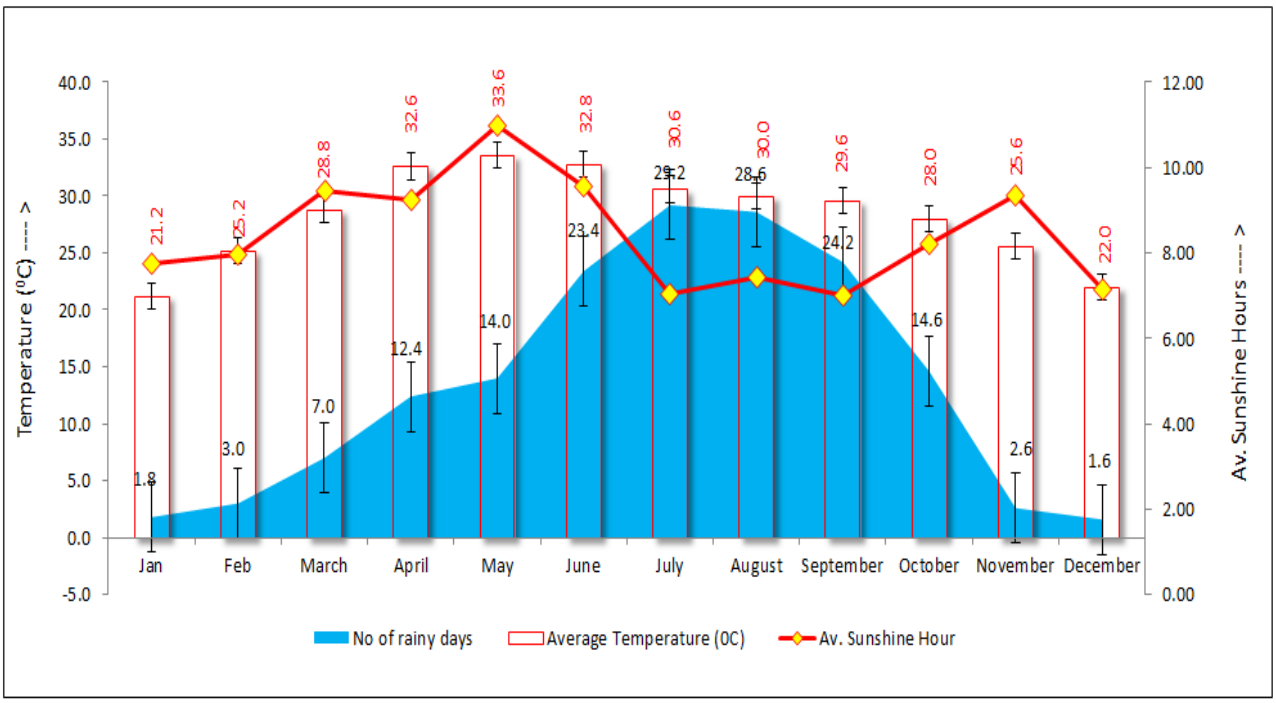


Fig. 2 : Multivariate study of mean temperature, avg. sun shine hours and no. of rainy days.

Enabling Access to Weather Science for Climate Safe Crop Production

The FAO emphasizes that 'A profound change of the global food and agriculture is needed if we are to nourish the additional 2 billion people expected by 2050'. However, considering that input intensive chemical agriculture is continuously depleting the very resource base on which agriculture stands; as well as the impact of the existential climate change, the relevance of 'Sustainable Agriculture' has increased manifolds.

In the Indian perspective and more so in West Bengal the situation is critical considering that the food is mainly grown by the resource poor marginal and small farmers, who will now have to grow more food from their same fragmented land with poor soil health and under the climate change impact, while overcoming the bottlenecks created due to poor education and lack of technical support that lead to overutilization/ misuse of the toxic pesticides especially under any sudden climatic disturbance that might threaten crop production.

IORF believes that agriculture when backed by science transforms into sustainable agriculture and hence, took up the initiative to inculcate the same in every aspect of the project starting with the access of Weather Science for the project farmers. In this respect IBM suggested the Agrolly App which provides Weather forecast, Farming related insights, Soil management, etc.; and see how the predictability can be utilized towards formulation of customized recommendations for Soil & Plant Health Management and for undertaking weather safety measures for the crops.

But IORF did not restrict to just utilizing the weather updates but took up the initiative to provide solution to one of the major problems of the small and marginal farmers i.e. lack of access to Technology Support w.r.t. Crop Production, which is especially crippling for the Vegetable farmers considering short duration – high value crops.

To provide a sustainable solution for resource poor farmers with limited adoption capabilities, IORF introduced the Project Farmers to the Agrolly App during the various farmers' meetings held during the Project period and also took up the initiative to enroll all the 400 Project Farmers in the App so that they could be well advised even post the Project Period.

HIGHLIGHTS

- **400 Project Farmers have been registered under Agrolly App**.
- The App insights like Weather Updates, forecasts, etc. have been utilized by IORF for providing climate smart field management guidelines – ***A 1st Ever Initiative Pan India towards Sustainable Agriculture***
- IORF also utilized Crop Specific stress period forecast; to provide time specific prescription for ***Plant Stress Management*****.**

  A 1st Ever Initiative in Indian Agriculture for the Small and Marginal farmers (hardest hit by the climate change impact); to enable Climate Resilient Crop Production.

CHAPTER 7 : THE ADOPTED WORK PLAN IN BRIEF

The work plan was designed to attend multifarious components required for achieving the set milestones and to enable technology transfer at the field level so that the project farmers become well acquainted and can conveniently adopt the interventional technology towards safe and sustainable crop production.

In this respect, work was initiated with extensive farmers' meetings regarding the relevance, importance and the objectivity of the Clean Food Program along with detailed Farmers' Survey with a pre-defined questionnaire to collect information regarding socio-economic status, present land use, crop productivity, management practices and constraints perceived by farmers.

Detailed soil sampling was done for the entire project area and comprehensive Soil Analysis encompassing physical, physicochemical, fertility and microbial parameters (*a 1st ever approach by IORF*) was conducted to assess the health status of the farm lands. This was followed by development of Village level 'Soil Resource Maps'. Soil Analysis also formed a primary component of SWOT Study and the data was utilized to develop several SWOT Interactive Maps. Both of these approaches were unique in respect of Indian Agriculture.

Training programs were conducted towards efficient on- farm resource management through Novcom Composting Method (developed by IORF) that can convert any type of biodegradable material into stable, mature and non- phytotoxic compost containing a huge population (10^{16} c.f.u.) of self- generated microflora; within a short period of 21 days.

Major Steps of the Work Plan

- Farmers' Meeting & Farmers' Survey
- Benchmark Study on Pesticide Load
- Soil Survey and Resource Mapping
- Registration of farmers under 'Agrolly' App
- SWOT Study & Soil Health Management Program
- Demonstration of on-farm Novcom composting.
- Development of Model farm
- Adoption of IRF Plant Health Management Program.
- Development of 'Clean Food'
- Residue Analysis of 'Clean Food' using the Colorimetric Pesticide Assay Test.
- Establishment of Farmers' Producer Company (FPC) for lab to land technology transfer.
- Establishment of SafeU Agricultural Pathways Ltd. for supply chain development from farm gate to consumer plate

Novcom compost was used as the primary component for Soil Health Management towards reduction of nitrate fertilizers. Along with compost, Soil Tonic (CDS concoction) developed by IORF was also used to rejuvenate the soil microbial population towards better soil functioning.

Demonstrations and training was also undertaken in respect of on- farm production of different organic concoctions. **These along with Customized Schedule *(especially developed for the project*) of Inhana 'Energy' Solutions were utilized for Plant Health Management- a crucial component of Sustainable Agriculture but completely ignored under Conventional Crop Production System.** The innovative approach of Plant Health Management under IRF Technology was inducted towards development of 'Healthy Plants' - for higher agronomic efficiency, improved Resilience towards the climate change and higher immunity/ host- defense mechanism against pest and disease causing pathogens- **all of which were crucial towards meeting the dual objectives of Crop Sustainability and Lowering/ Eliminating the use of Non-renewable (*synthetic fertilizers & pesticides*) Inputs.**

One of the primary limitation faced by the small and marginal farmers is the lack of access to modern technologies that can assist towards climate safe crop production. In this respect IORF introduced the Agrolly App (*suggested by IBM*) that provides advance weather predictability both for short and long term and the associated risk on crop. About 400 Project Farmers were enrolled in the App and the weather updates especially any predicted extremities were considered towards formulation of crop specific customized Soil and Plant Health Management.

Crop wise Pesticide use details was also collected for assessment of Toxicity load on the Crop and Soil in the project area utilizing the Pesticide Pollution Indices. This was crucial to generate the benchmark data and to get an indication regarding the intensity of Plant Health Management that needs to be undertaken towards the objective of Safe & Sustainable 'Clean Food' production, especially considering that these were short duration vegetable crops.

Clean Food Means : A 360 Degree Care for the Farming Community

- **Transfer of Complete Road Map for 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**

At the same time actual authentication of the safety aspect of Safe & Sustainable 'Clean Food' was done through laboratory analysis. To ensure the scope for batch wise safety monitoring which is critical for consumer safety compliance especially in respect of the multiple harvest vegetable crops, IORF standardized the Colorimetric Pesticide Assay Test – an effective, speedy yet an economical alternative to the Costly and Time- taking Chromatographic Testing methods, which makes pesticide residue testing an unviable proposition for the farmers especially the small and marginal land holders. **About 1200 samples comprising 30 different vegetable types of varied origin and varied seasons were analyzed towards standardization of the 'Colorimetric Assay Test' and this test method was then utilized to authenticate the batchwise safety aspect of about 13 different types of vegetables grown in the Project area.**

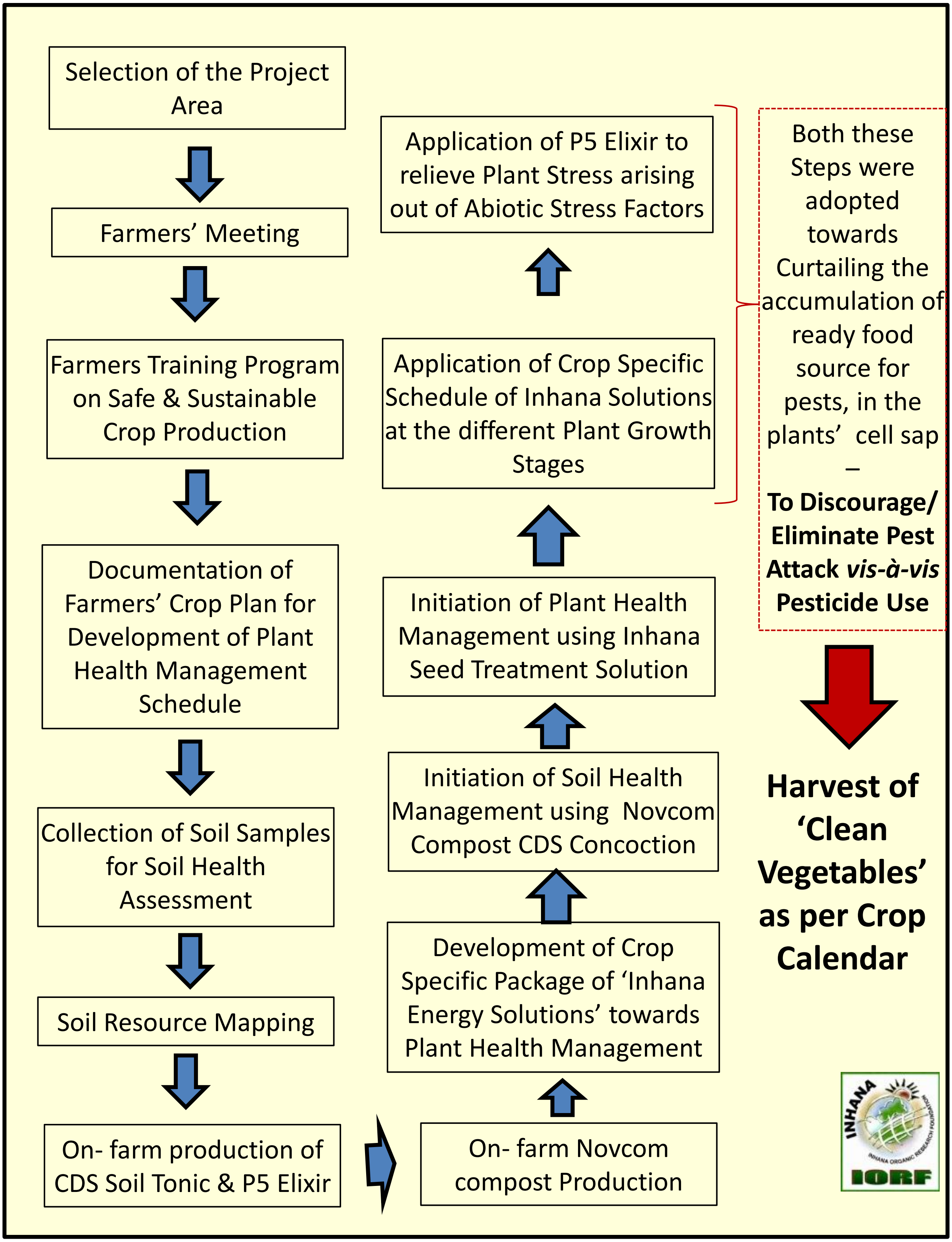
To adjudge the impact of the Sustainable Crop Technology (IRF Technology) on the Safe & Sustainable 'Clean Food', Quality Assessment was conducted in the laboratory in terms of **Vitamin- C, Protein and Antioxidant Richness of 12 major vegetables** grown in the Project area, which have crucial relevance towards human health.

IORF established a **Farmer Producer Company (FPC)**, the one and only of its kind in the entire country, being dedicated solely towards safe and sustainable agriculture, facilitating and organizing all farming and ancillary activities to ensure that Sustainability is maintained at the farm level. And in order to encompass both the Crop Producers and the Consumers within a common rink of sustainability another organization namely **SafeU, was designed to deliver economic sustainability at the two extremes of this unique value chain**; i.e., the producers (*procuring Clean Food at competitive market prices, or even slightly higher at times*) and the consumers (*retailing Clean Food at competitive market prices of chemical-laden conventional produce, at no premium whatsoever*).

Clean Food Project
Farmers Program in Brief

- Farmers' training programme.
- Soil Testing & SWOT Analysis .
- Development of Resource Maps.
- Crop & problem specific customized solutions:
  1. Seed / Planting Material Treatment Package.
  2. Nursery/ Seed Bed Management Package.
  3. Crop Specific Customised Plant Health Mgt
  4. Solutions for Compost Production.
  5. Disease Mgt. (through Plant Health Mgt).
  6. Solutions for On-farm Concoction Preparation .
- **On-farm Resource Recycling & Soil Health Management.**
- **Monitoring & Supervision.**
- **End Product Quality & Residue Assessment.**
- **Development Of Scientific Documents**.

Activity Flow Chart towards Clean Food Production



CHAPTER 8 : EVALUATION OF SOIL HEALTH, THE FIRST STEP TOWARDS SUSTAINABLE AGRICULTURE

Soil Health Evaluation – The Need in the 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.

West Bengal shares 2.4% of Indian Total Geographical Area, <2% of India's Arable land but provides food to 8% of Indian population and supports 71.23 lakh farm families which is about 5% of Total Indian Farmers' families. West Bengal with its variety of agri- horti crops, varied agro-climatic zones, different crop specific soil limitations, and fragmentation of land due to highest presence of small and marginal farmers, **depicts high Agricultural Vulnerability**. The vulnerability can be further judged from the fact that a considerable area falls in the highly productive Indo-Gangetic zone, which ensures **highest production in a number of crops, but in case of crop productivity, not a single crop grown in the state holds the first place**. The situation is further complicated by the Climate Change impact as reported by CRIDA '**West Bengal will face a significant impact of climate change in respect of the Indian context; which will further challenge the agriculture sustainability'.**

Soil Health Evaluation – a Dire need in West Bengal with High Climatic Vulnerability and Highest Presence of Small and Marginal farmers

In the Project area, the situation is awfully complex. 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, leading to very high usage of unsustainable inputs like chemical fertilizers and pesticides and extreme resource poorness due to the land demography. These **resource-poor and socially marginalized (not merely "marginal" in terms of their landholding) individuals toil inhumanly hard, both against the erratic forces of nature as well as the suppressive forces of our socio-economic hierarchy**, to till their utterly fragmented lands and grow food for us. **SOIL ANALYSIS & SOIL HEALTH MANAGEMENT, IS THE LAST THING THAT THESE POOR FARMERS CAN WORRY ABOUT!**

With High Cropping Intensity and Higher Dependency on Land for livelihood, Small and Marginal Farmers need Sustainable Pathways which starts with Soil Test Based Soil Health Management Program

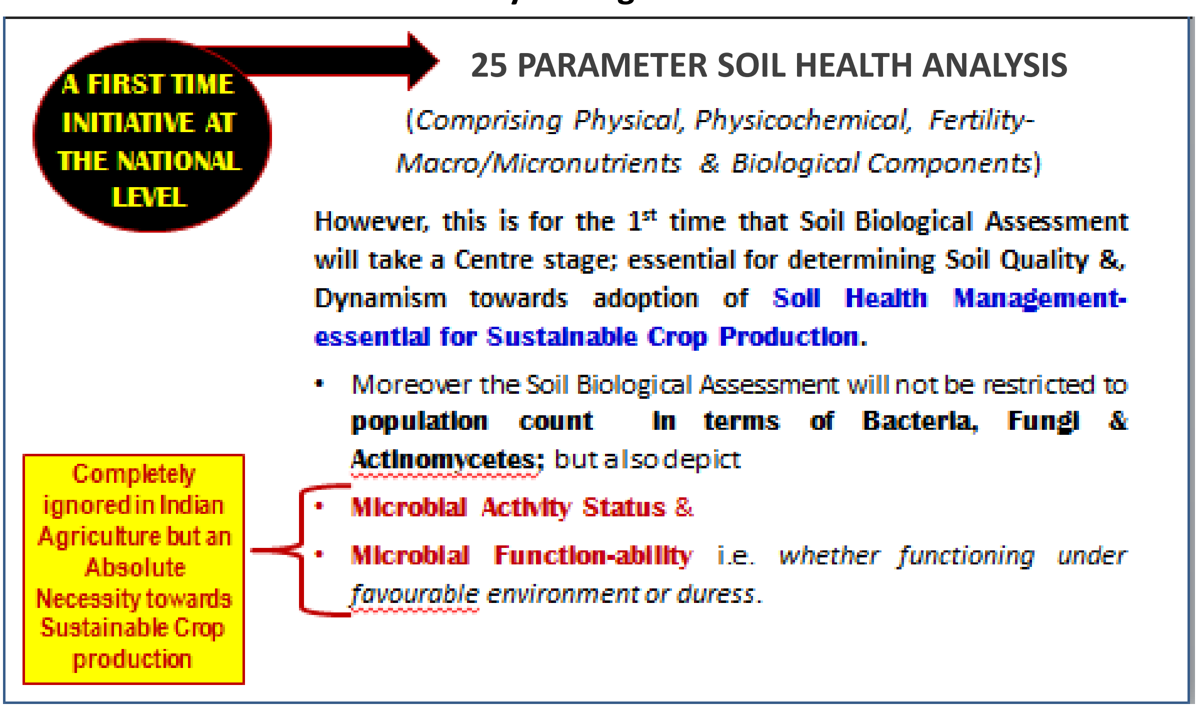
The IBM-IORF Sustainability Safe and Sustainable 'Clean Food' Project aimed at reducing the dependence of the small, marginal and resource poor farmers on the unsustainable inputs like chemical fertilizers and pesticides. And for this qualitative rejuvenation of the soil health was extremely crucial. Assessment of Soil Quality Status is 1st step in this direction and **was critically relevant for the Project Site considering the very high land fragmentation**.

Exposure to the Critical Problem of Land Fragmentation

The average land holding size of the small and marginal farmers in India is about 0.38 hec., which is less than 80% of the classified range of 2.0 hec. (< 1.0 hec. for marginal & 1-2 hec. for Small farmers). **With the Sustainability Stimulus from IBM India, IORF took up the mandate for Resource Mapping of 100 hec. Project Area comprising about 350 to 400 farmers. For this about 350-400 soil samples were to be analyzed.**

But actual field evaluation revealed the critical land fragmentation considering that the land holding size in the Project area was even <0.26 ha and they were not contiguous but scattered in two or more locations. Hence for appraisal of land specific Soil Quality Status (SQS); IORF needed to go down to the micro grid size of 0.16 hec. Also, as the Project Farms were not located adjacent to each other but distributed in a cluster of five villages, so the Project Influence area was about 589 hec. comprising about 1200 to 1500 farmers . IORF realized that Resource mapping of solely the 100 ha Project Area will not serve the purpose, and considering the Final Objective of developing a 'Deliverable Model for Sustainable Agriculture'; Soil Quality Status assessment of the entire **Project Influence Area** was utmost necessary. **So IORF took up an exhaustive Soil Analysis Program, considering four different Sampling Grids : 10 hec., 2.5 hec., 0.6 hec. & 0.16 hec. – which led to** about 1200 Soil Samples.

25 Parameter Soil Health Study – A Significant First at the National Level



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

1st Time in India, the Most Exhaustive Soil Analysis Program for development of a Unique Soil Health Card – has been done under the **IBM-IORF Sustainability Project.** For the 1st Time, Pan India the IORF- IBM Soil Health Card will provide **25 Soil Quality Parameters Study with comprehensive Soil Microbiological Analysis** – The Most Relevant Component for Soil Health vis-à-vis Sustainable Crop Production. **And for the 1st Time in Indian Agriculture; Each Farmer will get an Actual Report Card** for his farm land (on a pilot scale, Soil Health Proximity Model was also utilized to interpret the data base generated from analysis of soil samples collected on 2.5 ha grids).

Soil Health Card

Sl.	Parameters	Ideal Range	Analytical Value
Soil Physical Characteristics			
1.	Sand %	20 – 70 %	7.25
2.	Silt %	20 – 70 %	62.92
3.	Clay %	10 - 40 %	29.83
4.	Soil Texture	SL, CL, SCL, SC, L, SCL	Silty Clay Loam
5.	Soil Bulk Density (gcm^{-3})	1.10 – 1.40	1.30
Soil Physico-Chemical Characteristics			
6.	pH$_{water}$	6.5 – 7.5	6.23
7.	EC$_e$ (dS^{-1})	< 1.0	0.299
8.	Organic Carbon (%)	> 0.75	0.90
9.	Available NO_3^- (ppm)	20 – 40	27.86
10.	Available N (kgha^{-1})	280 - 600	366
11.	Available P_2O_5(kgha^{-1})	45.0 – 90.0	126
12.	Available K_2O (kgha^{-1})	150 - 340	379
13.	Available SO_4^- (kgha^{-1})	60 - 120	88
Soil Biological Characteristics			
15.	Microbial Biomass Carbon (µg CO_2-C/gm dry soil)	150 - 600	186.97
16.	Soil Respiration (mg CO_2-C/gm dry soil per day)	< 2.0	0.221
17.	Soil FDAH (µg/gm dry soil)	120 - 240	36.56
18.	Microbial Quotient (qMBC)	2.0 – 4.0	2.10
19.	Microbial Metabolic Quotient (qCO_2)	1.00 – 5.00	1.18
20.	qFDAH	1.60 – 3.20	0.41
21.	Microbial Respiration Quotient (QR)	0.30 – 0.80	0.04
Soil Micronutrients			
22.	Available Fe (ppm)	5.0 - 10.0	14.25
23.	Available Mn (ppm)	2.0 – 10.0	12.25
24.	Available Zn (ppm)	0.60 – 1.50	0.71
25.	Available Cu (ppm)	0.20 - 2.00	0.95
26.	Available B (ppm)	0.50– 1.50	0.72

5 Soil Physical Parameters

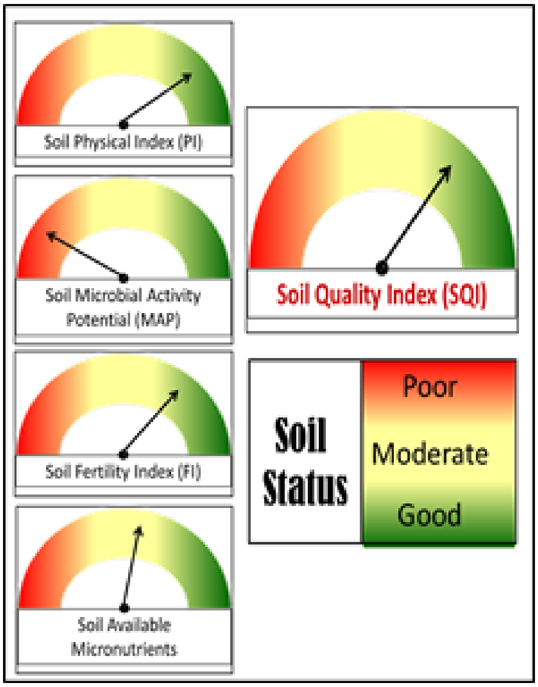
8 Soil Physico – chemical & soil fertility Parameters

7 Soil Biological Parameters

5 Soil Micronutrients

A Comprehensive Study including Soil Physical, Physicochemical & fertility (Macro & Micro) and Soil Biological Parameters to assess the **Soil Quality Status** and develop **Recommendations for Sustainable Soil Health Management**

Development of Soil Quality Indices with Colour Coding is an innovative development that enables better understanding of Soil Health Status at the farmers' level.



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**

In order to provide Individual, Soil Health Card to the Farmers as per their fragmented land holdings, in a mere 100 ha Project Area, IORF had to draw about 650 soil samples and carry out more than16000 analyses .

And to complete the task within a scheduled time period IORF had to pool in all of its available resources However, this exercise in the Project Area brought forth a Crucial indication that **Soil Health Assessment of Individual Farmland will be Practically Impossible in a Country like India dominated by Small & Marginal Farmers and marred by Critical Land fragmentation- Until an ALTERNATIVE, SPEEDY & ECONOMIC Solution is provided.**

Chapter 9: Quantification of Soil Health Status using Soil Quality Index

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. A simple and easily understood soil quality index is requisite for every farmer towards understanding their soil as well as for undertaking complementary management practice towards supporting crop yield.

Soil Quality Index (SQI) was developed jointly by Inhana Organic Research Foundation (IORF) and Krishi Vigyan Kendra (Howrah), BCKV, ICAR after analysis of more than 3000 soil samples from different Agro-Ecological sub regions.

SQI is the function of soil physical index (PI), soil fertility index (FI) and soil microbial activity potential (MAP). SQI value >0.75 indicates soil conditions highly favourable for plant growth. While time and area specific composite management practices will be requisite in case the value is lower.

Now Soil Fertility Index (FI was formulated by taking seven major soil parameters *viz.* pH, ECe, organic carbon, available N, available P_2O_5, available K_2O and available SO_4. Increasing FI value will indicate a balanced nutritional approach towards sustainable crop production. Where as 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 (qCO_2), microbial respiration quotient (QR) and specific hydrolytic activity (qFDA). Higher MAP value support sustainable crop production & minimize soil borne disease infestations. Soil Physical Index was formulated by taking five major soil physical parameters *viz.* soil depth, coarse fragment (%), soil texture, soil bulk density and soil aggregates.

Pic. 1 : Soil sampling and analysis under the IBM-IORF Sustainability Project

Table 1 : Soil physical, physicochemical, fertility, biological properties and soil quality indices in the study area (mean value of grid soils)

Average Soil Quality Value	Cluster of Project Villages				
	Satyapole	Bhabanipur	Panchkahania	Bansbona	Dhopagachi
Soil Physical properties					
Sand (%)	21	20.28	17.63	12.89	18.2
Silt (%)	52.18	51.84	52.8	51.39	56.73
Clay (%)	26.82	27.88	29.57	35.72	25.07
Texture	Silt Loam	Silt Loam	Silty Clay Loam	Silty Clay Loam	Silt Loam
Aggregates	Medium	Medium	Medium	Medium	Medium
Bulk Density (gcm^{-3})	1.37	1.39	1.4	1.33	1.39
Soil Physicochemical properties					
pH_{water}	6.28	6.36	6.57	6.34	6.42
Ece (1 :1)	0.11	0.11	0.12	0.11	0.1
NO_3-N (ppm)	58.44	55.04	65.26	61.48	60.77
Organic C%	0.81	0.69	0.76	0.94	0.7
Av. N ($kgha^{-1}$)	329.4	306.3	340.5	357.1	287
Av. P_2O_5 ($kgha^{-1}$)	114.45	118.8	96.85	125.68	122.96
Av. K_2O ($kgha^{-1}$)	366.8	371	339.2	391.2	386.7
Av. SO_4 ($kgha^{-1}$)	107.85	109.77	125.2	89.56	138.63
Soil Microbial Properties					
Soil Respiration (SR) (mg CO_2-C/g dry soil/day)	0.234	0.211	0.18	0.181	0.183
Soil MBC (µg CO_2-C/ g dry soil)	166.04	153.8	178.63	173.78	175.25
FDAH (µg / g dry soil)	38.59	34.34	37.21	38.71	27.13
Microbial Quotient (qMBC)	2.29	2.38	2.47	1.92	2.63
Metabolic Quotient (qCO_2)	1.63	1.52	1.25	1.11	1.12
q FDA	0.55	0.53	0.58	0.42	0.39
QR	0.04	0.05	0.07	0.05	0.05
Soil Quality Indices					
Soil Physical Index (PI)	22.00	22.03	21.92	22.39	22.13
Soil Fertility Index (FI)	25.42	24.26	24.41	26.23	25.23
Soil Microbial Activity Potential (MAP)	8.57	8.32	7.52	7.20	7.38
Soil Quality Index (SQI)	0.52	0.50	0.48	0.51	0.50

Note :
SR : FDAH : Fluorescein di-acetate hydrolyzing activity (FDAH) (µg/gm dry soil);; **qFDA :** FDAH Quotient (µg/gm dry soil / Organic C); **QR :** Microbial Respiration Quotient.

Soil quality and Impact of Intensified Chemical Agriculture

The soil samples were collected grid wise and analyzed for various quality parameters and village wise mean value was given in Table 1. As per the mean value , the soils of the area were mostly Silty clay loam to silt loam. The soils were basically light soils with no limitation in terms of soil depth, coarse fragment, bulk density and aggregate stability. **Thus physical index (PI) value indicates in terms of soil physical quality, it was good for agricultural crops.**

Soil pH of the area varied from neutral to slightly acidic, where as soil EC value indicated there was no problem of soil salinity. However soil organic carbon in all the villages were less than 1.0 % indicating poor to very poor status. Status of available- N,P,K,S values indicated moderate available-N, and high to very high phosphate, potash and sulphate. **Thus as per Soil Fertility Index (FI), the soils had moderate** (15-20) **to moderately high** (20-25) **nutrient availability in** more than 50% **of the area.** However, interpretation of the analyzed database revealed heavy load of chemical fertilizer considering that the average value of Av. NO_3 was 60.2 ppm and the ratio of Av. NO_3 and $KMNO_4$ extractable N was 0.19, an unusually high value (commonly the ratio was < 0.10). Similarly average value (116.0 kg/ha) of available phosphate was also very high. In contrast, the organic carbon status was low to very low with an average value of 0.78%. It is quite clear from the database that intensive chemical farming and lack of organic amendments has made the soil most vulnerable in respect of future crop sustenance.

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

To actually determine the soils' potential as an effective medium for plant growth, a mere population assessment in terms of total count or differential count (i.e., bacteria, fungi and actinomycetes) is not sufficient. Hence, IORF went a step ahead and took up the initiative to assess the functional responses of the soil microflora.

Soil Microbial Activity Potential (MAP) is actually a tool, which indicates 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 & 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) to low (8-10) in a major 83% area. Moderate (10-12) values were observed in only about 11% area.** The Project area has a cropping intensity of close to 2.5 to 3.0 and in a year the soil receives repeated application of fertilizers, especially nitrogenous which are known for their deleterious impact on the soil microbial dynamics.

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 have been identified to estimate soil quality.** Inhana Organic Research Foundation has developed **Soil Quality Index (SQI) suitable for Indian condition which is the function of soil Physical Index (PI), Fertility Index (FI) and Microbial Activity Potential and it was calculated as the area of a triangle.**

Soil Quality Index (SQI) in the Project Area was moderate (0.46 – 0.60) in majority of area (72.4 % area) followed by poor status in 22.2 % area and moderately high status only in about 5.4 % area.

CHAPTER 10 : THE CONCEPT OF SOIL RESOURCE MAPPING

Soil is the mainstay of agriculture as it forms the medium in which growth and ultimately the yield of food producing crops occurs. Most of the agricultural crops being of short duration, soil has to give the needed support, otherwise there would not be any satisfactory production, despite applying incremental dose of fertilizers and newly formulated pesticides. In the last few decades, due to continuous practice of conventional chemical farming, there has been disruption of the fine ecological balance that in one way has helped in increasing immunity of pests to pesticides, but what is more significant is that soil has been the worst hit victim; suffering severe loss in character along with manifolds decrease in the soil flora and fauna.

Now in the event of climate change impacts and the production going astray, restraining further deterioration of soil should be the prime focus and for this understanding the present soil quality and proper mapping of the same will form the first step. Moreover in India, considering that the majority of the farmers are marginal and poor, an easy and comprehensive visual interpretation of their field's condition that the farmers can see at a glance and understand will be requisite in order to enable the adoption of Sustainable Soil Management.

In the Indian Agricultural scenario, soil analysis for various components is done in an isolated manner and it has remained confined to the limits of theory. No comparative representation of the parameters for assessing the cumulative impact on the qualitative functioning of soil is being done. But to get an idea about the soil in a nutshell; indexing becomes important. Moreover, as of now soil quality indices if any, have been based on physicochemical and fertility parameters. Hence in the IBM-IORF Sustainability Project, focus was pointed towards soil biological parameters since microflora are the drivers of all soil ecological processes culminating into the inherent soil quality.

The Analytical Data Pool from the 26 Soil Quality Parameter Study was Interpreted by IORF Team using its various Tools & Indices towards computation of Soil Indices i.e., **Physical Index (PI), Fertility Index (FI), Microbial Activity Potential (MAP) &, Micronutrient Index (MI).** The value of these indices was finally utilized for arriving at the **Soil Quality Index (SQI)- a 'Soil Health Indicator'** that depicts the **Soil Quality Status (SQS)** in terms of poor, moderate, good, etc. or in other words the **soil's potential in supporting Sustainable Crop Production**.

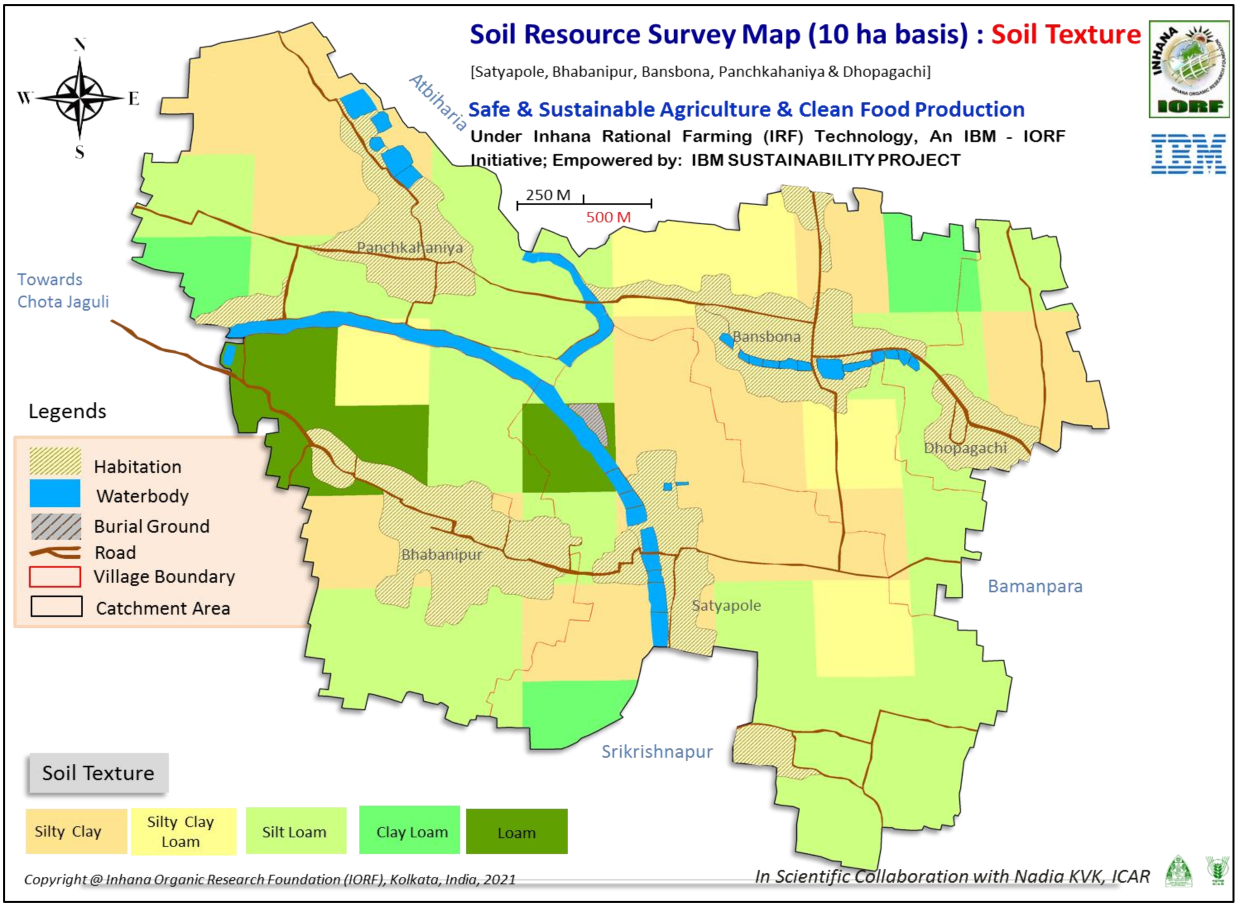
Finally Resource Maps were developed based on the different Soil Quality Parameters as well as the Soil Indices

Initially it was decided that **4-5 Resource Maps** will meet the requirements, but with escalation in mandate, we developed Resource Maps in a phase wise manner and **Finally Submitted 96 Maps in All**

- **Location Map, Demography Map & Land Use Map.**
- **18 Soil Resource Maps of the 5 Project Villages.**
- **75 Soil Resource Maps of Project Farms located in the 5 Project Villages** (*15 Resource Maps for each village*)

Soil Texture

Soil texture is an important soil property that drives crop production and field management. Texture is a very stable characteristic that influences soil biophysical properties. It is associated with soil porosity, which in turn regulates the water holding capacity, gaseous diffusion

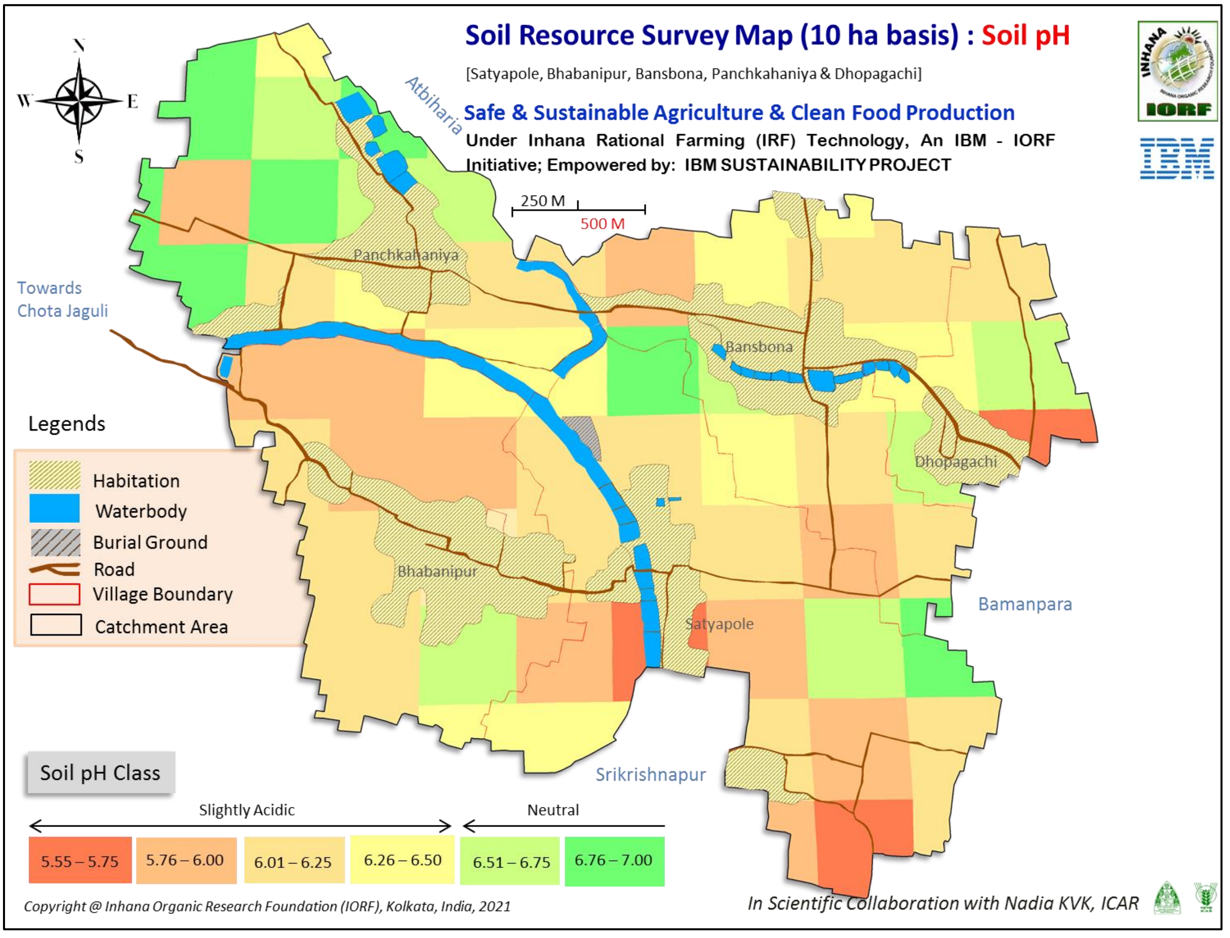


and water movement that determines the soil health. It is associated with soil porosity, which in turn regulates the water holding capacity, gaseous diffusion and water movement that determines soil health. Soil texture is also interrelated with the soil fertility and quality in the long term. Most Importantly, is an important soil characteristic that can modulate the effect of climate change via its influence on components of the carbon cycle , including crop growth response and soil organic matter retention. Fine particles have higher specific surface area and are more reactive than coarse particles, therefore clay-textured soils generally store higher amounts of carbon than sandy soil. Soil texture is important for crop growth as plant growth is influenced by the size of soil particle through controlling of nutrition availability and root growth. The agricultural practice with appropriate soil texture and proper crop selection produces optimum productivity with minimum water and fertilizer what consequently sustains soil health as well as concerned agricultural systems.

Soil Textural Analysis in the project area showed dominance of medium textured soil with highest presence of silt loam in 42.80 % area followed by 32.70 % area under silty clay, 10.3 % area under silty clay loam, 6.7 % area under Loam and 6.1 % area under clay loam. However in terms of crop growth and root penetration, 67.3 % area has no limitation while a slight limitation might be encountered in the rest 32.7 % area.

Soil pH

Soil pH is a master variable in soils because it controls many chemical and biochemical processes operating within the soil. It is a measure of the acidity or alkalinity of a soil. The study of soil pH is very important in agriculture due to the fact that soil pH regulates plant nutrient availability by controlling the chemical



forms of the different nutrients and also influences their chemical reactions. As a result, soil and crop productivities are linked to soil pH value. Though soil pH generally ranges from 1 to 14, the optimum range for most agricultural crops is between 5.5 & 7.5.

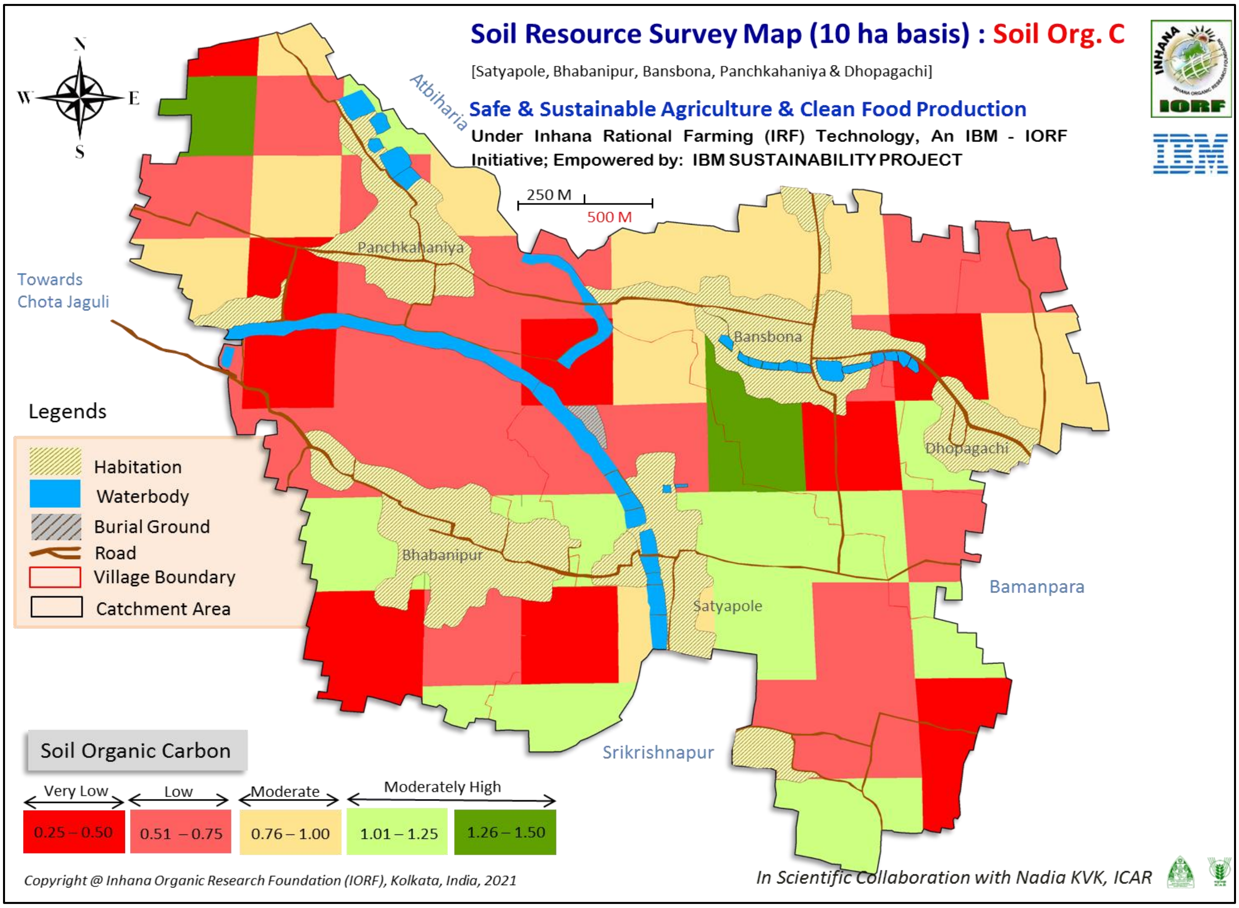
Vegetables and other plants grow best when the soil pH is optimal for the plants being grown and it is important to match a plant to the soil pH or to adjust the soil pH to a plant's needs.

The Project Area, which represents a major vegetable belt of the Nadia District of West Bengal State (India) is characterized by hugely fragmented lands with a contrasting crop intensity as high as 2.5 to 3.0- meaning huge dependence on chemical fertilizers. The situation gets further complicated when due to resource scarcity and lack of adoptable guidelines, the farmers refrain from taking up any sustainable practices with respect to the soil.

So pH was the primary component of relevance for the project area especially considering the objective of Safe & Sustainable Crop Production. Analysis revealed that in the Project Influence Area (Cluster of Five Villages) pH is in the slightly acidic range (5.5-6.5) in a major three fourth area, while close to neutral pH range (6.5 – 7.5) is found in only about 25% area.

Soil Organic Carbon

Soil Organic Carbon is an important indicator for soil health in relation to its contribution to food production. But more importantly in the present day, Agriculture is the only Sector that can be utilized for developing both the mitigation and adaptation strategies towards climate change



and hence; can play a profound role in the achievement of the FAO Sustainable Development Goals – And SOC is the major component in this respect.

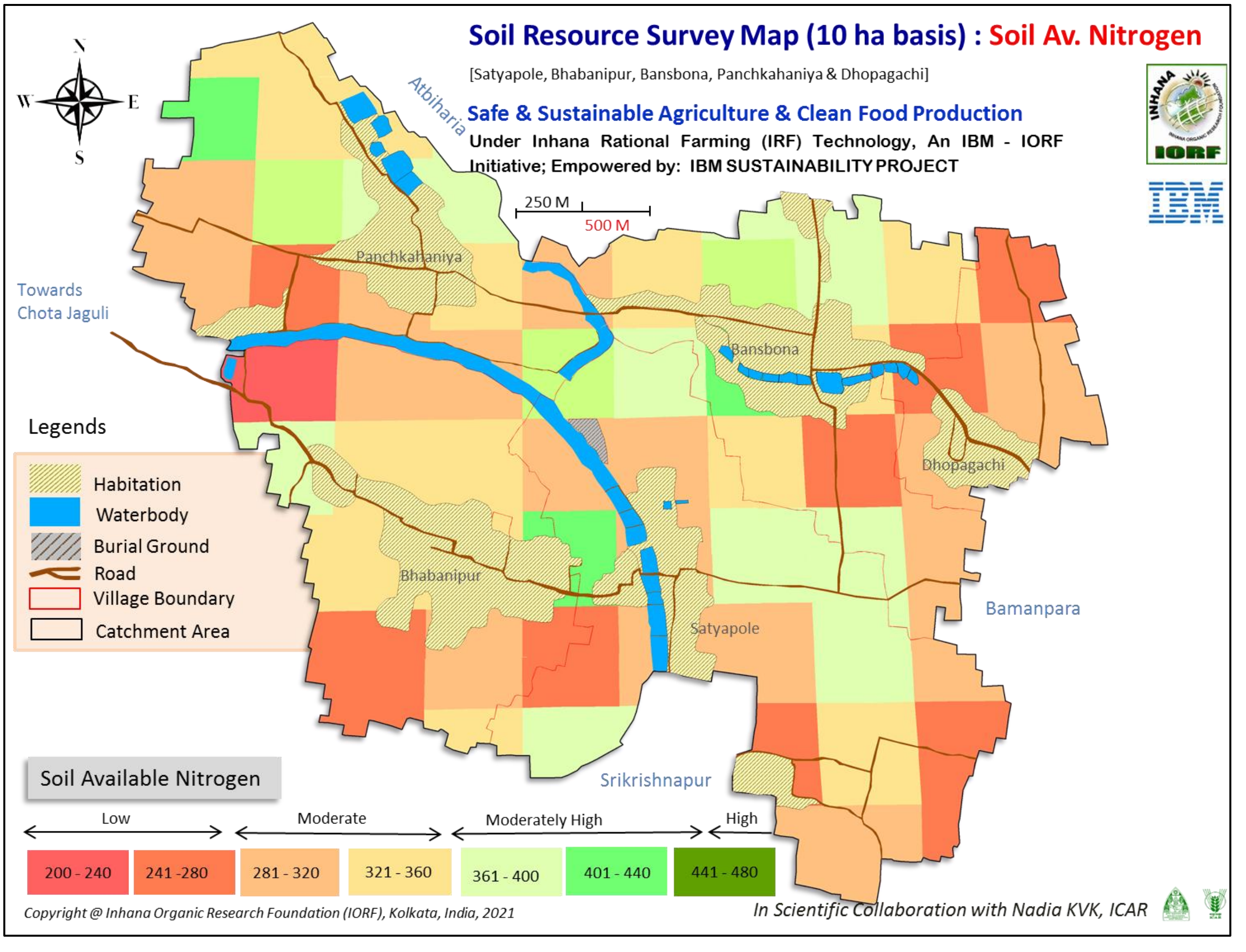
A high SOM content provides nutrients to plants and improves water availability, both of which enhance soil fertility and ultimately improve food productivity. Moreover, SOC improves soil structural stability by promoting aggregate formation which, together with porosity, ensure sufficient aeration and water infiltration to support plant growth.

Soil organic carbon (SOC) is dynamic, but whether it will act as a net sink or a net source of atmospheric greenhouse gases (GHG) will depend on the human interventions – more specially the pathway followed for Crop Production. Intensive Farming that involve chemical fertilizer and pesticides lead to a decrease in the soil organic carbon (SOC) while Sustainable Agriculture has the potential to be a powerful tool for climate change mitigation and increased soil fertility through SOC sequestration.

Hence, assessment of the soil organic carbon is a very important component of this project for Safe & Sustainable Crop Production. Analysis revealed that in the Project Influence Area (Cluster of Five Villages) O.C is low (0.5 to 0.75%) to very low (<0.5%) in more than half of the area, moderate (0.75-1.0%) in about 21% area and Moderately high in the rest 23% area.

Soil Available- Nitrogen

Nitrogen is an essential macronutrient for plant function and is a key component of amino acids, which forms the building blocks of plant proteins and enzymes. It is also the most essential nutrient in crop production, because it is a major component of chlorophyll, the compound by which plants use sunlight



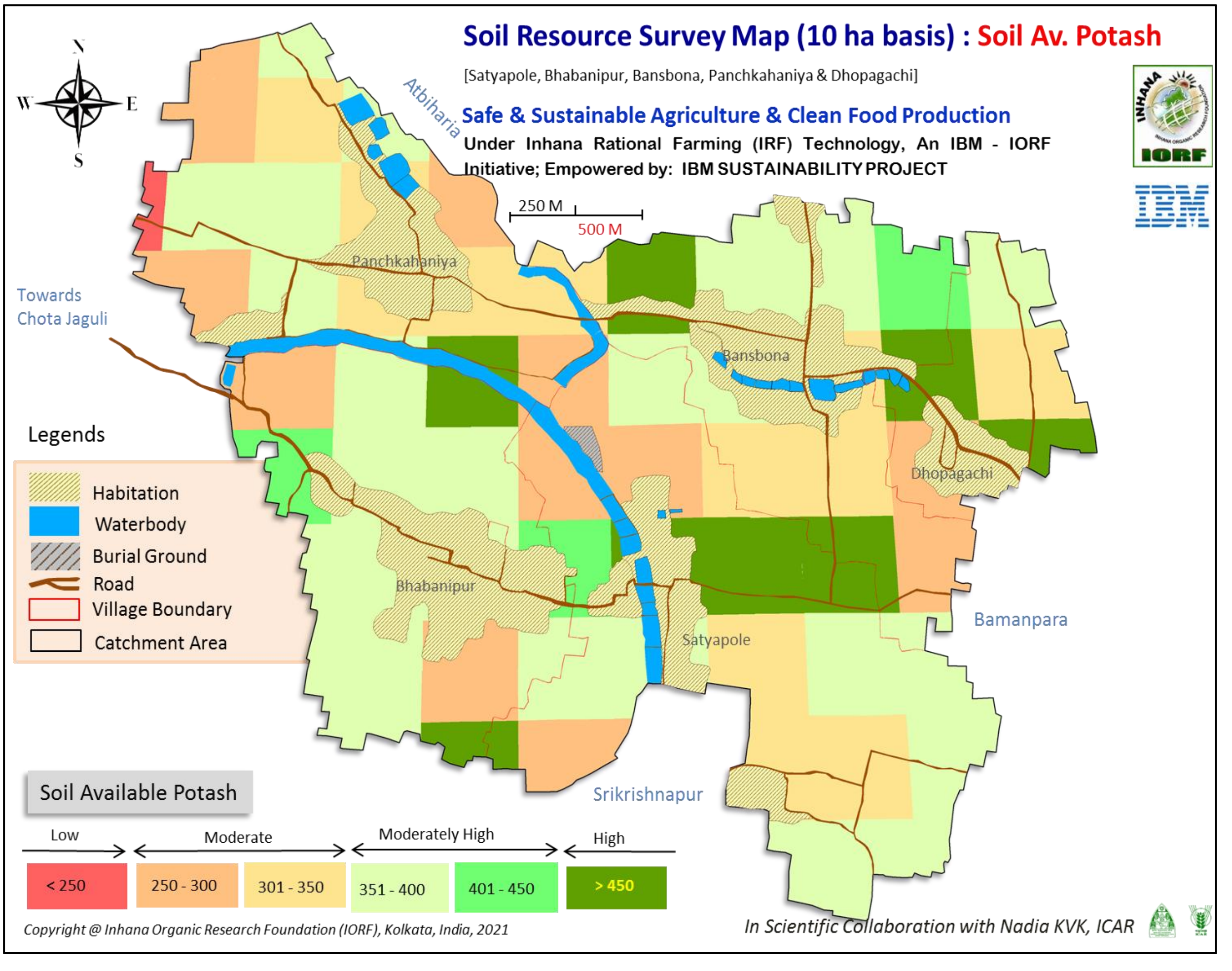
energy to produce sugars from water and carbon dioxide (photosynthesis). Nitrogen management in soil is central to global crop production, because the challenge is to provide enough to meet global food security needs while minimizing the flow of unused nitrogen — which is 300 times more polluting than carbon dioxide — to the environment. The environmental effect of nitrogen fertilizers has been a long-term issue.

Reducing the use of nitrate fertilizers is a prime objective of Sustainable Agriculture. 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 health management plan.

Analysis revealed that in the Project Influence Area (Cluster of Five Villages) the available- N is low (200-280 kg/ ha) to moderate (280-360 kg/ ha) in about 72% area. Moderately high available- N content (360-450 kg/ ha) is observed in about 26% area while a very negligible (1.8%) area has a high content (>450 kg/ ha) .

Soil Available- Potash

Potassium is essential for plant health and there must be an adequate supply in soil to maintain good growth. When the potassium supply is limited, plants have reduced yields, poor quality, utilize water less efficiently, and are more susceptible to pest and disease damage. Potassium is required by plants in approximately the same or slightly larger amounts as nitrogen.



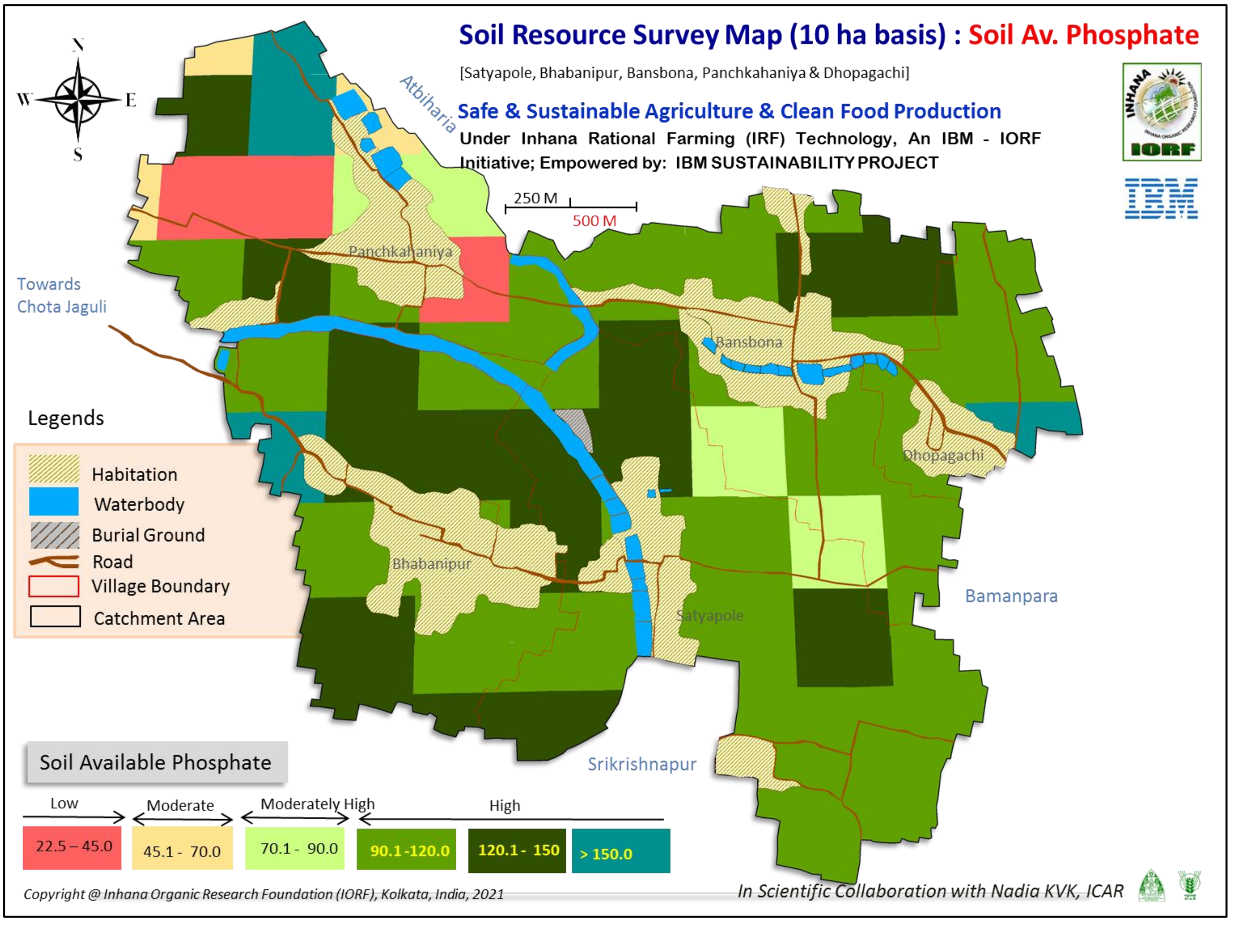
Many critical physiological processes such as photosynthesis, carbohydrate transport, and water regulation are directly influenced by potassium. Managing optimum levels of potassium in the soil and the plant leads to improved disease resistance, increased drought tolerance, and vigorous vegetative growth. Considering the short duration of the vegetable crops efficient potash management is an essential criteria towards crop sustainability.

Analysis revealed that in the Project Influence Area (Cluster of Five Villages) the potash content is moderate (250-340 kg/ ha) to moderately high (340-450 kg/ ha) in 41% and 47% area respectively; while high potash content (>450 kg/ ha) is observed in only about 12.5% area.

Soil Available- Phosphate

Phosphorus is required by the plant from the seedling stage to maturity – and has a measurable impact on crop quality and yield.

However, 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.

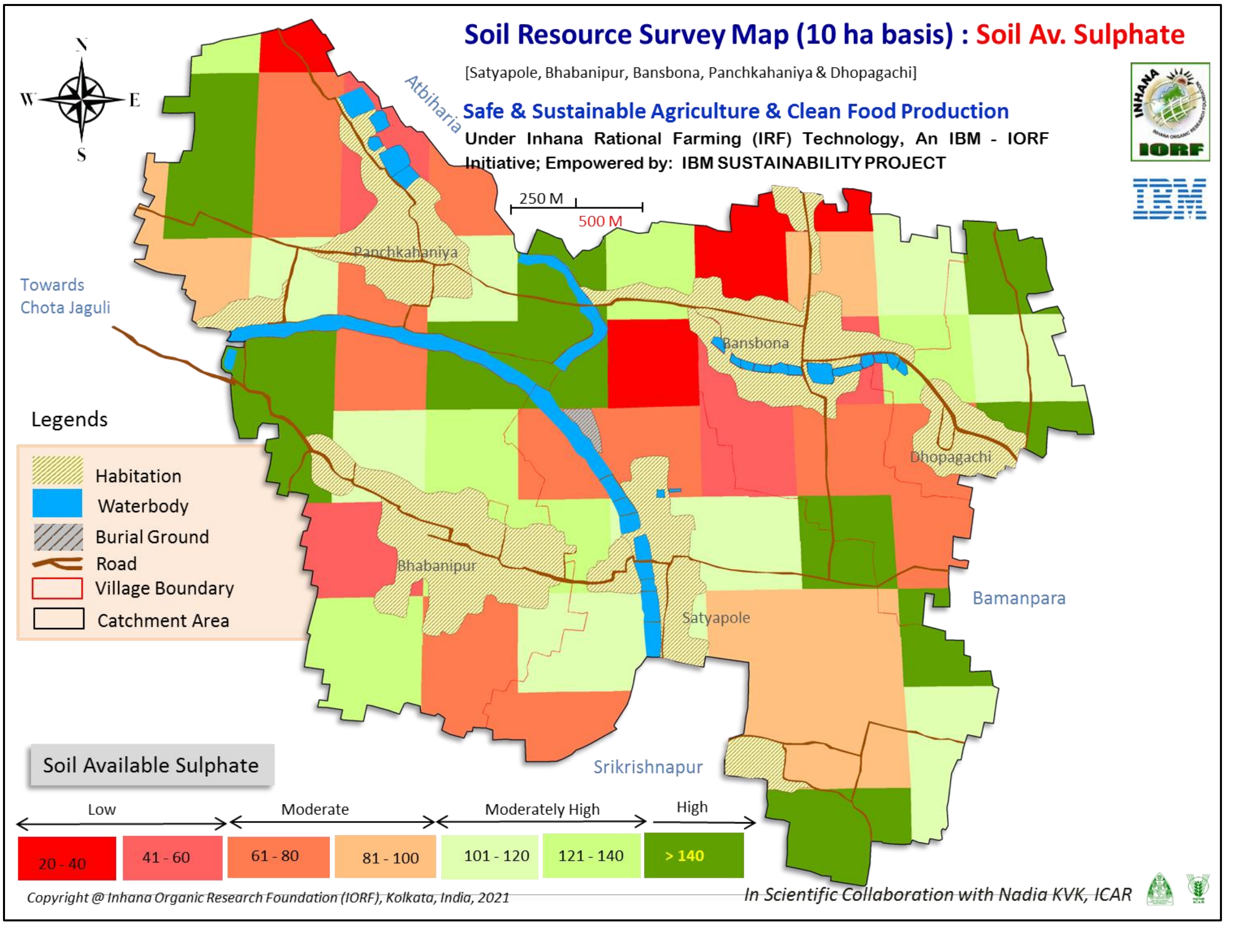


A varying but often substantial part accumulates in the soil as "residual P". This reserve can contribute to P in the soil solution and utilized by the plant but an efficient process of mineralization is required for the purpose, for which an efficient soil microbial dynamics is important. Thus, it is essential to measure the status of available phosphate in the soil in order to plan out a sustainable soil management program.

The above forms one of the primary objectives of the Safe & Sustainable Project and hence, evaluation of the phosphate content was a crucial component of the Soil Quality Analysis. Soil available phosphate was in the relatively higher range (>90.0 kg/ ha) in close to 86% of the area while low to moderately high (22.5 to 90 kg/ ha) in the rest 14.3% area. Unlike other plant nutrients, phosphorus does not leach in the soil. This means that too much phosphorus in the soil can build up over the course of several growing seasons due to repeated use of chemical fertilizers. The finding vividly depicts the requirement for an effective and sustainable pathway for management of soil phosphate towards sustainable crop production without harming the environment

Soil Available- Sulphur

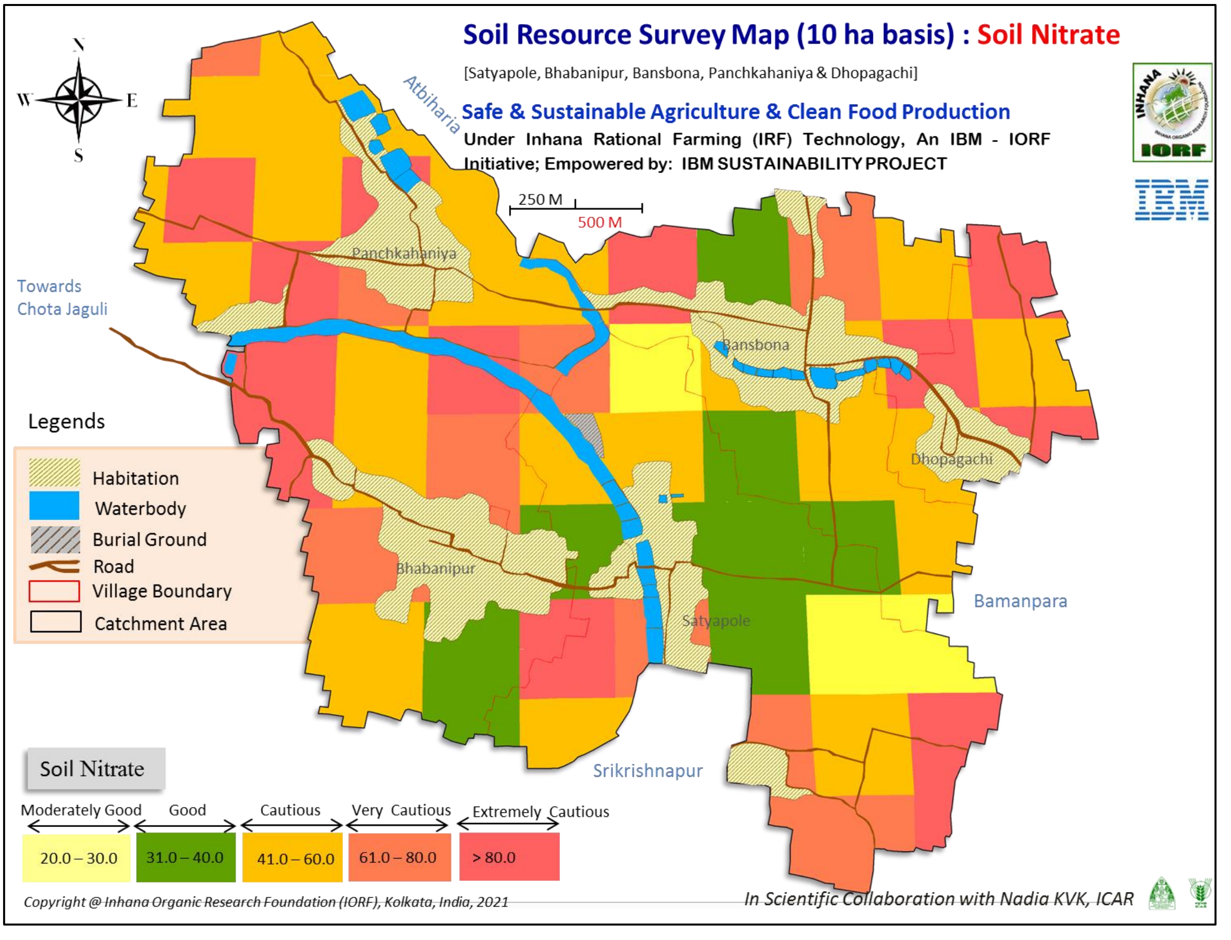
Sulphur can only be taken up by plants from the soil solution as sulphate. As with readily-available nitrate, it can be liable to loss through leaching. The majority of S in most soils is contained in organic matter. Organic S must be mineralized to the inorganic sulfate anion before it can be taken up by crops.



Hence an efficient soil dynamics is essential for meeting the plants' sulphate requirement. Nitrogen (N), phosphorus (P) and potassium (K) are critical components of a well-fertilized crop. But to achieve yields and more nutritious foods, crops need sulphur (S). Hence the relevance of sulphur might be understood in respect of the nutritional security objective of the FAO. In the Project Area the soil available sulphate was in low (20-60 kg/ ha) to moderate range (60-100 kg/ ha) in close to 49% area while moderately high (100-140 kg/ ha) to high (>140 kg/ ha) content was observed in the rest 51% area.

Soil Available- Nitrate

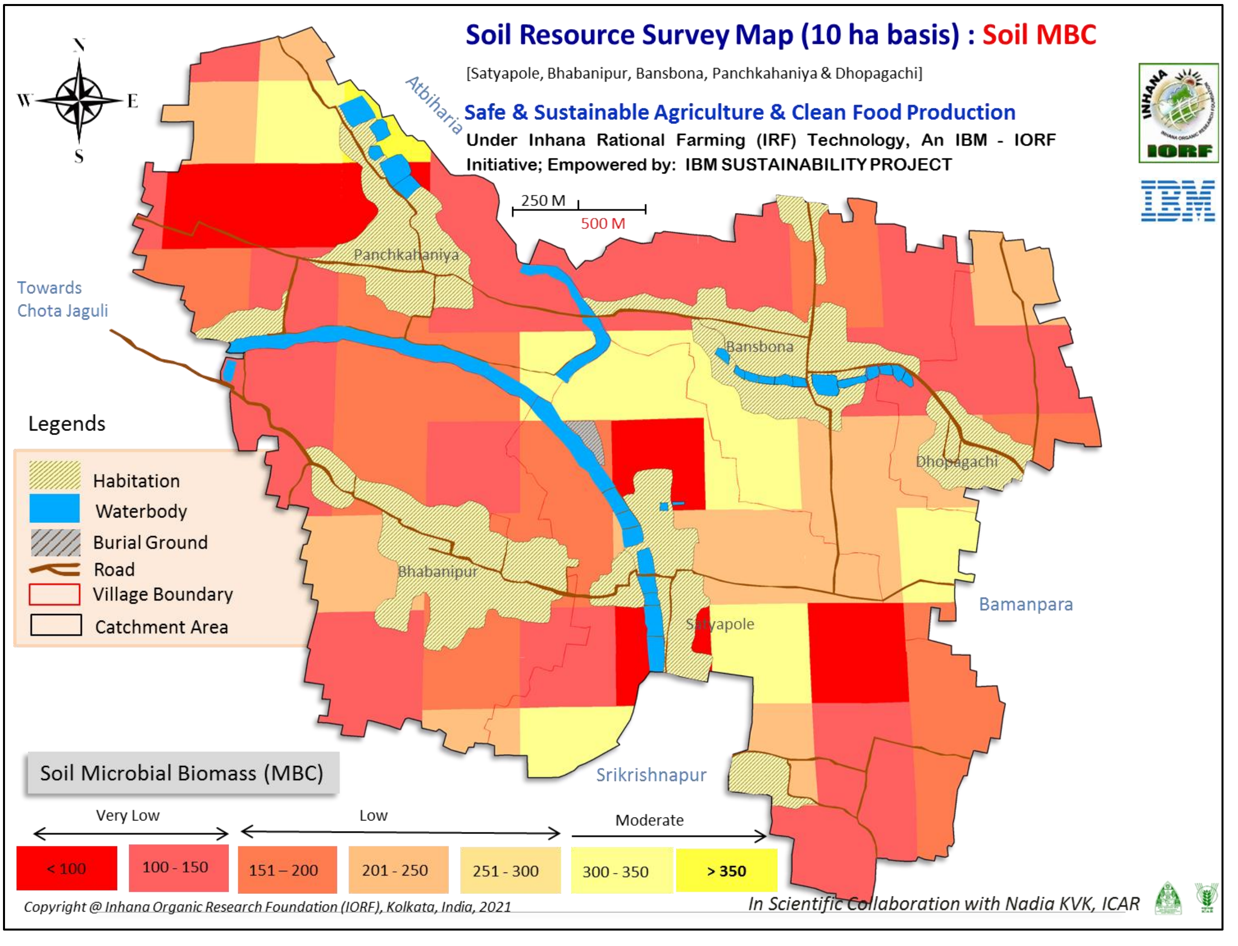
IORF puts special emphasis on the assessment of the soil nitrate considering that when correlated with the available-N content it can provide important information about nitrogen Dynamics (N- dynamics) of the soil. Hence, in the Project area evaluation of the Nitrate value and their ratio can provide an



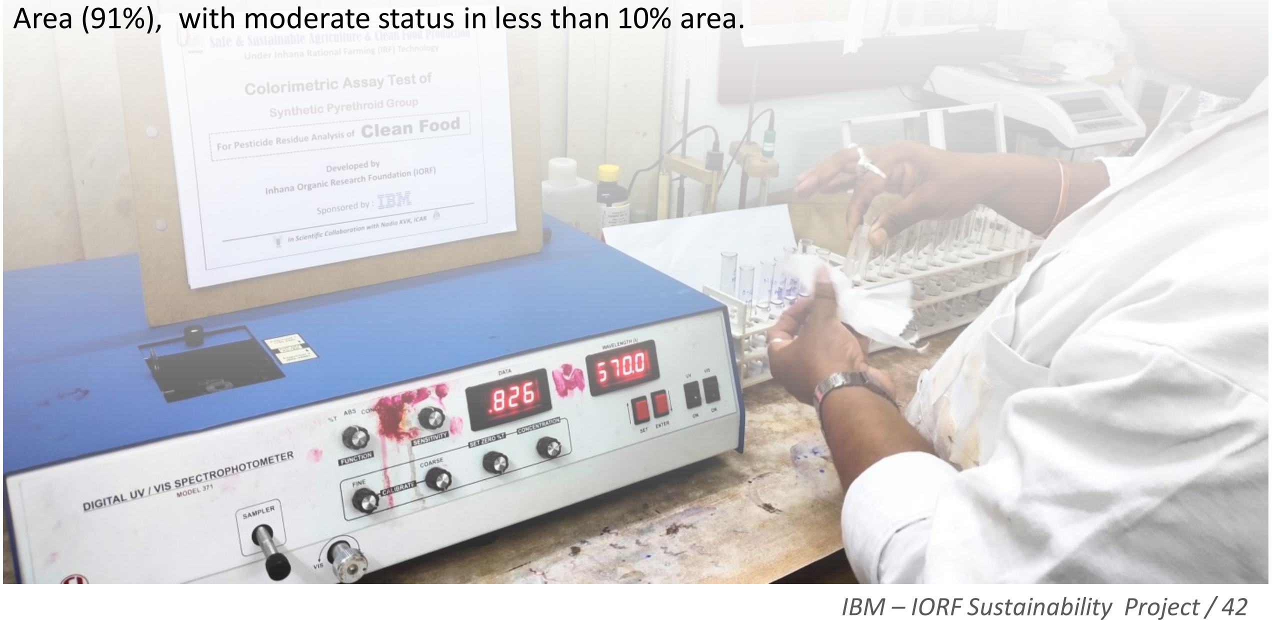
indication of the ionic status of N in the soil, especially considering the high cropping intensity and the huge dependence on the nitrogenous fertilizers. In the Project Area Soil Nitrate is moderately good (20-30 kg/ ha) to good (30-40 kg/ ha) in about 22% area. But higher values, (40-60 kg/ ha), (60-80 kg/ ha) and (>80 kg/ ha) were documented in about 40%, 17% and 21% of the Project area respectively; indicates caution so as to avoid the chances of soil and groundwater pollution.

Soil Available- Soil Microbial Biomass Carbon (MBC)

Microbial biomass is a useful indicator of soil quality and change rapidly in response to changes in soil properties. Their high status indicates beneficial biological functions in soil and the scope for future increase in organic carbon, while decline in value is considered to have a negative effect on soil quality.

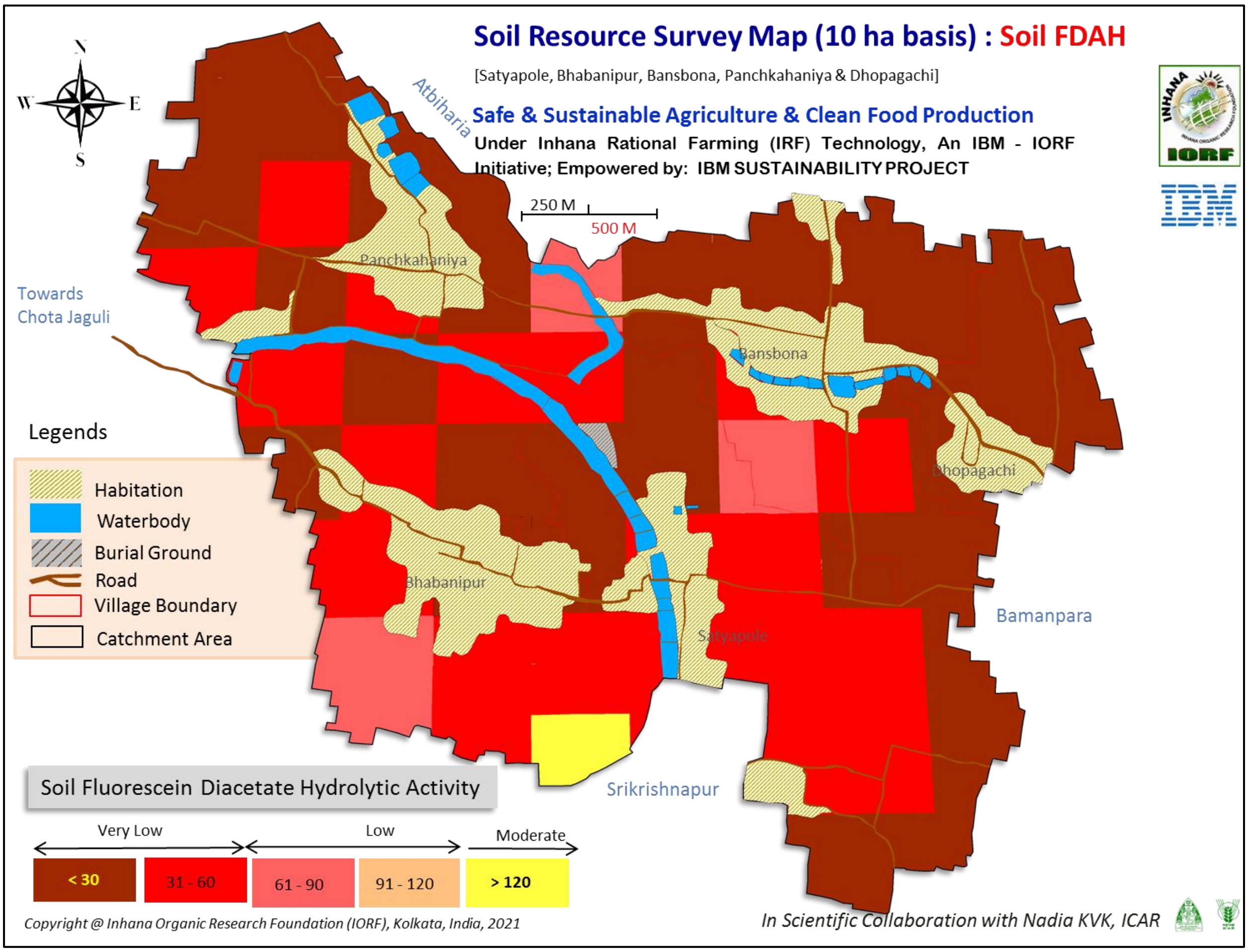


Low (150- 300) to very low (<150) microbial biomass was found in almost the entire Project Area (91%), with moderate status in less than 10% area.



Soil Fluorescein Diacetate Hydrolysis (FDAH)

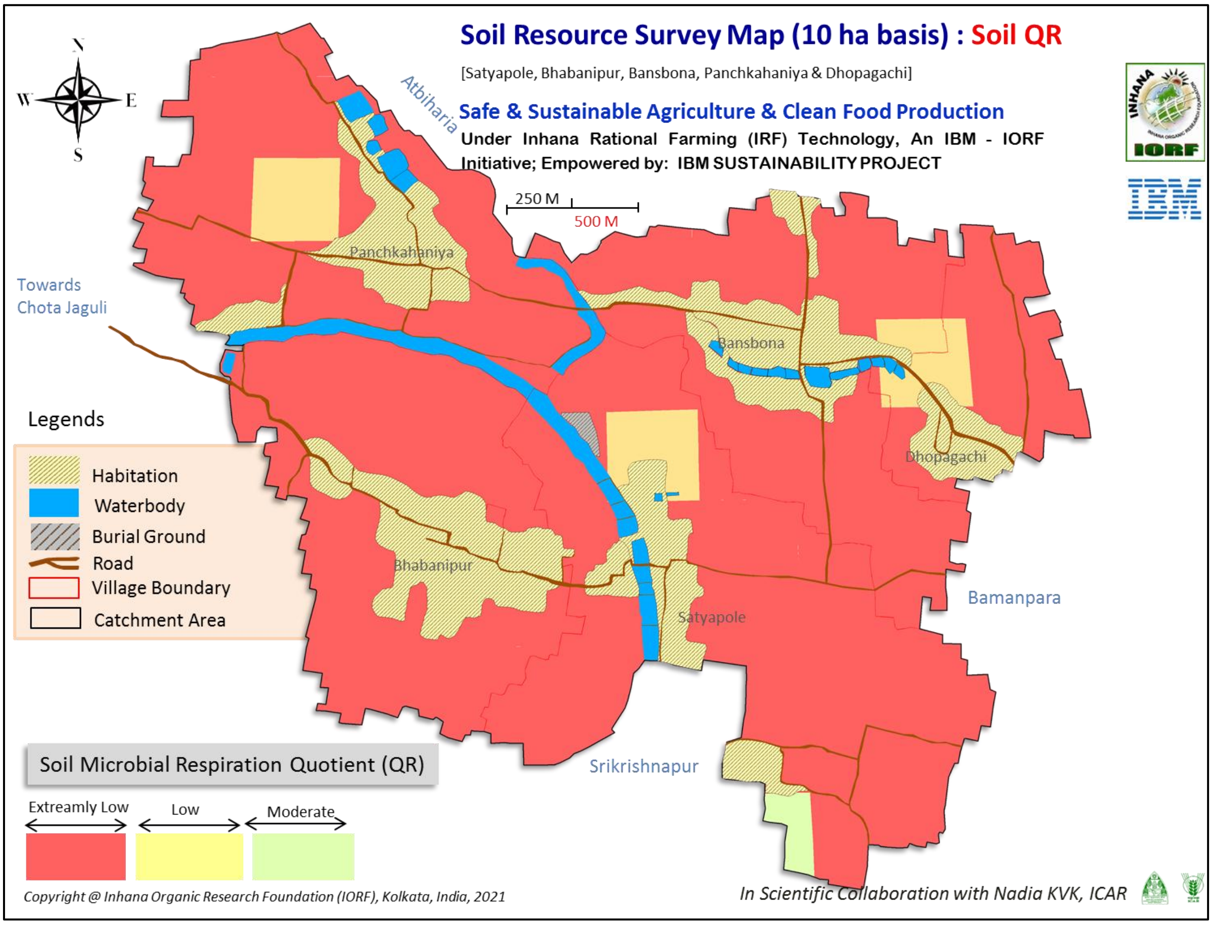
Fluorescein di-acetate (FDA) is a cell- permeant esterase substrate that can serve as a viability probe that measures both microbial enzymatic activity, required to activate its fluorescence, and cell membrane integrity, for intracellular retention of their fluorescent product.



A higher value generally indicates higher number of microbes in active form which is required for soil-plant nutrient equilibrium. The study revealed that the soil microbial activity was definitely a cause for concern in the Project area and was a result of the very high dependency on the chemical fertilizers. Very low fluorescence (< 60) was indicated in almost the entire project area (91%) while less than 10% area represented low (60- 120) activity.

Soil Microbial Respiration Quotient (QR)

QR, also termed as microbial respiration quotient is also used to assess the effects of various perturbations in soil ecosystems. QR values near zero indicate environmental stress. In contrast, a QR approaching 1.0 reflects the absence of respiratory response to substrate addition, i.e., the absence of potentially active microorganisms.

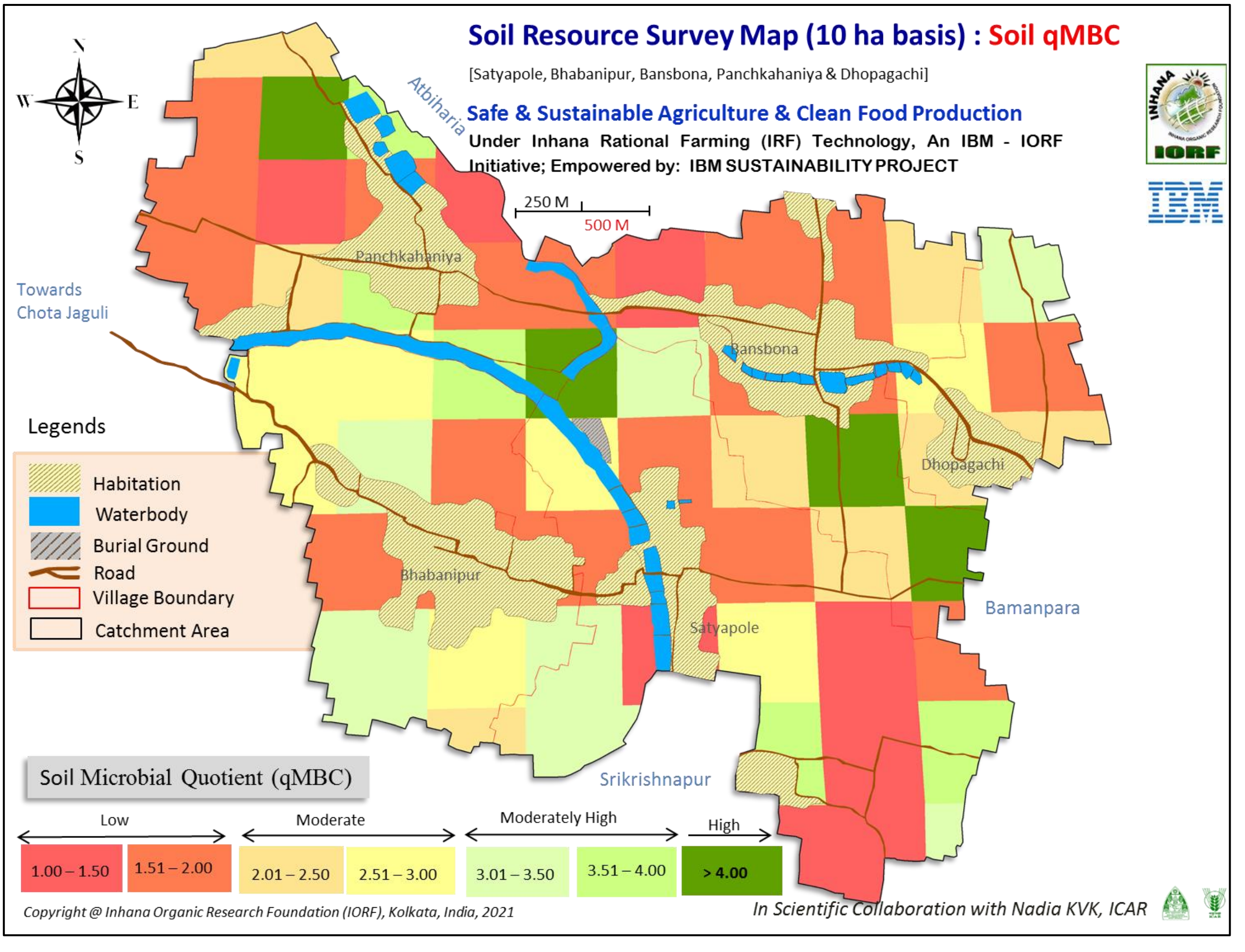


The respiratory-activation quotient (QR) represents the number of dormant or active microorganisms, ranged from 0.13 to 0.25. As stated by Eisentraeger et al. [14], the value of respiratory-activation quotient between 0.1 and 0.3 is low and indicates a large amount of biomass of inactive microorganisms. Increasing trend of QR value under conventional soil management was probably due to enhancement of soil basal respiration due to microbial stress. It might be contributed by higher salt concentration in soil solution due to higher synthetic fertilizer application as well as application of toxic pesticides for plant protection.

Respiration Quotient (QR) of the soil in the Project Area was very low (<0.1) in almost the entire garden area (93%), while a very small area (6%) was representative of a moderate QR status.

Soil Microbial Quotient (q_{MBC})

The microbial respiration per unit of microbial biomass is defined as the microbial quotient (qMBC) and 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,



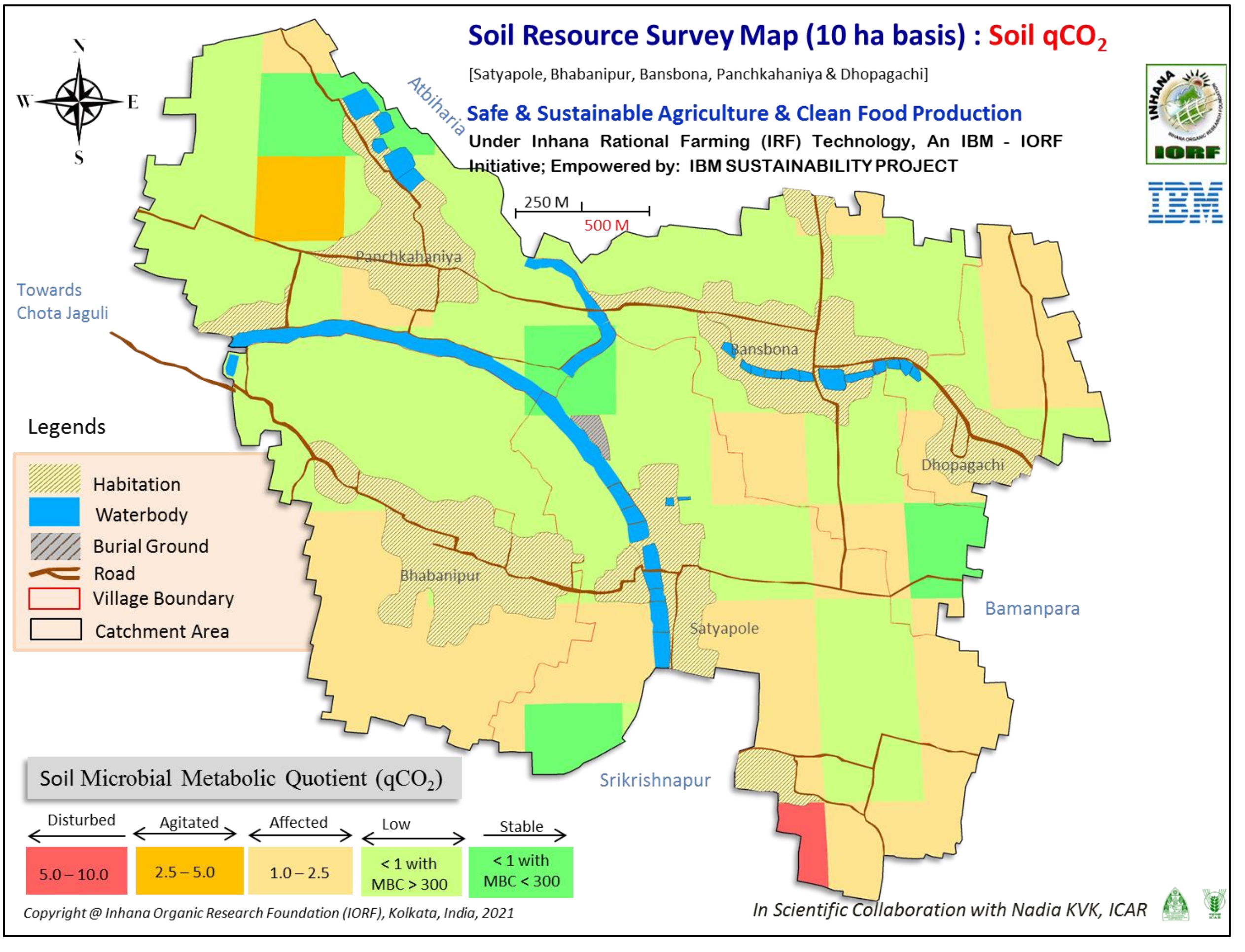
soil management and environmental variables. It is the ratio that expresses how much soil carbon is immobilized in microbial biomass.

Comparatively higher value of qMBC indicate better soil health with higher concentration of microbes in soil 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.

The qMBC of the soil in the Project Area was low (1.0-2.0) in about 45% area, moderate (2.01-3.0) in about 27% area and moderately high (3.01-4.0) in another 20% area.

Soil Microbial Metabolic Quotient (qCO_2)

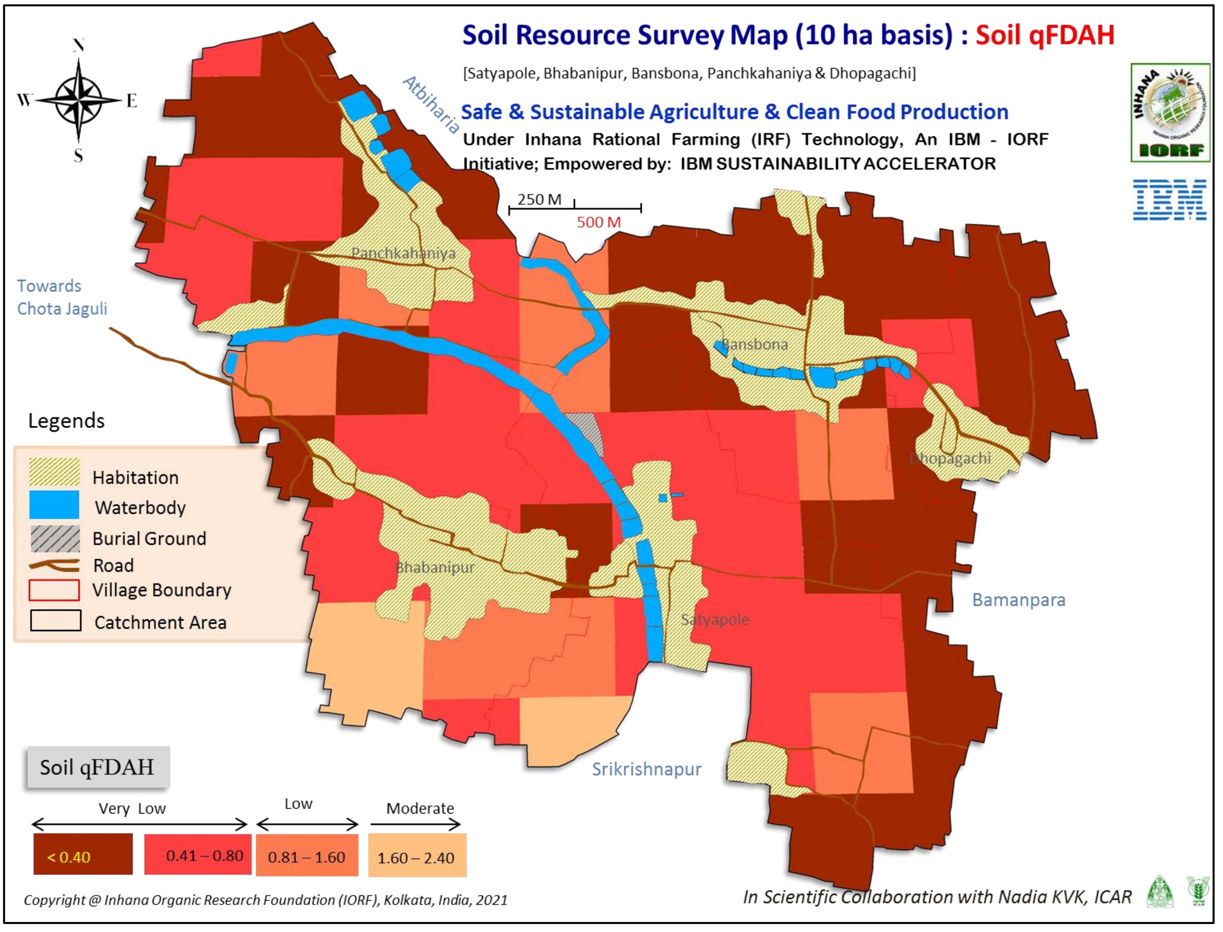
qCO_2 reflects the efficiency of heterotrophic microorganisms to convert organic carbon into microbial biomass. High values of *q*CO_2 usually indicate a stressful conditions in disturbed systems and, in general, conventional agro-systems present higher values in comparison to organic cultivation or natural



ecosystems. High values of *q*CO_2 usually indicate stressful conditions in disturbed systems (Garcia *et al*, 2002) and, in general, conventional chemical farming presents higher values in relation to organic cultivation or the natural ecosystems (Dilly and Munch, 1998). *q*CO_2 of the soil in the Project Area was very low (<0.1) in almost 42% area while a low status was observed in the rest (53%) area.

Soil qFDAH

qFDAH indicates the total enzymatic activity per unit organic carbon of the soil being tested. Higher value of qFDAH generally indicates higher number of microbes in active form which is required for soil-plant nutrient equilibrium. Organic/ sustainable soil management can influence the enhancement of qFDAH



values. In other words, qFDA can represent the dynamism of the soil or in other words, how much the soil is biologically active. qFDAH of the soil in the Project Area was very low (<0.8) to low (0.8-1.6) in almost the entire Project Area while a moderate (1.6-2.4) status was documented in a very insignificant area (5%).

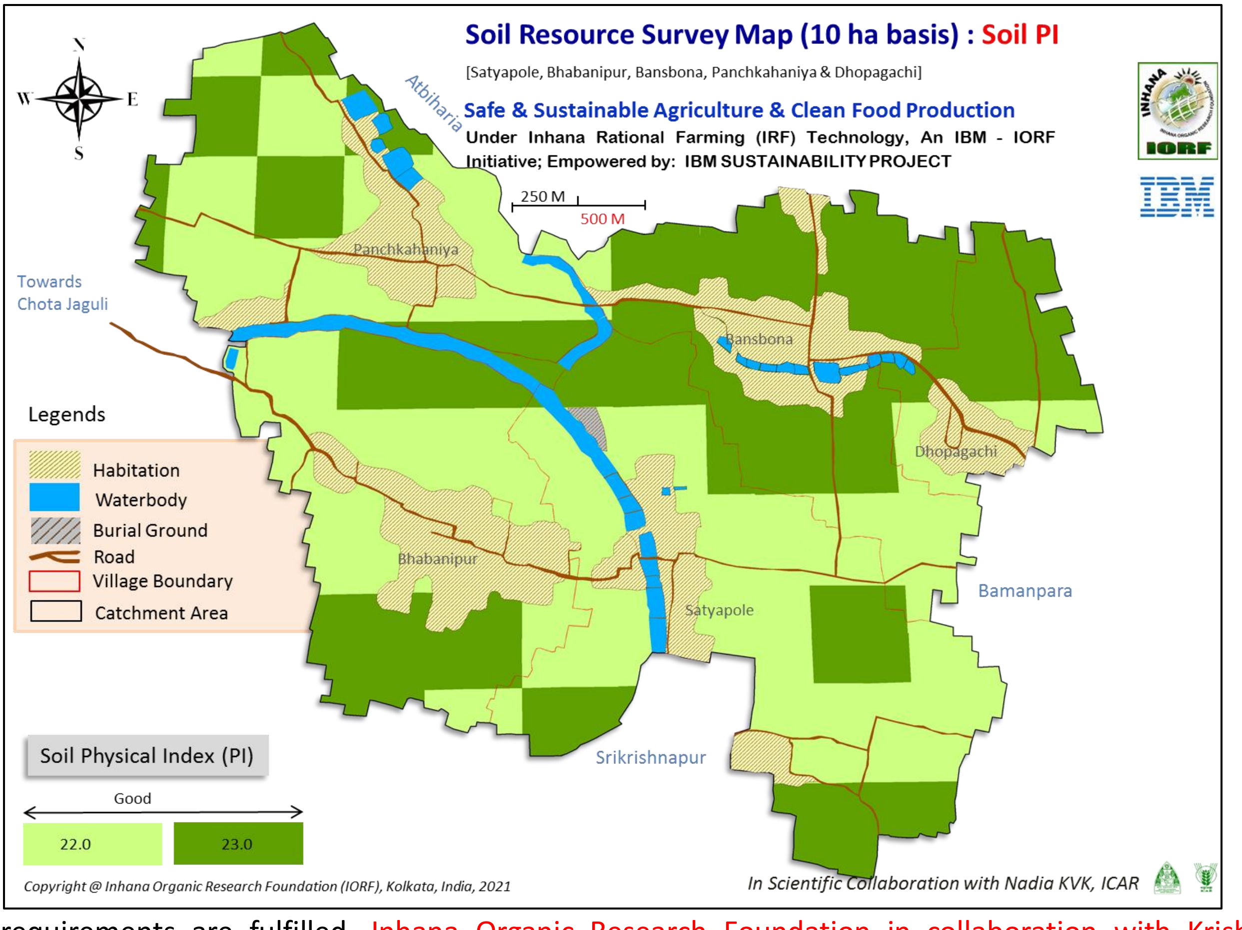
SOIL HEALTH INDICES

The Analytical Data Pool from the 26 Soil Quality Parameter Study was Interpreted by IORF using its various Tools & Indices towards computation of Soil Health Indices *viz.*, **Physical Index (PI), Fertility Index (FI) & Microbial Activity Potential (MAP).** The value of these indices were finally utilized for arriving at the **Soil Quality Index (SQI)- a 'Soil Health Indicator'** that depicts the **Soil Quality Status (SQS)** in terms of poor, moderate, good, etc. or in other words the **soil's potential in supporting Sustainable Crop Production**.

Interpretation of the soil analytical data in terms of various Soil Health Indices was done to provide the farmers access to their farm soil health status in a easily understandable format, in order to encourage the adoption sustainable soil practices

Soil Physical Index (PI)

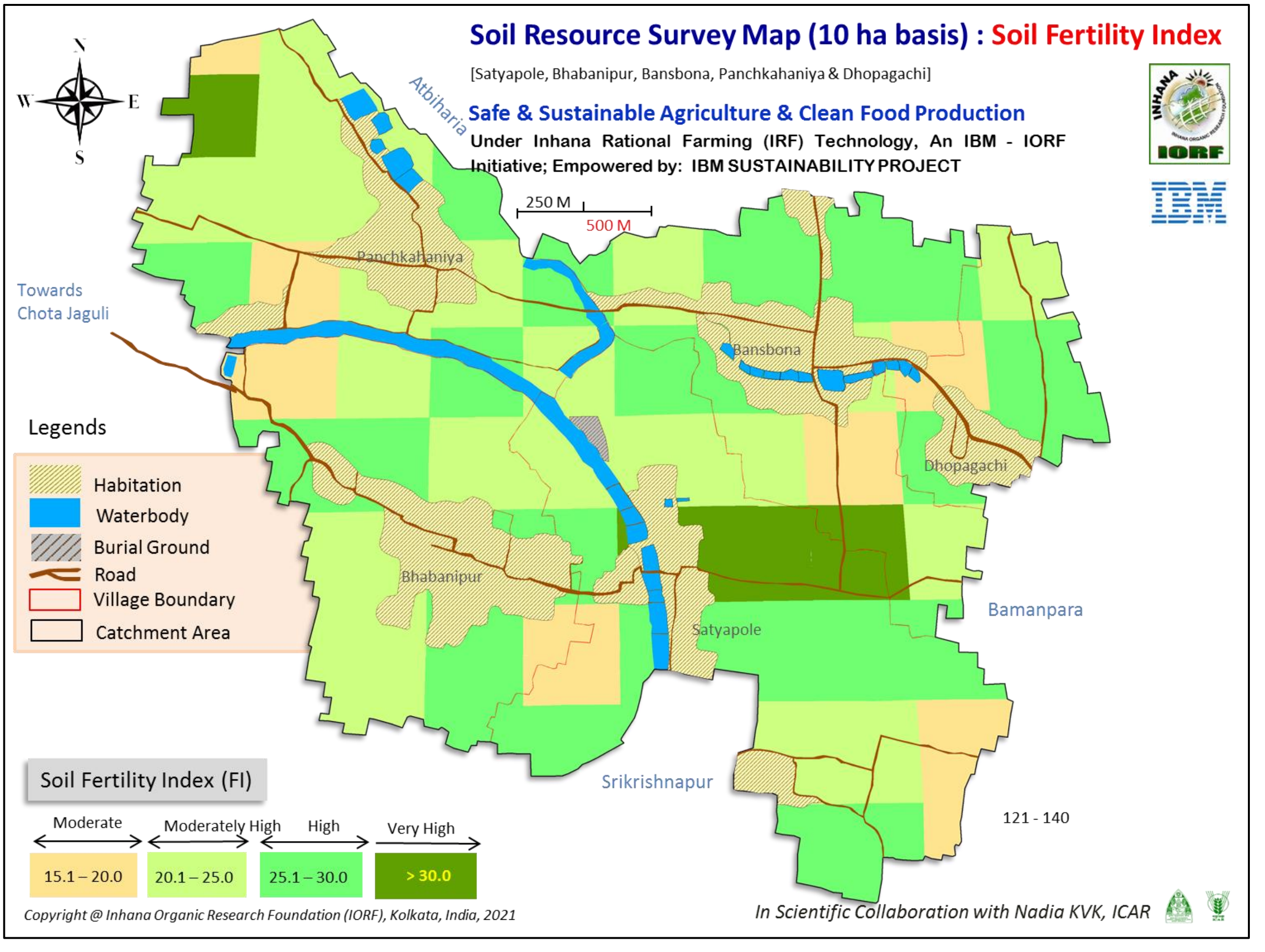
Knowledge of the physical properties of soil is essential for defining and/or improving soil health to achieve optimal productivity for each soil/ climatic condition. Unless the soil physical environment is maintained at its optimum level, the genetic yield potential of a crop cannot be realized even when all the other



requirements are fulfilled. Inhana Organic Research Foundation in collaboration with Krishi Vigyan Kendra (Howrah, ICAR) developed the Soil Physical Index (PI) to quantify the soil physical characteristics. Soil Physical Index (PI) was formulated by taking five major soil physical parameters *viz.* Soil Depth, Soil Coarse Fragment (%), Soil Texture, Soil Bulk Density and Soil Aggregates. Soil Physical Index (PI) of the soil in the Project Area was Good, and suitable for any type of vegetable cultivation.

Soil Fertility Index

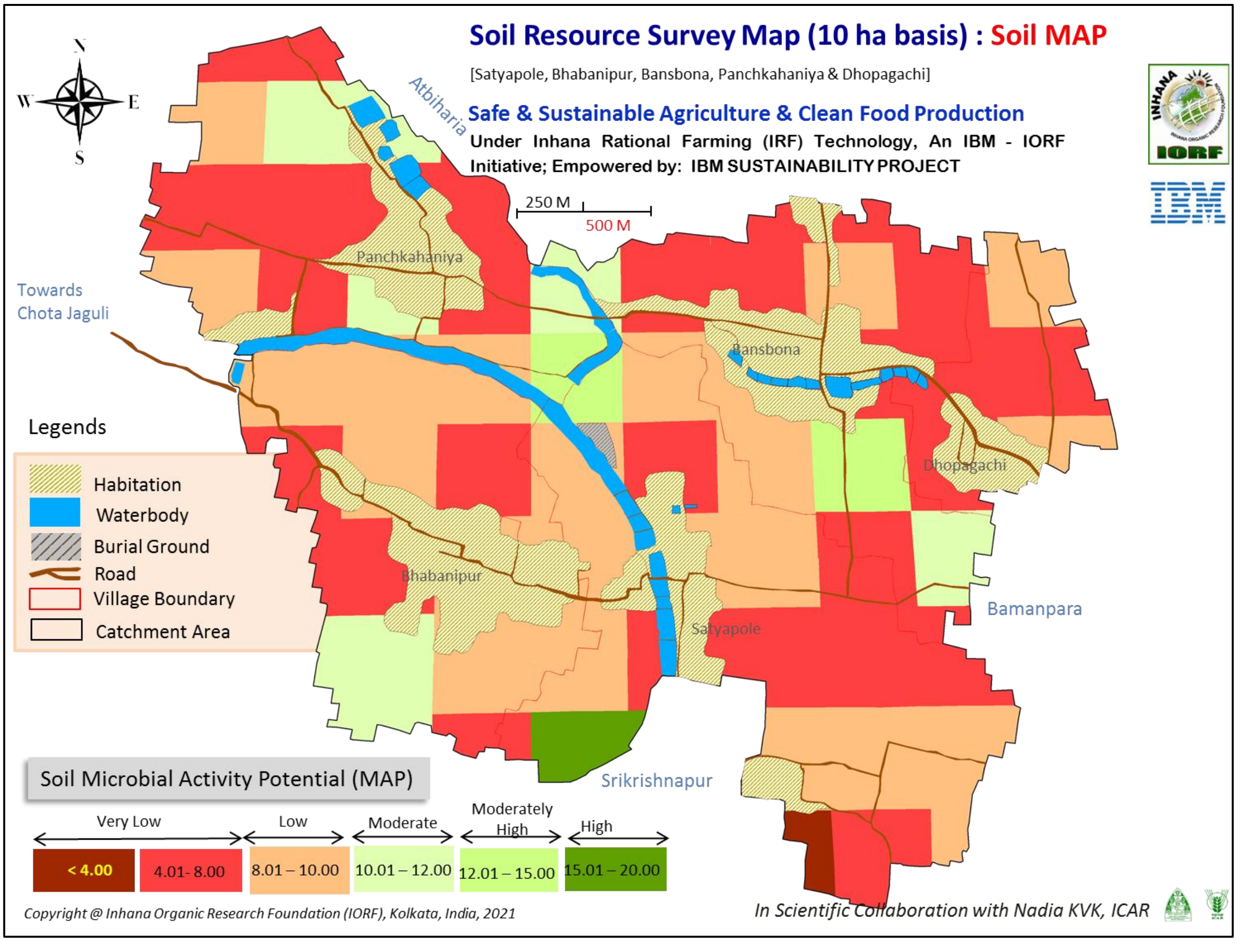
Soil Fertility Index (FI) is a tool for understanding the overall nutritive status of a soil for crop production as well as the extent of management required to sustain a desired yield. This tool was developed by IORF considering seven major soil parameters *viz.* pH, ECe, organic carbon, available N, 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 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 its overall nutrient supplying potential in terms of low, moderate, high, etc. Fertility Index of the soil in the Project Area was moderate (15-20) to moderately high (20-25) in more than 50% of the area, while high index value was noted in about 41% area.

Soil Microbial Activity Potential (MAP)

Soil Microbial Activity Potential (MAP) is actually a tool, which indicates 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),*

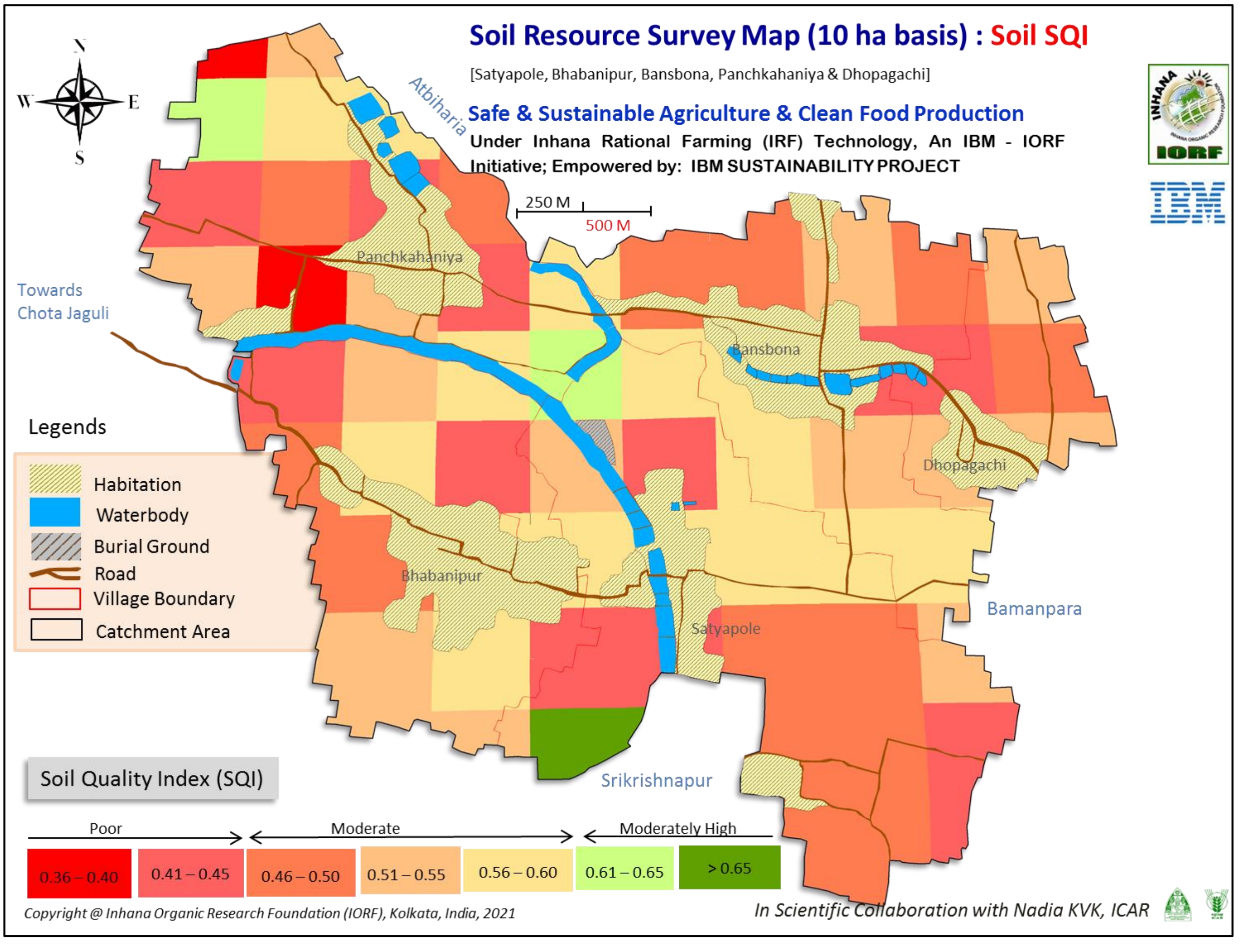


microbial quotient (qMBC), microbial metabolic quotient (qCO_2), microbial respiration quotient (QR) and specific hydrolytic activity (qFDA). Higher MAP value indicates a higher potential of the soil as a medium for sustainable crop production and also confirms the presence of the 'Soil Microbiological Barrier' against the soil borne disease causing pathogens.

Microbial Activity Potential (MAP) of the soil in the Project Area was very low (<8) to low (8-10) in a major 83% area. Moderate (10-12) values were observed in only about 11% area. The Project area has a cropping intensity of close to 2.5 to 3.0 and in a year the soil receives repeated application of fertilizers, especially nitrogenous which are known for their deleterious impact on the soil microbial dynamics.

Soil Quality Index (SQI)

On-farm assessment of soil quality and health is recommended to assist farmers to evaluate the effects of their management decisions on soil productivity. The main challenge is to develop soil quality and soil health standards to assess changes which are practical and useful to farmers. 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 have been identified to estimate soil quality. IORF, in collaboration with KVK (Howrah, ICAR) developed Soil Quality Index (SQI) suitable for Indian conditions which is the function of Soil Physical Index (PI), Soil Fertility Index (FI) and Soil Microbial Activity Potential and it was calculated as the area of a triangle.

Soil Quality Index (SQI) of the soil in the Project Area was moderate (0.46 – 0.60) in majority of area (72.4 % area) followed by poor status in 22.2 % area and moderately high status only in about 5.4 % area.

Development of SWOT Maps formed a very important component of the Project considering that quantification of the Strength, Weakness, Opportunity and Threat (if any) areas of the Project farms is crucial towards formulation of a Sustainable Soil and Plant Health Management Schedule, to meet the objective of Safe and Sustainable (Clean Food) Production. This study uniquely provides the sustainability status of a farm land and **such detailed assessment is presently lacking in the Indian agricultural scenario**, especially in the context of the small and the marginal land holdings.

In the Project area, the small and marginal farmers comprise 96% of the Total Farmers and the average land holding size is <0.26 hec. that is less than 1/6th of the set limit (2.0 hec.) Moreover, this small land holding is further fragmented in 4-5 plots with a size of about 0.1 hec. (i.e., about 95% lower than the suggested range) and that too is located in a scattered manner in a large radius of area. But in stark contrast, the cropping intensity is very high (about 2.5 to 3.0), meaning extreme dependence on land, leading to very high usage of unsustainable inputs like chemical fertilizers and pesticides. On the flip side the farmers lack the technological support or the scientific know- how in respect of adopting sustainable agricultural practices and the extreme resource poorness due to the land demography creates further bottleneck in this respect. Hence, IORF realized that first the Soil Health Status of the entire project area, going up to the micro level grid size of 0.16 hec.; has to be analyzed, then SWOT study has to be done and SWOT Interactive Maps encompassing all aspects of the soil as a resource base has to be developed so that a customized Sustainable Plan for Soil & Plant Health Management can be devised.

Initially it was decided that **1-2 SWOT maps will justify the objective**. However, as the data started coming in, it was revealed that the Criticality is far more than that considered during Project formulation towards disseminating Sustainability to the majority Agri- Producers i.e., the small and marginal farmers. **WE FINALLY DEVELOPED 10 SWOT MAPS**.

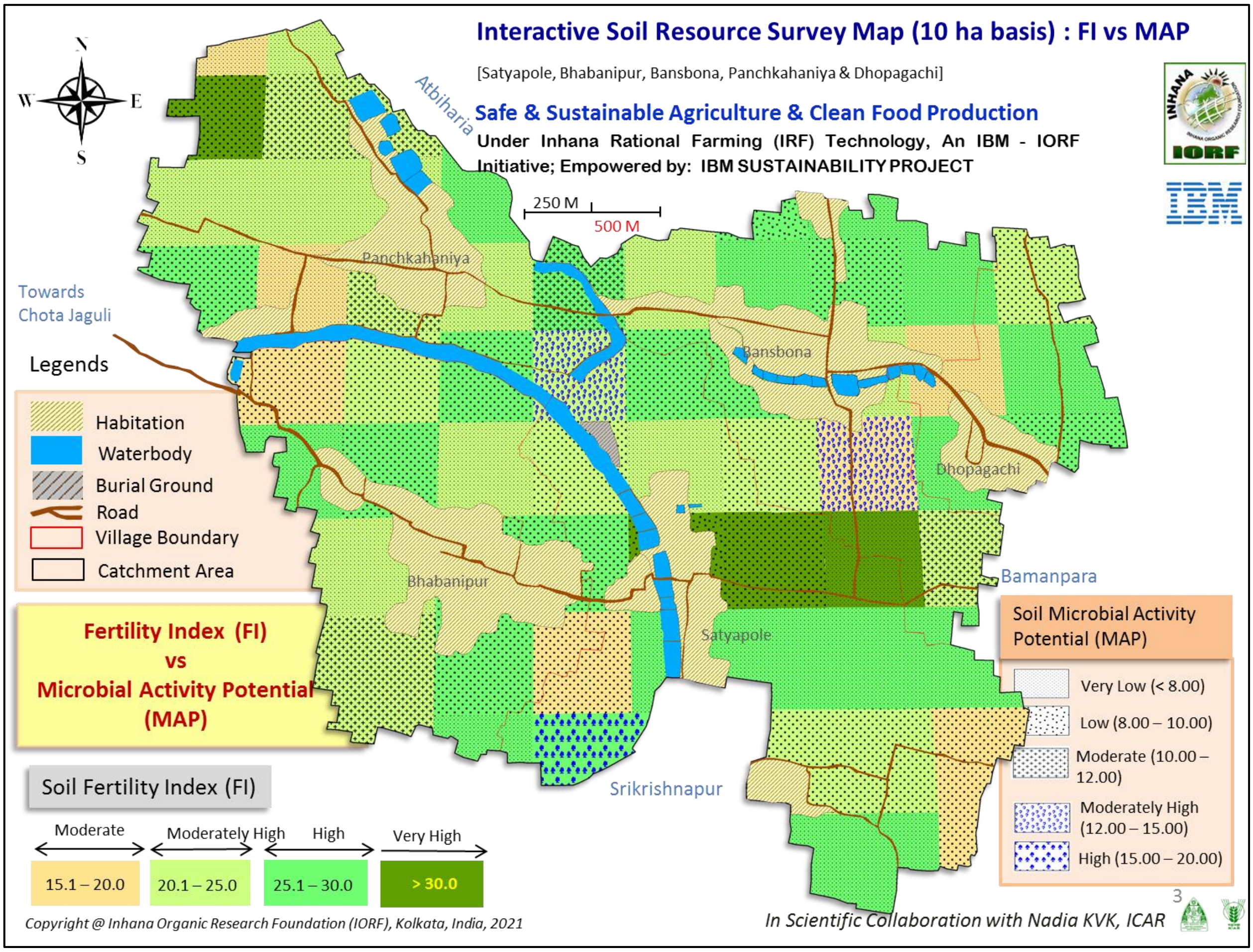
SWOT INTERACTIVE MAPS DEVELOPED

1. **Soil Fertility Index vs. Soil Microbial Activity Potential (MAP)**
2. **Soil Organic Carbon Status vs. Soil Microbial Activity Potential (MAP)**
3. **Soil Organic Carbon Status vs. Soil Nitrate- N**
4. **Soil Available- N vs. Soil Nitrate- N**
5. **Soil Microbial Biomass Carbon (MBC) vs. Soil Fluorescein Diacetate Hydrolytic Activity (FDAH)**
6. **Soil Quality Index (SQI) vs. Soil Microbial Activity Potential (MAP)**
7. **Soil Quality Index (SQI) vs. Soil Fluorescein Diacetate Hydrolytic Activity (FDAH)**
8. **Soil Quality Index (SQI) vs. Soil Organic Carbon**
9. **Soil Quality Index (SQI) vs. Soil Fertility Index (FI)**
10. **Soil Quality Index (SQI) vs. Soil Microbial Biomass Carbon (MBC)**

SWOT INTERACTIVE MAP: Fertility Index vs. Microbial Activity Potential

This Interactive Map shows the interrelatedness of Soil fertility with the Microbial Activity Potential.

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. A higher FI value indicates a balanced nutritional



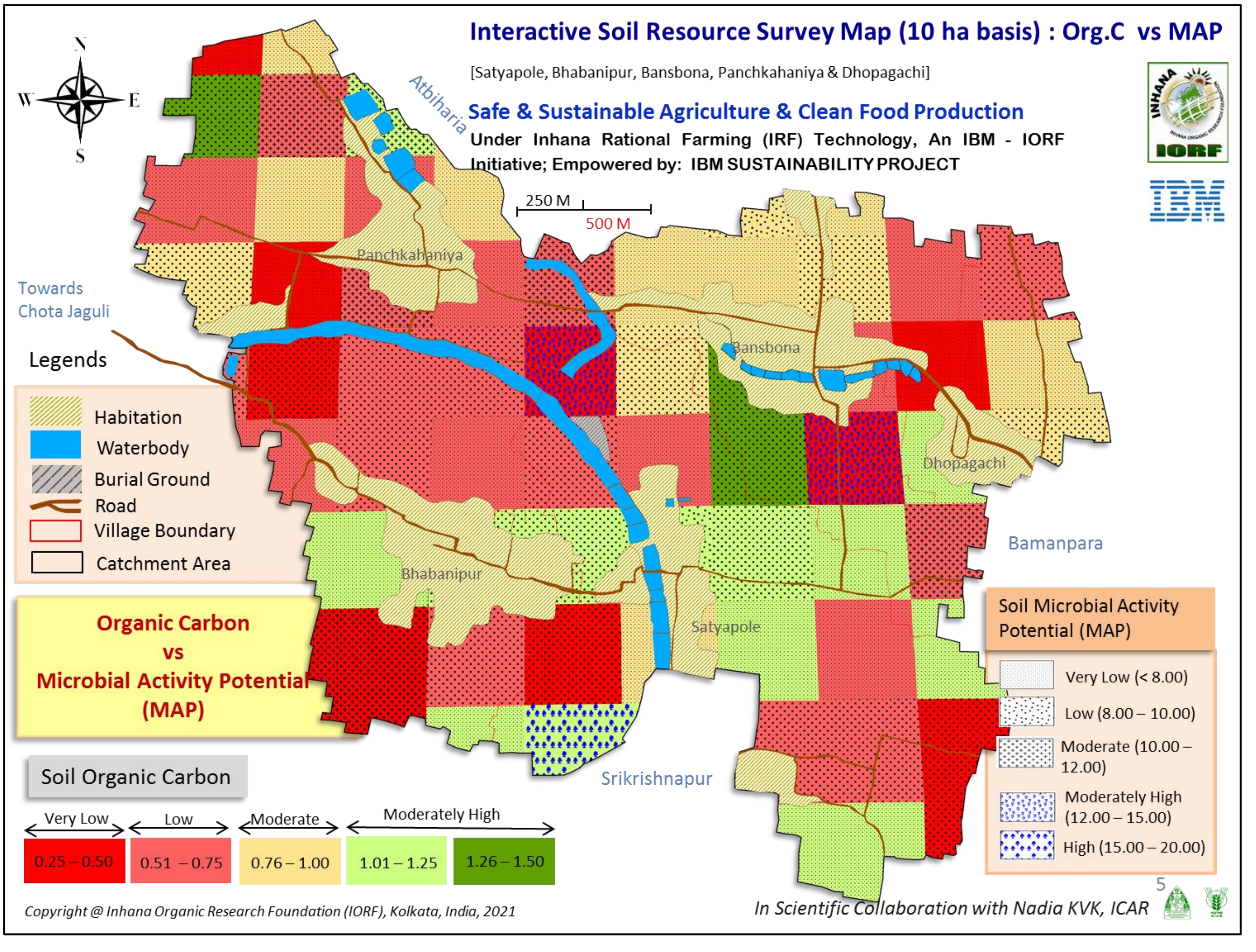
approach towards sustainable crop production. Soil Microbial Activity Potential (MAP) is another tool, which indicates the overall soil microbial status and its activity towards soil nutrient dynamics. Higher MAP value indicates a higher potential of the soil as a medium for sustainable crop production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

This SWOT Map indicates that the Project Area is representative of moderate to moderately high fertility, with contrasting low to very low MAP. This implies that due to lower microbial activity, loss of nutrient specially from these light textured soils is very high. Also crop productivity might not tally with the fertility as uptake and utilization of nutrients without active microbial presence will be seriously compromised.

SWOT INTERACTIVE MAP : Organic Carbon vs. Microbial Activity Potential (MAP)

This map depicts very interesting facts.

i) Low organic carbon with low microbial activity potential (MAP) indicates poor soil carbonic transformations and microbial dynamics. It warrants the need to reduce nitrogenous fertilizers and adopt sustainable Soil Management in order to restrict further soil depletion and initiate soil microbial interactions.



ii) Low organic carbon with moderately high microbial activity potential (MAP) : indicates some form of stress or pollutants in the soil which is inducing higher microbial activity as a survival strategy. This is a critical factor that can threaten crop yields and therefore needs immediate attention.

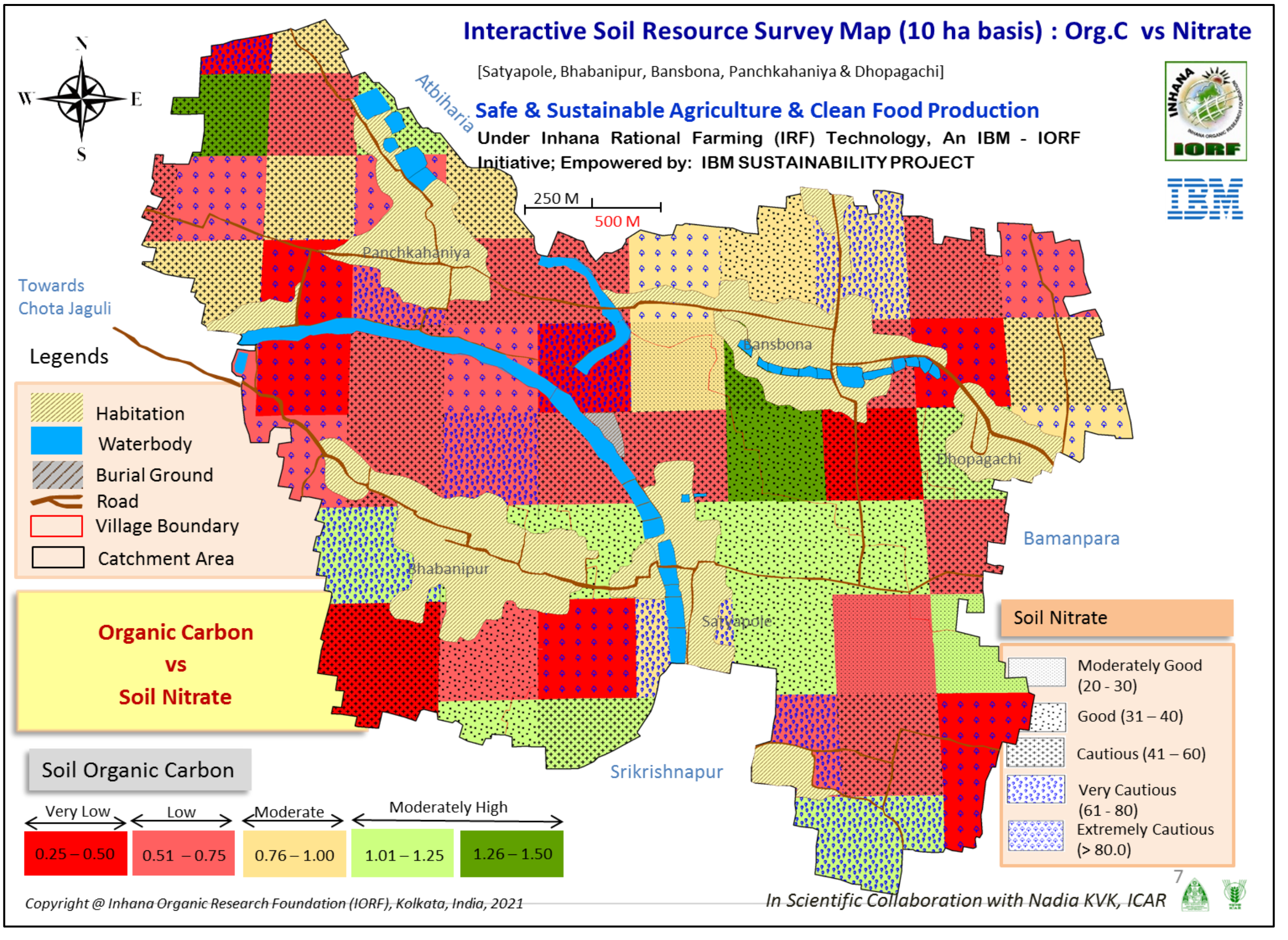
iii) Moderate high organic carbon with moderate microbial activity potential (MAP) : indicates that despite the availability of food resource, the microbial population in soil is relatively low and therefore the lower activity. This indicates towards the need for introducing an ideal exogenous soil inoculation that can jack up the micro flora population and thereby their activity potential.

iv) Moderate high organic carbon with moderate microbial activity potential (MAP) : indicates that only a little bit of soil integration with quality compost along with Plant Health Management can boost up the crop productivity.

SWOT INTERACTIVE MAP : Organic Carbon vs. Soil Nitrate

This map demonstrates a few important points :

i) Low organic carbon with low soil nitrate indicates poor soil nutrient dynamics and indicates that the soil is not at all functioning as an effective growth medium for plants. So crop sustainability is at stake till the time an effective Soil Health Management is undertaken.



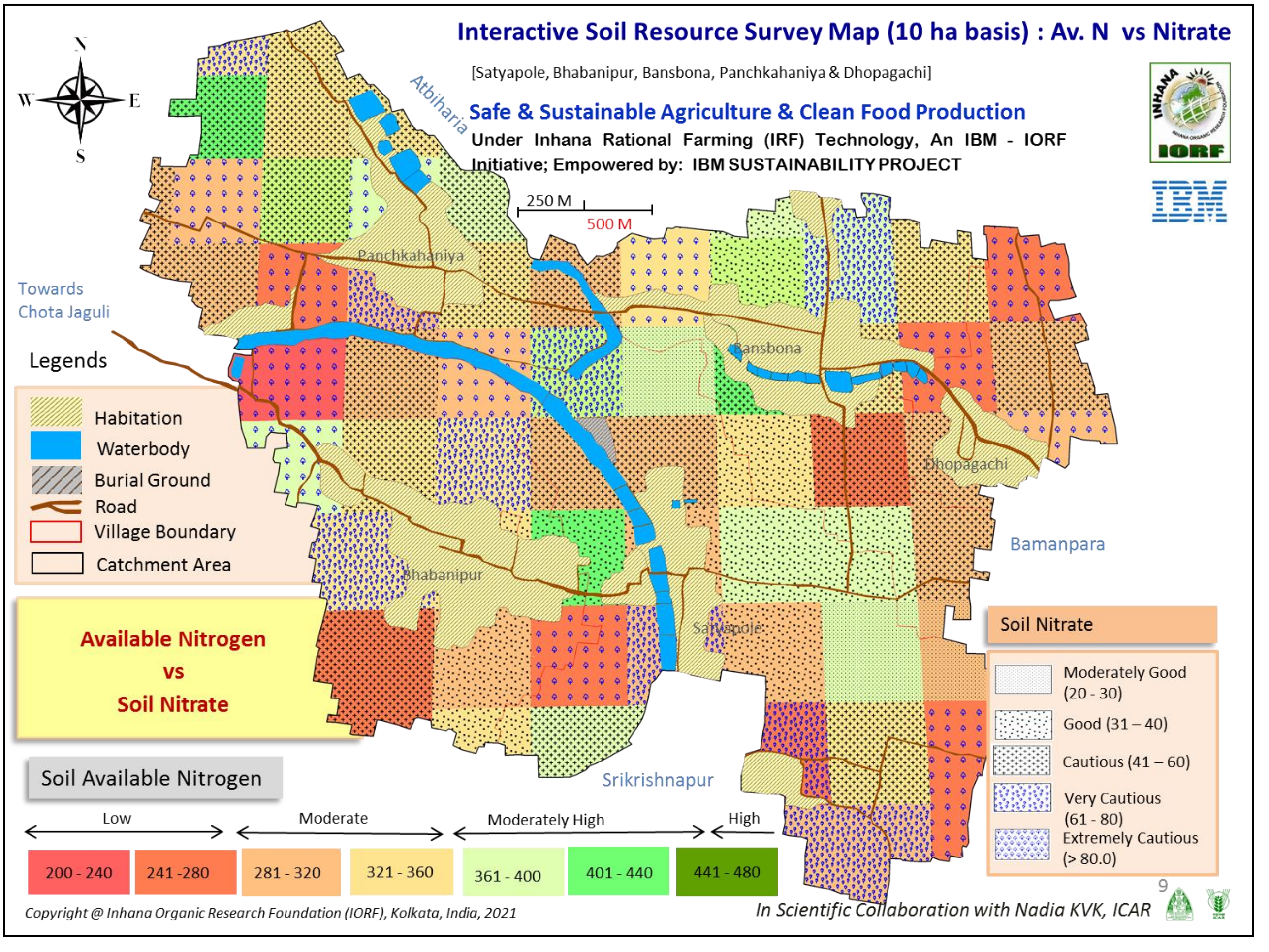
ii) Low organic carbon with moderately high (>40 kg/ ha) soil nitrate : indicates CAUTION considering higher chances of nitrate leaching resulting in soil and groundwater pollution. This indicates the immediate need for application of quality compost – having a high population of self- generated microflora, in order to improve the holding capacity of the soil as well as the soil- nitrogen dynamics.

iii) Moderate High organic carbon with moderate to moderately good nitrate : indicates an overall efficient soil nutrient dynamics that can provide the desired crop support. However, it also indicates the need for reducing the application of nitrogenous fertilizers and adoption of integrated management in soil in order to maintain the required nitrate content.

Soil Available- N vs. Soil Nitrate

This map demonstrates a few critical points :

i) Low soil available- N with low soil nitrate : indicates very poor soil Nitrogen dynamics, probably due to poor soil microbial activity. However, this is a critical factor considering that it can pose serous limitation to the crop yields especially considering that the project area is



a major vegetable growing belt of the Nadia district of West Bengal.

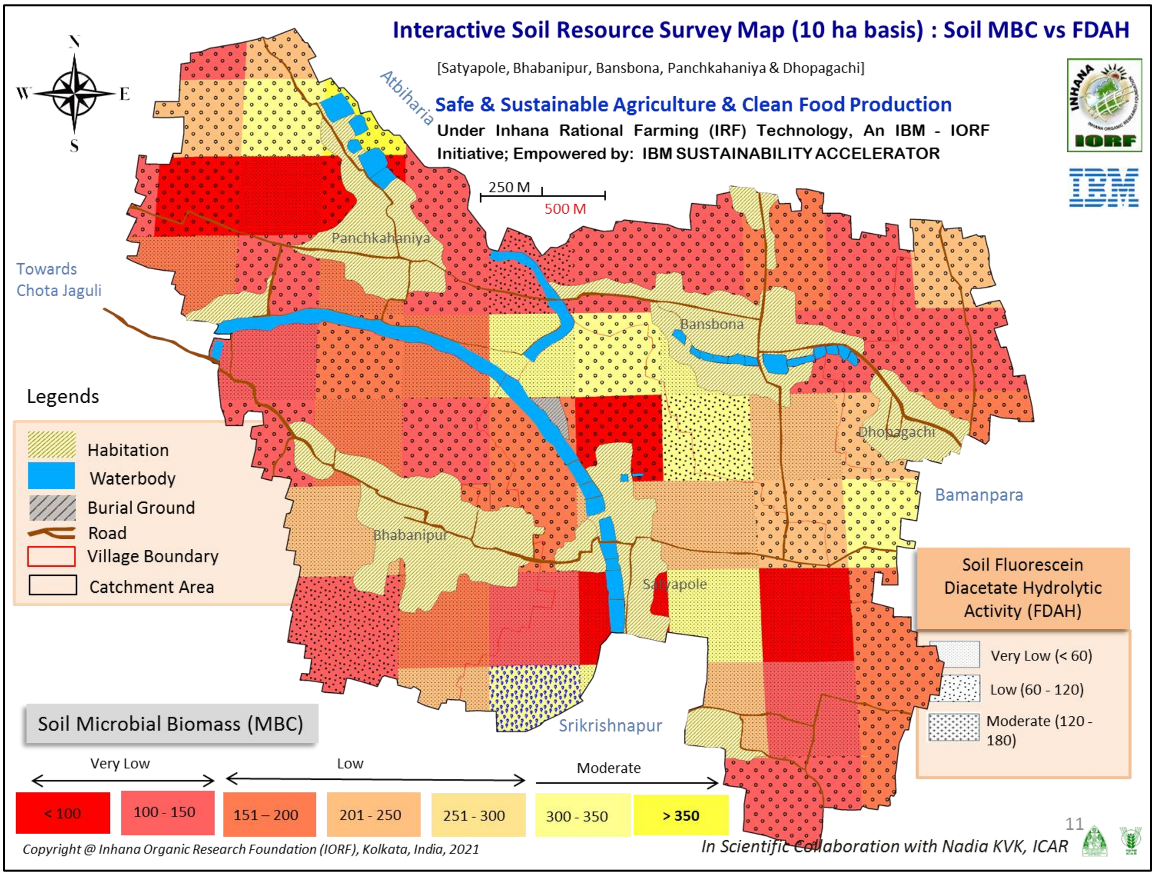
ii) Moderately high available- N with high (>40 kg/ ha) soil nitrate : indicates extreme CAUTION, considering higher chances of losses from the applied nitrogenous fertilizers. The Project Area is dominated by the small and marginal farmers with huge land fragmentation and huge dependence on the most unsustainable input i.e., chemical fertilizers. Diminishing fertilizer use efficiency means higher quantitative requirement *vis-à-vis* higher economic burden and the related unsustainability.

iii) Moderate High organic carbon with moderate to moderately good nitrate indicates an overall efficient soil nitrogen dynamics that can provide the desired crop support. However, it also indicates the need for adopting integrated management in soil in order to maintain the required available-N/ nitrate ratio.

Soil MBC vs. Soil FDAH

Microbial Biomass Carbon (MBC) is a sensitive indicator of changes in soil organic matter content because of variations in management and soil perturbations by pollutants.

FDAH indicates the total enzymatic activity of the soil being tested. Higher value of FDAH generally indicates higher number



of microbes in active form which is required for soil-plant nutrient equilibrium. In other words, this parameter represents the biologically active status of the soil. Now this Interactive Map provides some very interesting revelation:

i) Very low to low MBC with low FDAH : indicates that the soil is basically devoid of life with very poor microbial dynamics. So there is a critical need for reducing the chemical fertilizers on one hand and adopt an exhaustive Soil Health Management Program through the application of an ideal exogenous soil inoculation containing self- generated microflora; that can better acclimatize even in antagonistic soil conditions and thereby help in building up the native microbial population as well as their functional dynamics.

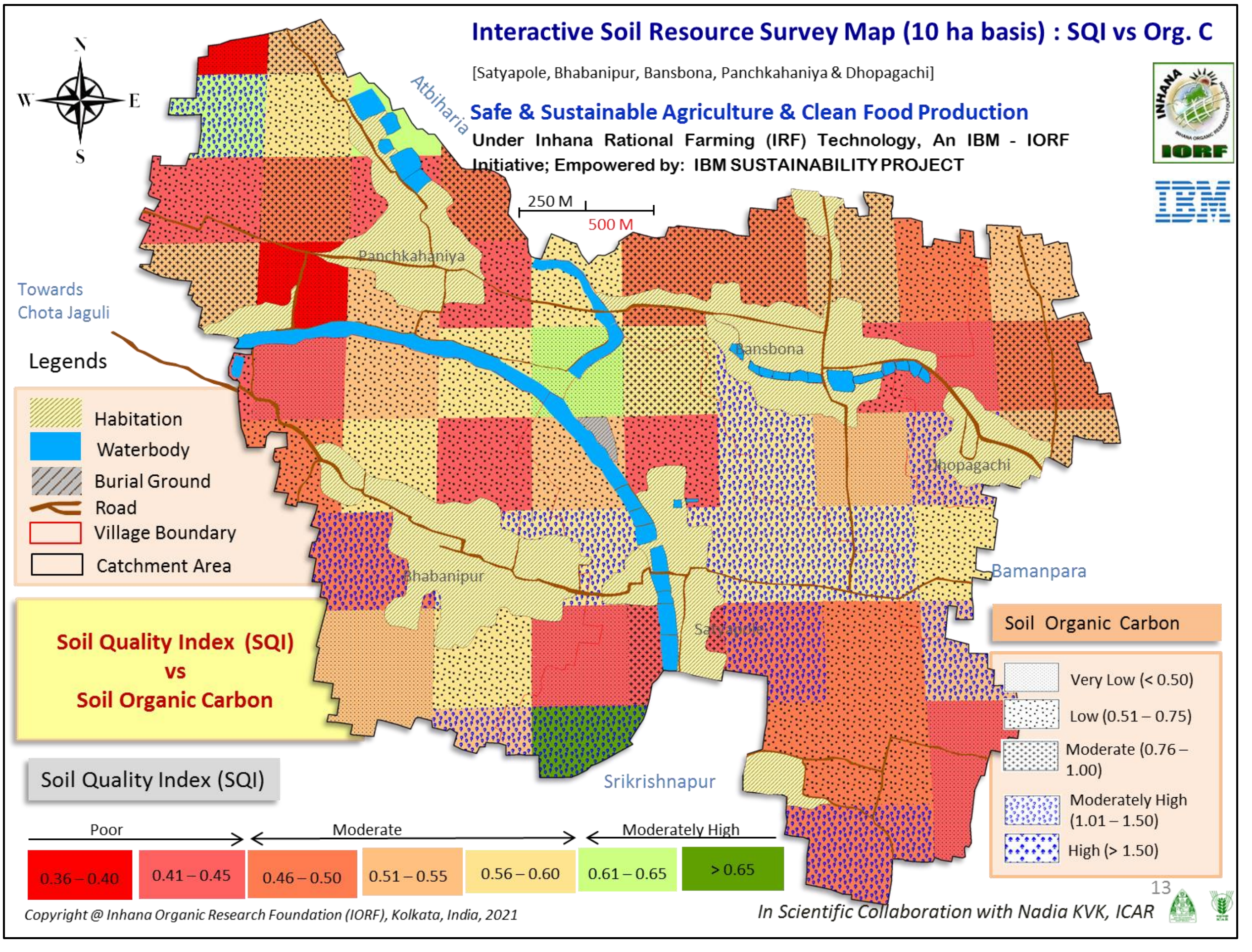
ii) Very low to low MBC with moderate FDAH : indicates low microbial population but moreover some form of stress or pollutants in the soil which is inducing higher microbial activity as a survival strategy. This is a critical factor that can threaten crop yields and therefore needs immediate attention.

iii) Moderate MBC with moderate FDAH: indicates a moderate soil dynamism, which needs to be built up through effective soil integration in order to ensure sustained crop production.

Soil SQI vs. Organic Carbon

The SQI developed by IORF is the function of soil physical index (PI), soil fertility Index (FI) and soil microbial activity potential and is calculated as the area of a triangle - is perhaps the most suitable in respect of the Indian farm soils.

Soil Organic Carbon is an important indicator for soil health in relation to its contribution to food production.



But more importantly today Agriculture is the only Sector that can be utilized for developing both the mitigation and adaptation strategies towards climate change and hence; can play a profound role in the achievement of the FAO Sustainable Development Goals – SOC is the major component in this respect.

This SWOT map indicates two very interesting phenomenon:

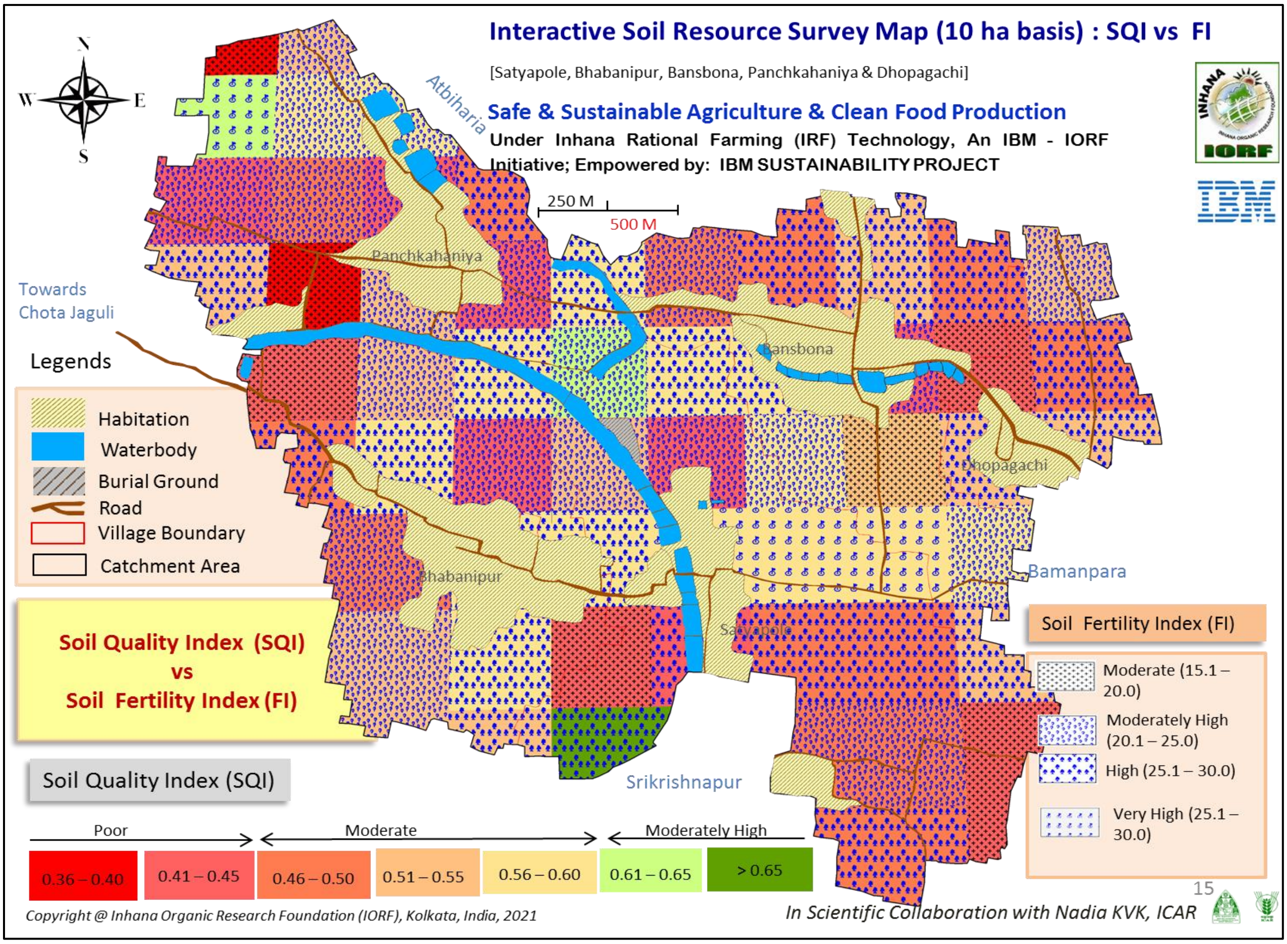
i) Poor Soil Quality Index with Moderately High to High Organic Carbon- this indicates that the carbon cycle in the soil is not effectively functional due to the concurrent poor soil microbial activity and is therefore unable to contribute much in building up the Soil Health Status.

ii) Moderate to Moderately High SQI with Moderately High to High SOC- this indicates a more stable carbon cycle with a dynamic influence towards the soil quality enhancement, which if properly managed can have critical relevance towards enhancement of the overall agricultural productivity in the project area.

Soil Quality Index (SQI) vs. Soil Fertility Index (FI)

This SWOT map indicates two very interesting phenomenon:

i) Poor Soil Quality Index with Moderately High to High FI- this indicates that the available nutrients in the soil solution are basically sourced from the applied chemical fertilizers and have no interrelation whatsoever with the overall soil nutrients reserve

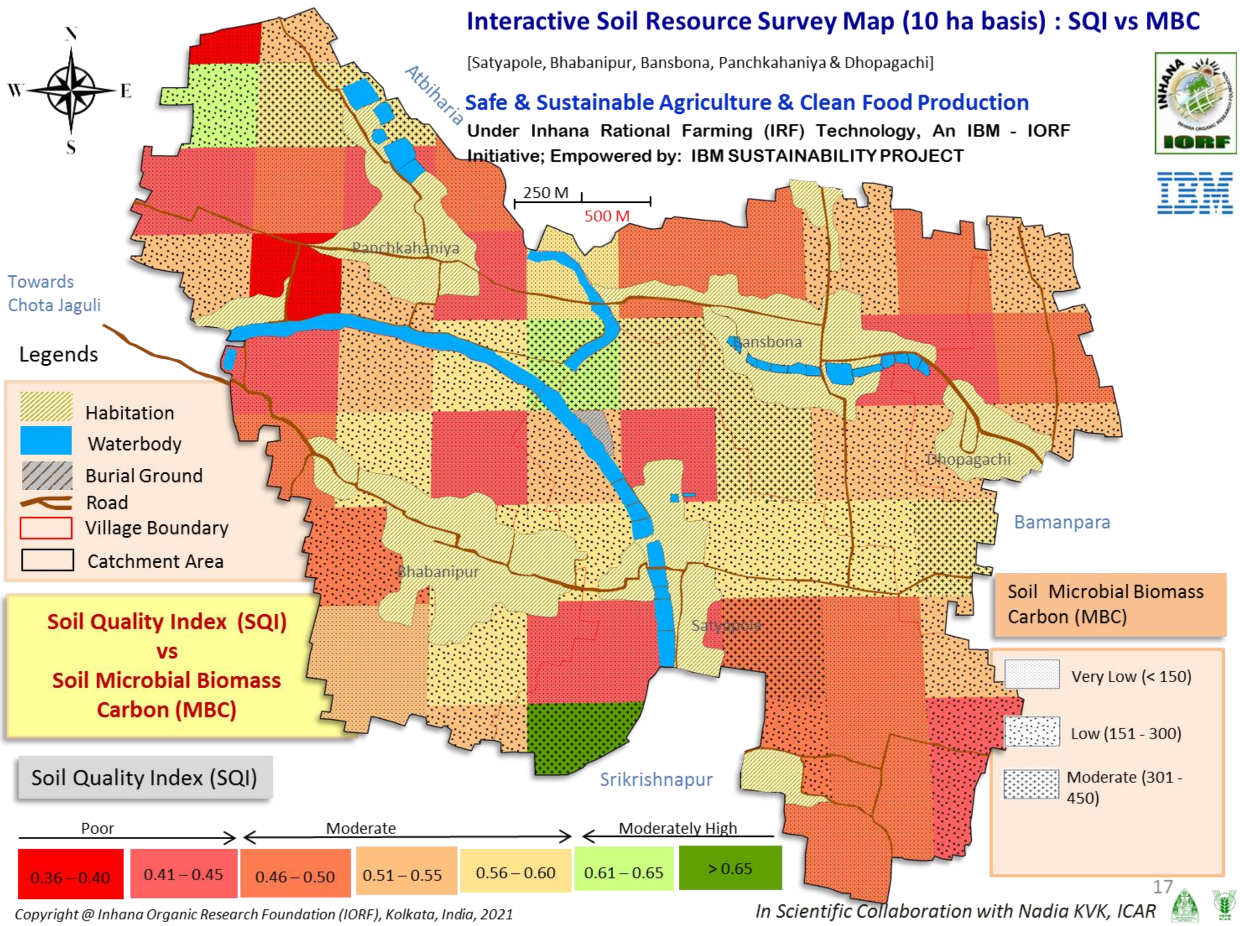


which is understandably poor. This indicates the extreme vulnerability of the soil towards crop sustenance and indicates that the existing dependence on unsustainable inputs is likely to become higher if comprehensive steps towards sustainable Soil Health Management is not undertaken.

i) Moderate to Moderately High SQI with High FI - this indicates a relatively better Soil Nutrient Reserve with a potential to supply the plant mineral requirements in the presence of an effective soil- plant- microbial dynamics. Reduction in the Chemical fertilizers and adoption of integrated management in soil will be prime requirement for that.

SQI vs. Soil Microbial Biomass Carbon MBC)

A simple and easily understood soil quality index is requisite for every farmer towards understanding their soil as well as for undertaking complementary management practice towards supporting crop yield. MBC represents the fraction of the soil responsible for the energy and nutrient cycling and

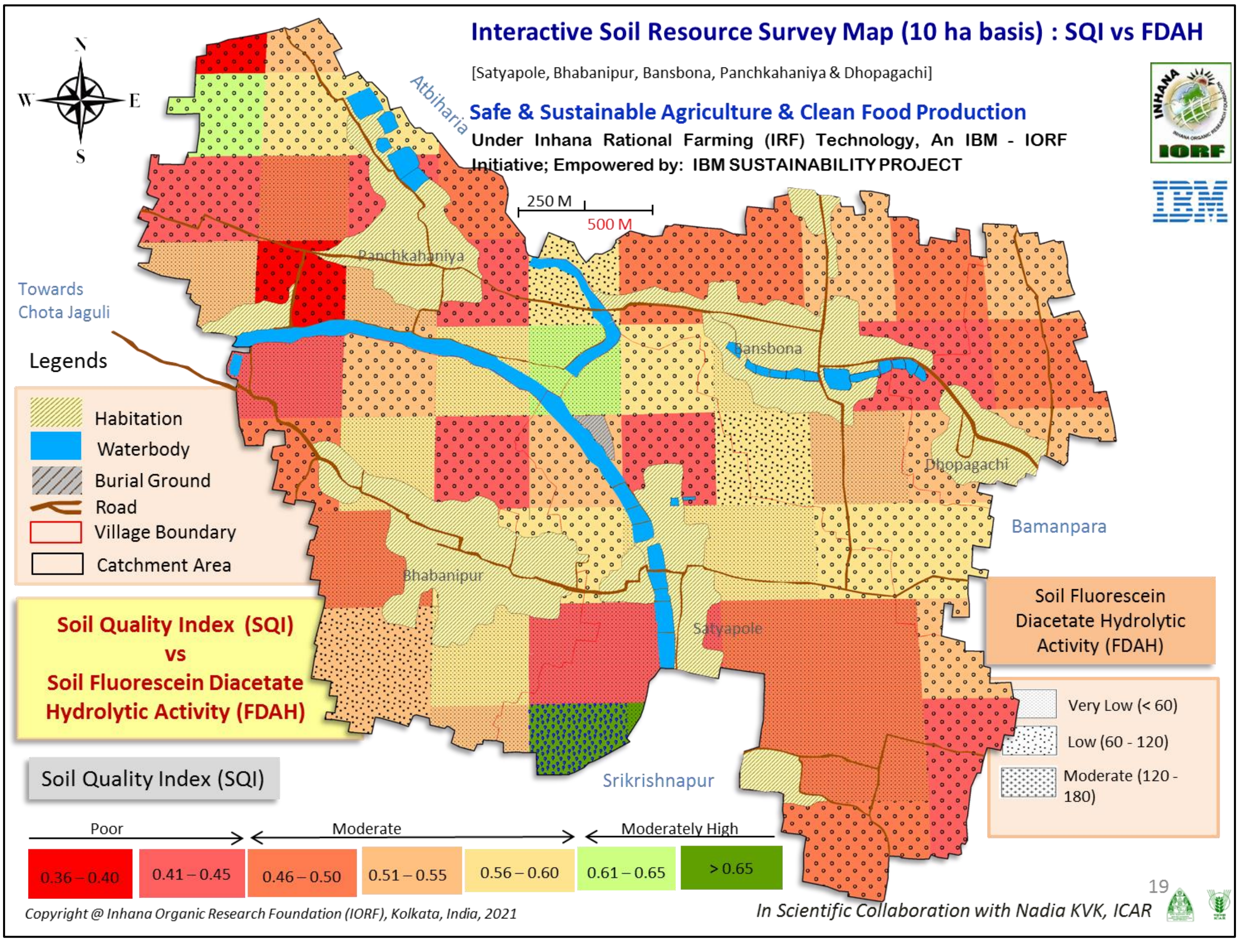


the regulation of organic matter transformation. It also has a close relationship with nitrogen mineralization and contributes to soil structure and stabilization; thus plays a crucial role in soil fertility as well as in agriculture. Thus soil quality and soil microbial biomass have a strong interrelatedness which is vividly depicted by this SWOT map of the project area; where most of the good soils (higher SQI value) have a comparatively higher soil microbial biomass value.

Soil Quality Index (SQI) vs. Soil FDAH

Soil Quality Index (SQI) is a tool towards understanding the true nature of soil productivity as well as measuring the change in soil quality in an accountable manner in relation to the undertaken management practices.

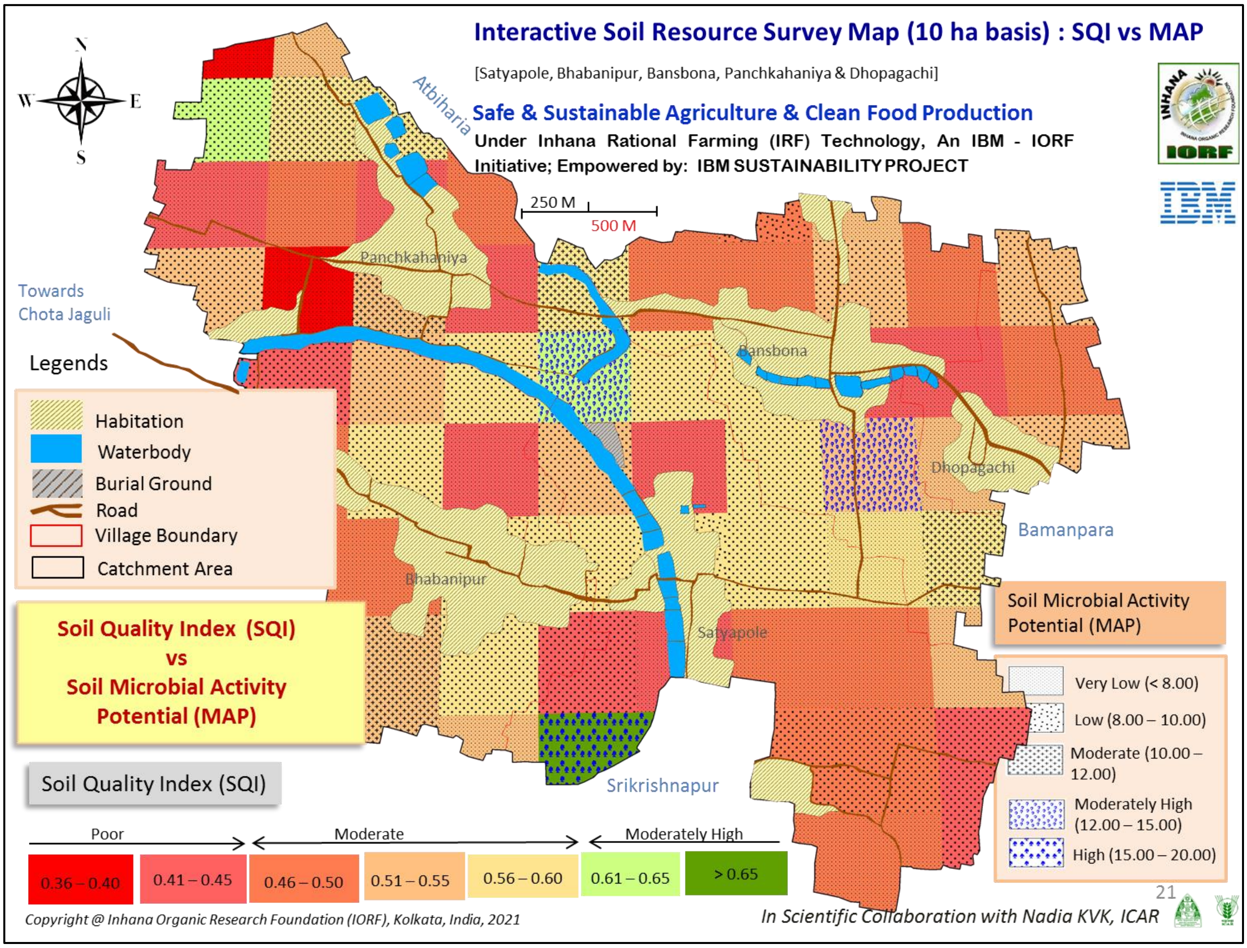
Whereas, Soil Fluorescein Diacetate Hydrolytic Activity (FDAH) represents the overall microbial activity in the soil in relation to the



state of the soil environment. The interactive map showed that soil quality and microbial activity represented by Soil Fluorescein Diacetate Hydrolytic Activity (FDAH) were closely interrelated considering that soil microbial activity was found to be comparatively higher in most of the higher soil quality zone and thus this interactive map has relevance in formulating area specific sustainable soil management guideline.

Soil Quality Index (SQI) vs. Microbial Activity Potential (MAP)

Expressing soil quality by a single point criteria or index is primarily focused on the needs of agricultural producers i.e. farmers, in order to provide them the tool for judging soil character, which has taken a paradigm shift from their local soil knowledge under years of industrial agriculture.



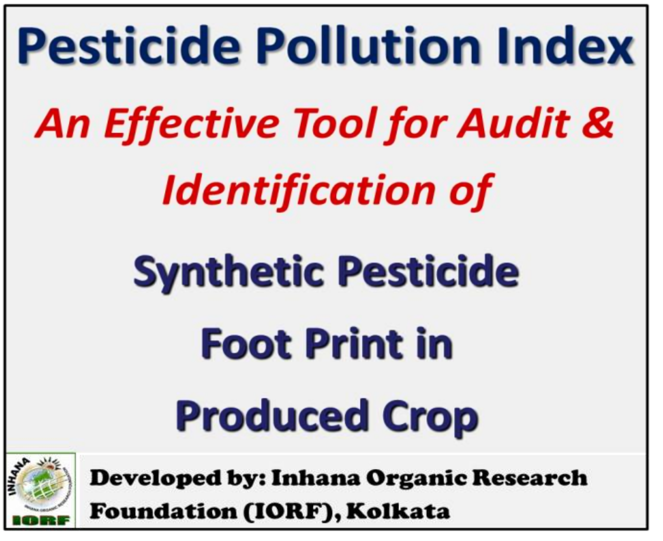
Soil Microbial Activity Potential (MAP) is another tool, which indicates the overall soil microbial status and their activity in respect of the soil nutrient dynamics. Higher MAP value indicates a higher potential of the soil as a medium for sustainable crop production and also confirms the presence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

The interactive map of the study area showed a close interrelationship between soil quality and soil microbial activity as most of the poor soils had a concurrent poor soil microbial activity.

Background

Due to the impact of climate change, plant pests are becoming more destructive and posing an increasing threat to food security and the environment. A single, unusually warm winter may be enough to assist the establishment of invasive pests (*Climate change fans spread of pests and threatens plants and crops, new FAO study, 2 June 2021, Rome*). According to the FAOSTAT database, global pesticide use (in tonnes of active ingredient) increased by 46% during the period 1996–2016. The growing human population has put increasing demand on agricultural productivity per hectare which contributes to intensified pesticide use.

As agriculture has grown and industrialized, farmers have become dependent on pesticides due to monocropping, intensified cropping practices season after season, on the same land and the loss of crop diversity. Moreover with poor education and no technical support, pesticide use by smallholders have deviated from agronomical recommendations, tending to overutilization of the hazardous compounds.



Pic. 1 : Awareness development program against indiscriminate pesticide use under IBM-IORF Sustainability Project

Ideally a pesticide must be lethal to the targeted pests, but not to non-target species, unfortunately, this is not the case. Moreover, even at levels deemed safe, pesticides have been shown to cause a loss of biodiversity, unleash ecosystem toxicity and contaminate the entire Food chain.

As for example, Neonicotinoids (or neonics), a popular class of pesticides that attack the nervous system of insects, are said to be safe chemicals due to their comparatively low toxicity to mammals and humans. However, a widening body of research links neonics to decline of pollinators – which will have wide ramifications towards crop production especially Vegetable Crops. A decline in pollinating insects in India is resulting in reduced vegetable yields and could limit people's access to a nutritional diet, a study warns. 'Pollination crisis' hitting India's vegetable farmers, *By Mark Kinver; Science and Environment Reporter, BBC News.*

In this context reliable pesticide risk indicators are pivotal to assess the potential risk associated with the use of pesticide. Pesticide risk indicators provide simple support in the assessment of environmental and health risks from pesticide use, and can therefore inform policies to foster a sustainable interaction of agriculture with the environment.

For their relative simplicity, indicators may be particularly useful under conditions of limited data availability and resources, such as in Less Developed Countries (LDCs).

This was the Background behind the development of Pesticide Pollution Indices by IORF.

Although Indian average consumption of pesticide is lower than many other developed economies, **the problem of pesticide residue is very high in India**. **This is due to the critical land fragmentation of the Indian Farms with contrasting High Cropping intensity**, leading to High Dependence on land and therefore extreme reliance on the unsustainable inputs like fertilizers and pesticides. In India **76% of the pesticide used is insecticide**, as against 44% globally (Mathur, 1999).

In respect of West Bengal, the pesticide use intensity is significantly higher than the other states. This is usually contributed by the fact that Vegetable Crops are grown in about 12.5 lakh hectare area, which is 24% of the net cropped area of the state. More than 98% of these vegetable farms are under small and marginal farmers with per capita land < 0.26 hectare that is almost 50% of the national average. Hence, the **resources are extremely scarce, the stakes are high and so is the pesticide use.**

In the project Area on one hand land fragmentation is critical (<0.26 ha), and on the other the cropping intensity is very high (2 to 3 and in some pockets >3)- indicates extreme dependence on land, very high crop pressure on land and simultaneously extreme dependence on the unsustainable inputs like pesticides and fertilizers to ensure that there is no crop loss.

Moreover, as the Project area falls in one of the major Vegetable Growing Belt of the state, and primarily follows the vegetable-vegetable cropping sequence- means land remains occupied round the year, hence the criticalness increases furthermore. Hence, it is Crucial to Assess the Pesticide Load on the Crop & Soil to understand the risk of Pesticide Contamination in the Project Area

Moreover as the objective of the Project is Safe & Sustainable 'Clean Food' Production, Safety was ensured through Two Mechanisms :

- Auditing Pesticide Use through Pesticide Footprint Study
- Actual Pesticide Residue Analysis of 'Clean Food'

Correlation Study to ascertain how the Audit results commensurate with the Analysis results.

What is Pesticide Footprint Study ?

Pesticide Footprint Study is the evaluation of the Pesticide Load on the Crop and Soil through the utilization of Pesticide Pollution Index (PPI). **This Index was developed to fulfill the requirement of a Simple yet Scientific Audit System for Risk Analysis** in terms of the Overall Toxicity Impact of the applied Pesticide on Crop and Soil.

i) Crop Pesticide Pollution Index (CPPI)

(ii) Soil Pesticide Pollution Index (SPPI)

The index can be easily assessed from available data, taking into account maximum related factors followed by their logical interpretation

What Do these Indices Indicate ?

Crop Pesticide Pollution Index (CPPI) indicates risk of pesticide contamination in the end product along with

(i) Risk potential related to crop sustainability

(ii) Impact of Management undertaken towards Ecological Farming.

Soil Pesticide Pollution Index (SPPI) indicates the usage status of toxic pesticides, along with their risk potential towards

(i) Soil Quality Degradation

(ii) Risk of pesticide residue in end product

(iii) Future vulnerability of crop sustainability under climate change impact.

SPPI is an Indicator of future Crop Sustainability. Study shows that SPPI is closely correlated with Microbial Metabolic Quotient (qCO_2), which represents microbial stress and serves as a useful measure of microbial efficiency (Wardle and Ghani, 1995). SPPI also correlates with the Microbial quotient (qMBC) that represents microflora dynamics within a soil system. The above indicate that the Soil Biological Properties which play a Crucial role towards ensuring Crop Sustainability is closely correlated with SPPI.

Background of Pesticide Pollution Index

Impact of pesticide pollution not only depends on the amount of pesticide used, but also on their chemical nature especially toxicity, persistence, and bioaccumulation potential etc. These indicate their actual threat towards food toxicity, soil quality degradation and ecological vulnerability at large. Ideally, an indicator needs to deal not just with the inherent hazard of a pesticide but rather with the potential risk it poses (Reus *et al.*, 2002). Development of Soil Pesticide Pollution Index (SPPI) & Crop Pesticide Pollution Index (CPPI) was done considering all related factors *viz.* toxicity, persistence in environment and contamination potential.

How was the Pesticide Pollution Index developed ?

Each Pesticide has different Toxicity and Harmfulness factor and simple summation of Individual Pesticidal load does not address the Issue. Five Critical Components drive the Pollution Potential of specific Pesticide on sprayed Crop. These are:

1. Toxicity (T_S)
2. Water Solubility (S_{WS})
3. Degradability Potential (D_C)
4. Persistence (P_C)
5. Bioaccumulation Potential (B_S)

How do these Critical Components Drive the Pollution Potential ?

Toxicity (T_S) : A pesticide with a lower LD_{50} is more toxic than a pesticide with a higher LD_{50}.

Water Solubility (S_{WS}) : Solubility of pesticides as it has two principal human health impacts due to (i) direct consumption of pesticide-contaminated water and (ii) consumption of fish and shellfish that are contaminated by pesticides (Ongley, 1996).

Degradability Potential (D_C) : Higher the half life (*the amount of time it takes for 50 percent of the parent compound to disappear from environment by transformation*), more threat of bio-accumulation in different ecological components.

Persistence (P_c) : Mobility of a pesticide in soil is dependent on partition coefficient K_{OC} value. Higher the value higher the risk of ground water contamination

Bioaccumulation Potential (B_S): Pesticides with a long half-life and high K_{ow} (*octanol-water partition coefficient*) have been shown to bio-accumulate in the food chain.

Factors Associated with development of Soil Pesticide Pollution Index (SPPI) /1

1. **Toxicity of an active ingredient (LD_{50} Value) :** Pesticides vary greatly in toxicity. Toxicity depends on the chemical and physical properties of a substance, and may be defined as the quality of being poisonous or harmful to animals or plants. A pesticide with a lower LD_{50} is more toxic than a pesticide with a higher LD_{50}.
2. **Exposure to surface water or Solubility :** Environmental exposure to active ingredients is greatly influenced by solubility of pesticides as it has two principal human health impacts due to (i) direct consumption of pesticide-contaminated water and (ii) consumption of fish and shellfish that are contaminated by pesticides (Ongley, 1996).
3. **Degradability Potential or half life (DT_{50}) :** Half-life DT_{50} which depends on chemical nature of a pesticide is the measure of the amount of time it takes for 50 percent of the parent compound to disappear from environment by transformation. Higher the half life, more threat of bioaccumulation in the different ecological components.
4. **Mobility Potential or pesticides partition coefficient (Log K_{OC}) value :** Mobility of a pesticide in soil depends on partition coefficient K_{OC} value of the pesticide. For a given amount of pesticide, the smaller the K_{oc} value, the greater the concentration of the pesticide in solution and higher risk of ground water contamination (FAO, 2000).
5. **Bioaccumulation potential (B_S) or pesticides octanol-water partition coefficient (K_{OW}) :** Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted and it has become a critical consideration in the regulation of chemicals. Pesticides with a long half-life and high K_{ow} have been shown to bio-accumulate in the food chain (PAN Pesticide data base, 2014).

Factors Associated with development of Crop Pesticide Pollution Index (CPPI)

Persistence (P_C) in terms of Pre-harvest Interval (PHI) : Pre-harvest interval (PHI) refers to the amount of time that must lapse (in days) after pesticide application before the crop is cut (i.e., swathed or straight cut). The pre-harvest interval (PHI) is a function of a pesticide's use pattern and of the amount of pesticide residues allowed on the crop at harvest. Risk of higher residue levels on a crop increases with high pre-harvest interval.

Scoring of Degradability Potential (D_P) based on half life of the active ingredients in plant : Pesticide risk and impact assessment models critically rely on and are sensitive to information describing dissipation from plants. Phase partitioning, inter-media transport, and degradation, that mainly drive pesticide dissipation and relate to the magnitude of residues in agricultural food crops and other plants (Fantke et al, 2014).

How CPPI & SPPI are calculated for Individual Pesticide ?

The major factors like toxicity, water solubility, degradability potential, persistence and bioaccumulation potential of individual pesticide; are used for calculating its Harmfulness Factor (HF).

The Harmfulness Factor value is then incorporated in Linear Indexing Formula to calculate Harmfulness Index (HI) of individual pesticide.

Harmfulness Index is finally multiplied with Active Ingredient load of each pesticide for Unit Crop or Unit Area to calculate Effective Pesticide Risk Potential in terms of CPPI and SPPI

HARMFULNESS INDEX (HI)- A Futuristic Tool for Safe & Sustainable Agriculture

Harmfulness Index (HI) is the fundamental base of Pesticide Pollution Indices – the most potent indicator of Safe and Sustainable Agriculture. HI is based on specific chemical properties of individual chemicals which determines the potential of specific pesticides in terms of their negative impact on environment as well as on human health.

Development of HI is probably the most comprehensive and scientific approach to identify a chemical pesticide as per its inherent potency towards becoming a threat to quality of any life form and stumbling block in the 'One Health' Concept conceived by FAO. According to FAO, One Health approach which integrates the health of humans, animals and the environment is crucial for achieving the Sustainable Development Goals (SDGs).

Calculation of Harmfulness Index was done from Harmfulness factors viz. toxicity, water solubility (S_{ws}), persistence (P_C), degradability in terms of pesticide dissipation half-life in plants (D_C), bioaccumulation potential (B_S) etc. through homothetic transformation method. Two different Harmfulness Index were developed looking at two different mechanisms of the spreading of toxicity of chemical pesticides which ultimately threatens the very objective of safe and sustainable agriculture.

When this HI (on crop) is multiplied with the dose & active ingredient percentage of that definite chemical it reflects the ACTUAL TOXICITY POTENTIAL of the Chemical. Thus, depending on the number of rounds sprayed of that chemical the TOXICITY LOAD due to that particular chemical will be judged that will help out in understanding the present risk of pesticide pollution as well as selection of comparatively less harmful chemical towards pest management.

Harmfulness Index is a 'less is better' index, where the index value cannot be zero as pollution by a given active ingredient cannot be completely nil. Higher value of HI will indicate potential of more detrimental impact of the chemicals on environment and the living beings. The Harmfulness Index (HI) have multipurpose usefulness towards not only the development of a tool for safe and sustainable agriculture, but at the same time an important curser for risk analysis in food safety, sustenance of biodiversity and most importantly evaluating threat factor to human health.

Uniqueness of HARMFULNESS INDEX (HI)

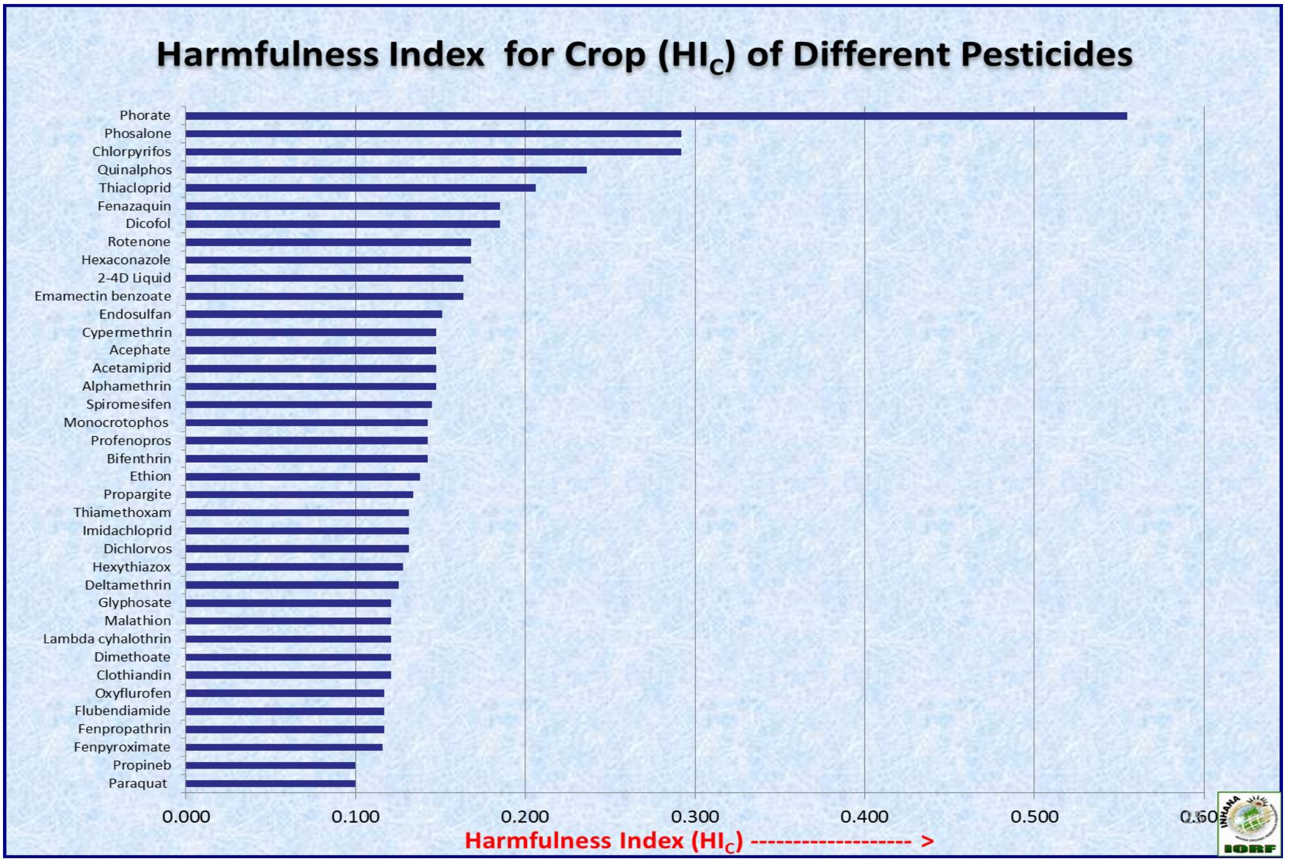
- **Indicates the Risk of Pesticide Pollution/ Actual Toxicity Load both Short & Long Term**.
- **The Total Toxicity Load (TTL)** can be measured in terms of :

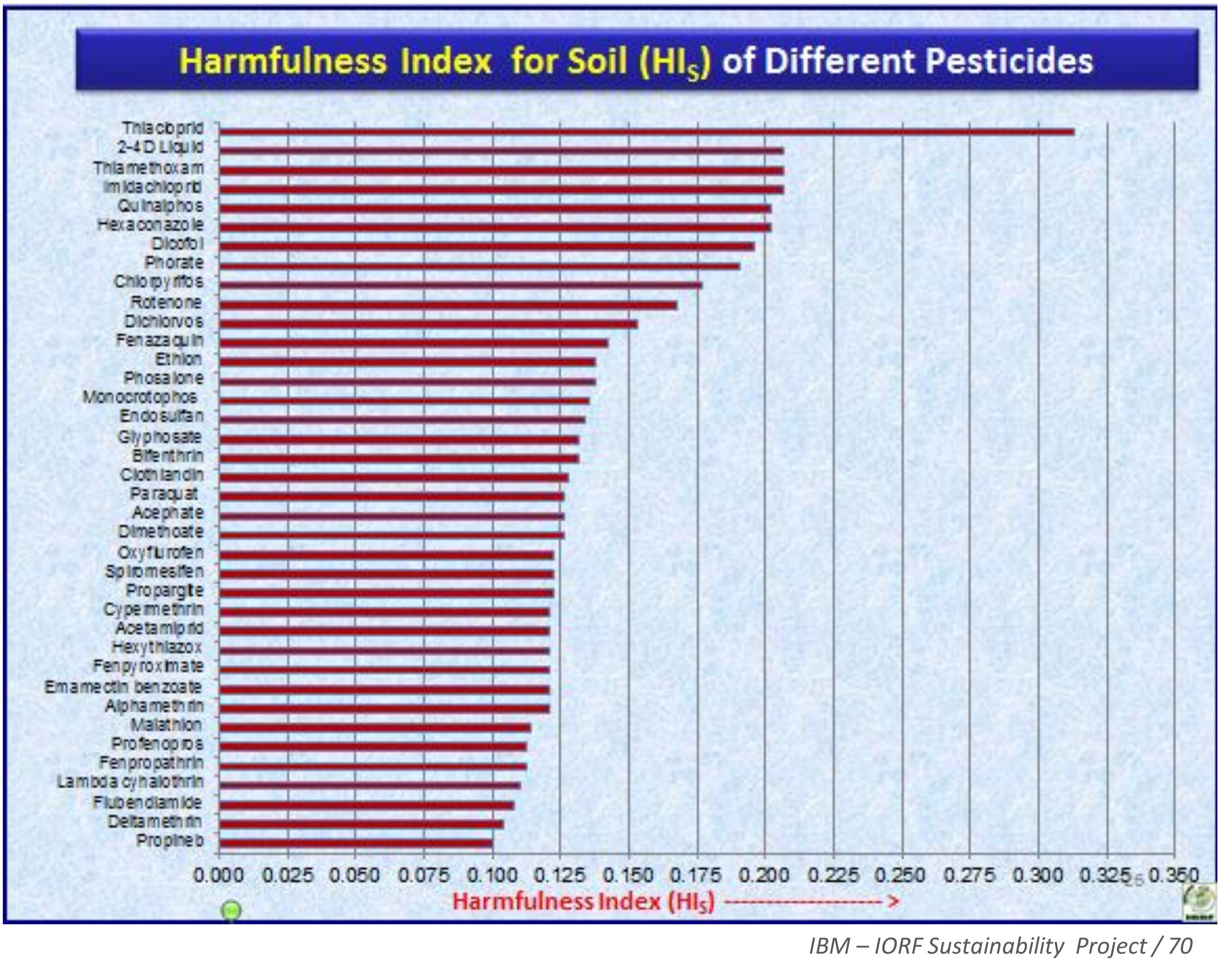
i. Specific Crop

ii. Specific time within the Cropping Period viz. weekly, monthly, etc.

HI can also play an important role in the process of decision making in conventional farming, towards undertaking sustainability initiatives or for measuring the management impact towards environmental sustenance. Attending environmental balance or manipulating ecological sustenance – All can be measured through HI based indicator tools.

Thus HI based Tools will form an integral part of futuristic Safe & Sustainable Initiatives to promote food safety and healthy diets, to increase the sustainability of agricultural practices, prevent environment-related human and animal health threats, as well as for combatting many other challenges related to Sustainable Development Goals (SDGs).


Harmfulness Index for Crop (HI_C) of Different Pesticides
Phorate
Phosalone
Chlorpyrifos
Quinalphos
Thiacloprid
Fenazaquin
Dicofol
Rotenone
Hexaconazole
2-4D Liquid
Emamectin benzoate
Endosulfan
Cypermethrin
Acephate
Acetamiprid
Alphamethrin
Spiromesifen
Monocrotophos
Profenopros
Bifenthrin
Ethion
Propargite
Thiamethoxam
Imidachloprid
Dichlorvos
Hexythiazox
Deltamethrin
Glyphosate
Malathion
Lambda cyhalothrin
Dimethoate
Clothiandin
Oxyflurofen
Flubendiamide
Fenpropathrin
Fenpyroximate
Propineb
Paraquat
0.000
0.100
0.200
0.300
0.400
0.500
0.600
Harmfulness Index (HI_C) ------------------- >


Harmfulness Index for Soil (HI_S) of Different Pesticides
Thiacloprid
2-4D Liquid
Thiamethoxam
Imidachloprid
Quinalphos
Hexaconazole
Dicofol
Phorate
Chlorpyrifos
Rotenone
Dichlorvos
Fenazaquin
Ethion
Phosalone
Monocrotophos
Endosulfan
Glyphosate
Bifenthrin
Clothiandin
Paraquat
Acephate
Dimethoate
Oxyflurofen
Spiromesifen
Propargite
Cypermethrin
Acetamiprid
Hexythiazox
Fenpyroximate
Emamectin benzoate
Alphamethrin
Malathion
Profenopros
Fenpropathrin
Lambda cyhalothrin
Flubendiamide
Deltamethrin
Propineb
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
0.200
0.225
0.250
0.275
0.300
0.325
0.350
Harmfulness Index (HI_S) ------------------- >

Crop Pesticide Pollution Index (CPPI)

CPPI was developed to assess the potential impact of the pesticides on Crop in the study area in a defined time frame.

A unique scoring system was developed related to pesticide toxicity (T_S), solubility (S_{WS}), degradability in plant (D_P), persistence (P_C) and bioaccumulation potential (B_S) before determining the harmfulness index for crop (HI_C) used to calculate the final Crop Pesticide Pollution Index (CPPI)

Pesticides' toxicity (T_S) which is used for final CPPI calculation also enables Product (chemical ingredient) wise Toxicity Load for easy reference by the farmers.

The crop pesticide pollution Index (CPPI) for a defined study area (A) and defined time scale and for a pesticide program including 'n' active ingredients was calculated as per following equation

$$\mathrm{CPPI} = \frac{1}{C} \times \sum_{i=1}^{i=n} (PL_{C1} \times HI_{C1}) + (PL_{C2} \times HI_{C2}) + \text{------} + (PL_{Cn} \times HI_{Cn})$$

For an easier representation CPPI value was transformed into five qualitative classes: Very Low, Low, Moderate, High & Very High. For development of CPPI class, minimum and optimum CPPI value were sourced from IORF and University Pesticide Data base of different farms.

Soil Pesticide Pollution Index (SPPI)

SPPI was developed to bring forth a simple tool for assessment of Product (chemical ingredient) wise Toxicity Load for easy reference by the farmers along with assessment of potential impact of pesticides towards soil in the study area within a defined time frame, SPPI was developed.

A unique scoring system was developed related to pesticide toxicity (T_S), solubility (S_{WS}), degradability (D_S), mobility (K_{OC}) and bioaccumulation potential (B_S) before determining the harmfulness index (HIS) for soil that is used for calculating the final Soil Pesticide Pollution Index (SPPI).

The soil pesticide pollution Index (SPPI) for a defined study area (A) and defined time scale and for a pesticide program including 'n' active ingredients was calculated as per following equation

$$\mathrm{SPPI} = \frac{1}{A} \times \sum_{i=1}^{i=n} (PL_{S1} \times HI_1) + (PL_{S2} \times HI_2) + \text{------} + (PL_{Sn} \times HI_n)$$

For an easier representation SPPI value was transformed into five qualitative classes: Very Low, Low, Moderate, High & Very High. For development of SPPI class, minimum and optimum SPPI value were sourced from IORF and University Pesticide Data base of different farms.

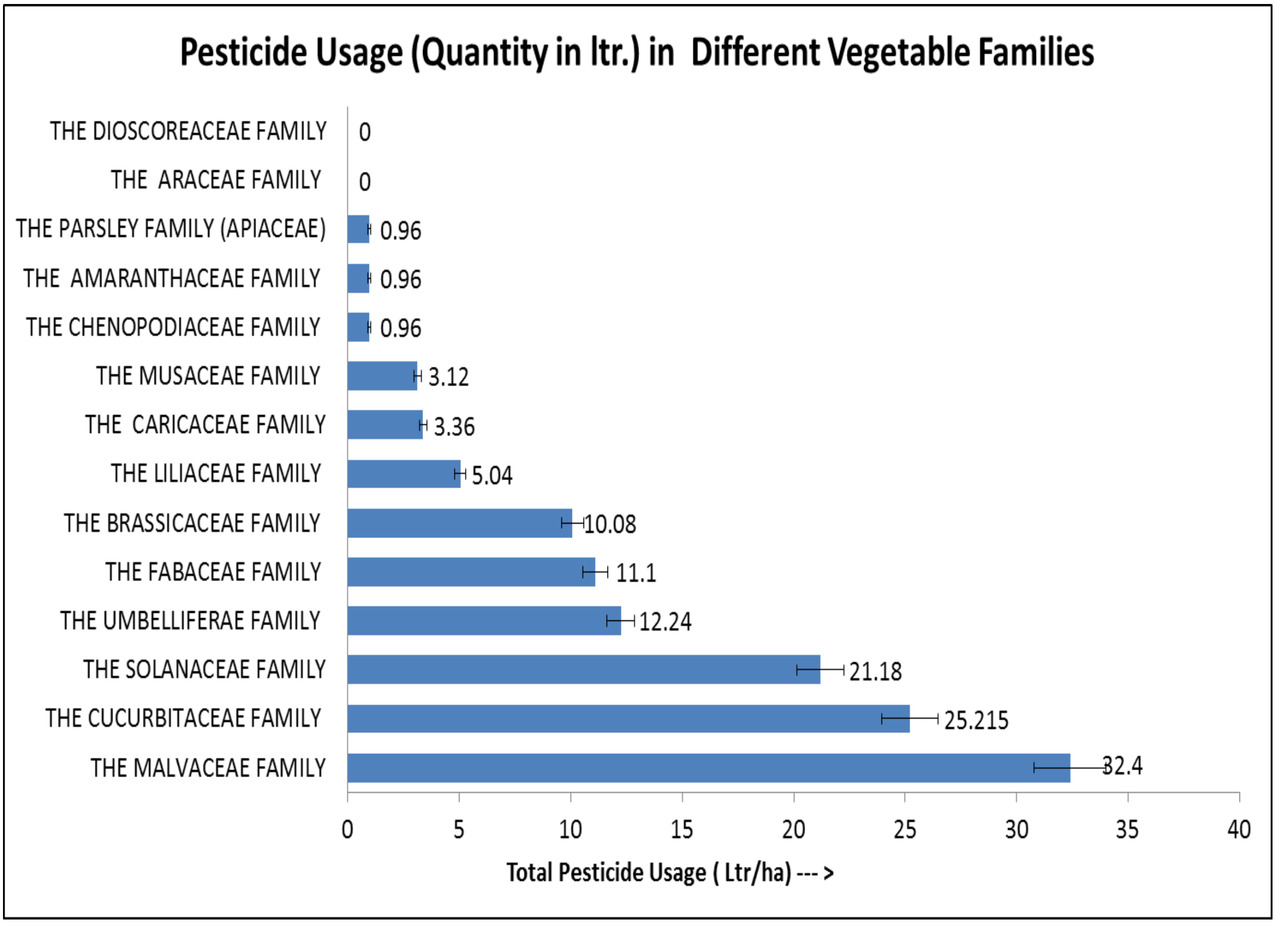
Why the Pesticide Pollution Index is Convenient to Adopt ?

The index is made in such a way, that it can be easily assessed from the available data, while taking into account maximum related factors with their logical interpretation.

Calculation of Crop Pesticide Pollution Load (CPPL) and Soil Pesticide Pollution Load (SPPL) is based on the essential factors *viz.* toxicity, half life, solubility, persistence, bioaccumulation potential, mobility etc. which govern the potential risk associated with each pesticide.

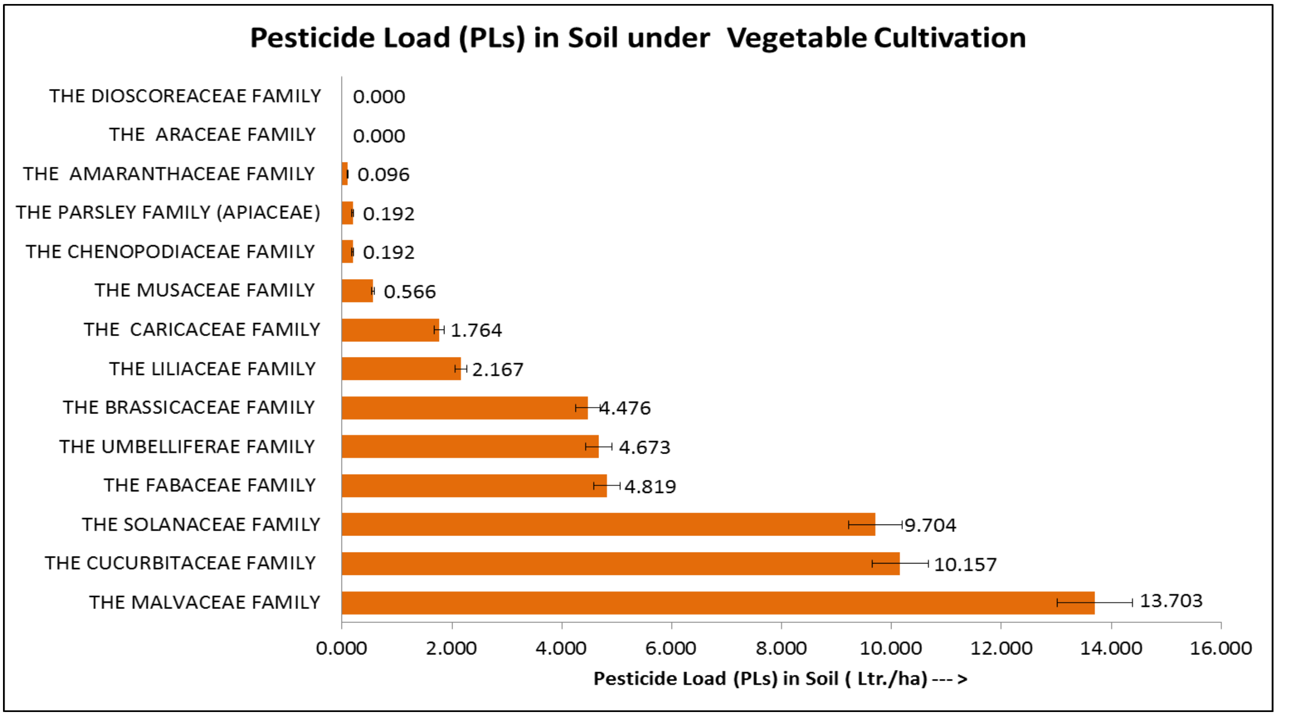
Further more related information was collected from authenticated sources like US Environmental protection Agency, Pan Pesticide Data base, WHO & FAO for Standard Data Quality.

What did the Evaluation Reveal ?

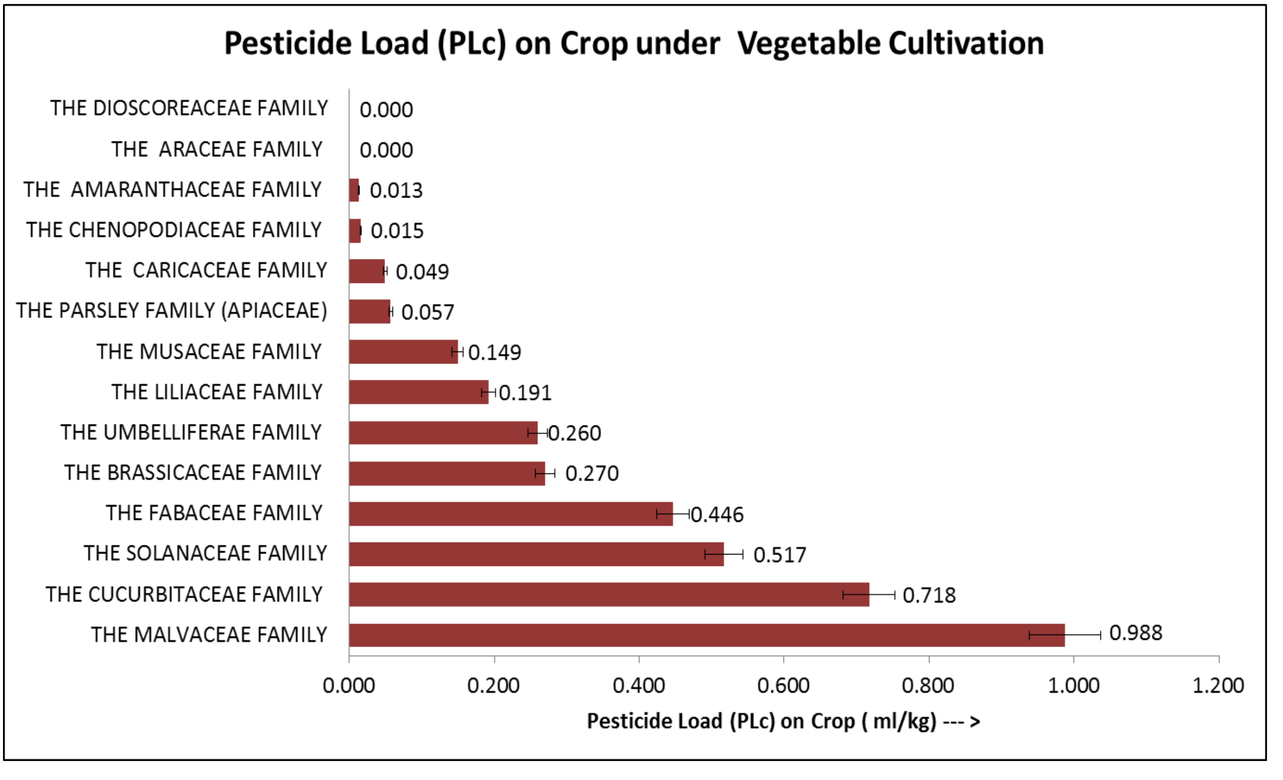


The Study revealed that the selection of Pesticide and Frequency of Spraying crop wise varies widely w.r.t. area, socio economic status of the farmer and seasonal variations.

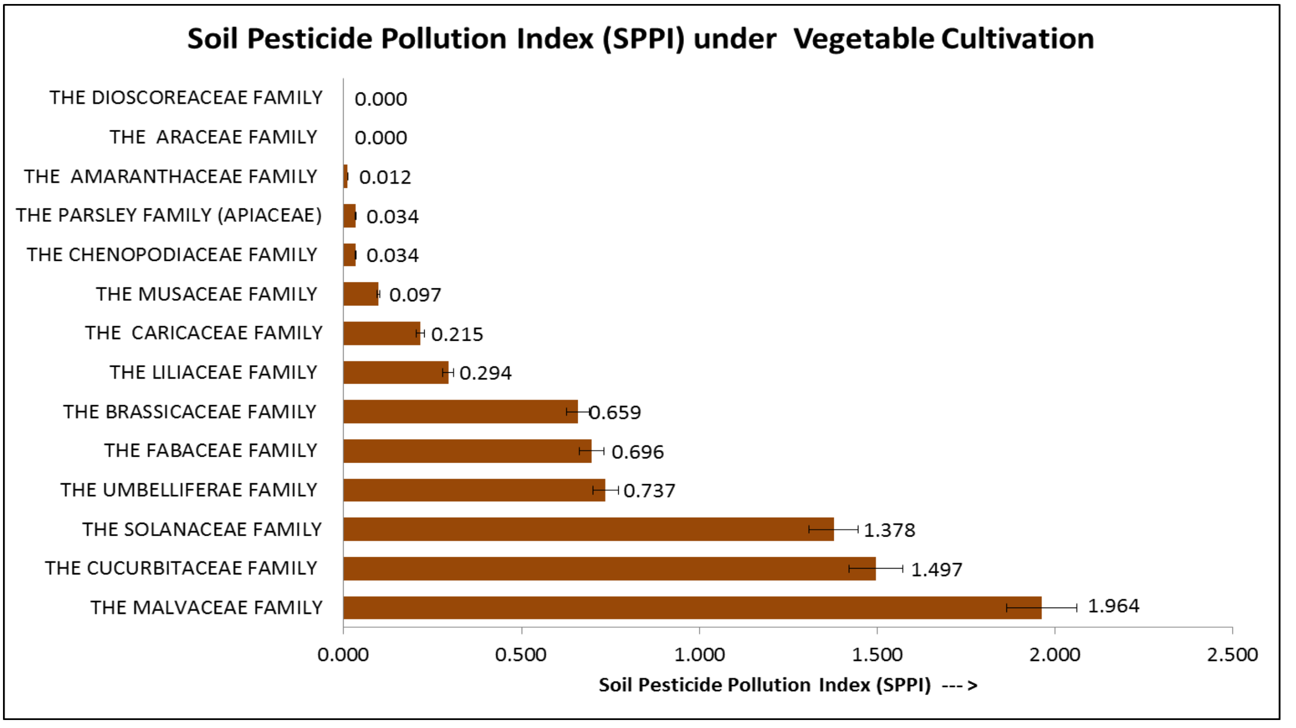
The preliminary assessment was made in respect of Total Quantity (ltr.) of Pesticide Used per hectare during the cultivation of different vegetables. Among the different vegetable families evaluated, a higher consumption was documented in case of solanaceae, and cucurbitaceae, with the highest in case of malvaceae family.



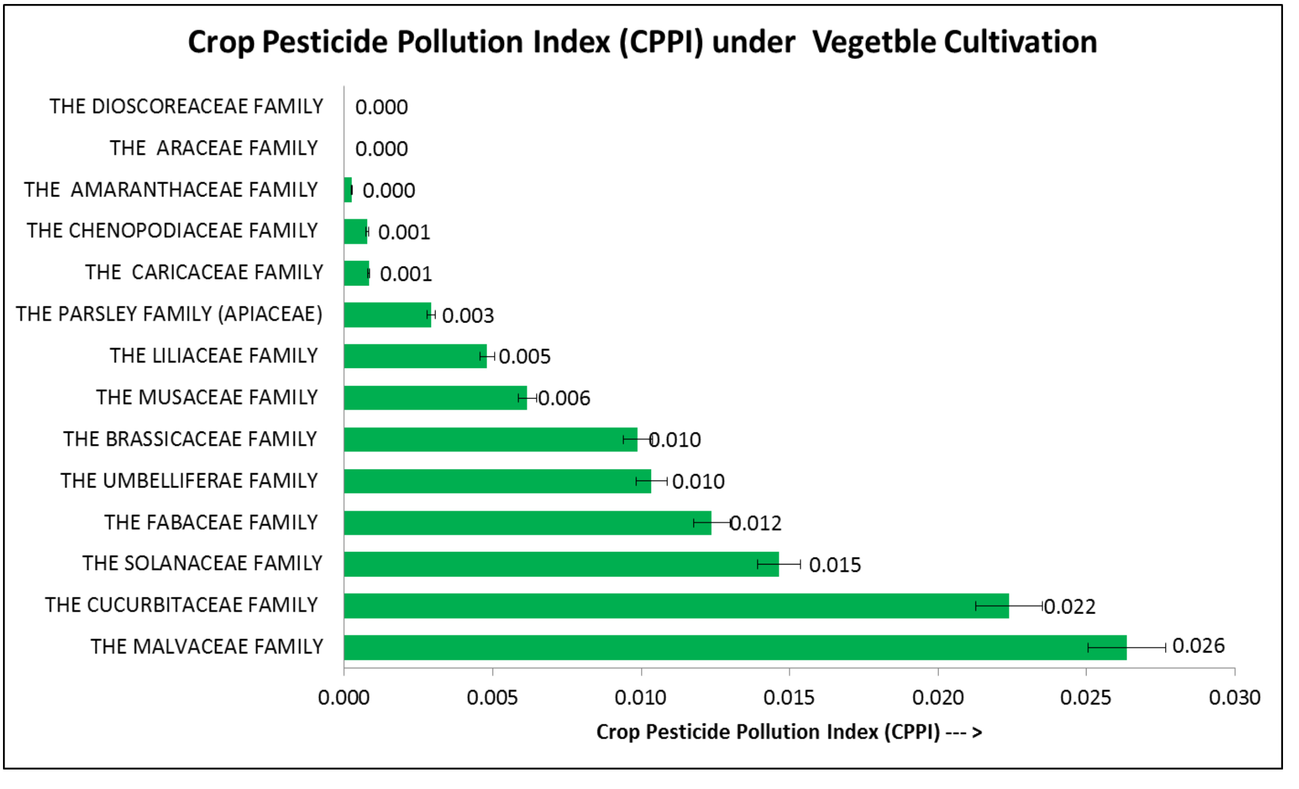
Assessment of Active Ingredient (AI) used per hectare indicated 35 to 41% higher Pesticide Load in the farm soils cultivating the malvaceae family of vegetables. The higher pesticide load indicates severe toxicity in respect of the soil microflora *vis-à-vis* the soil-plant-nutrient dynamics, which will ultimately impact the crop productivity.



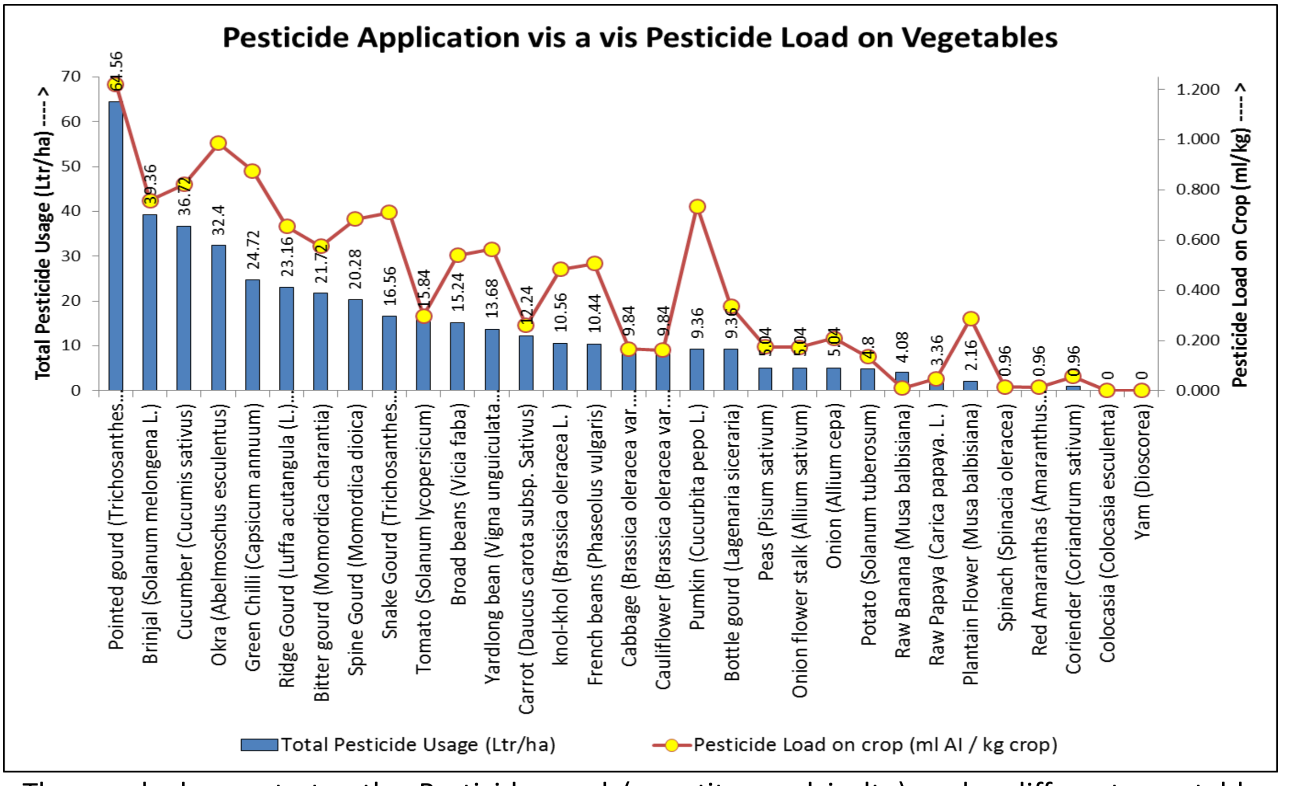
When evaluated in terms of Active Ingredient (AI) used per kg Crop the Pesticide Load almost doubles in the case of malvaceae family as compared to the solanaceae family of vegetables. The Pesticide load on the vegetable crops belonging to the cucurbitaceae family is also about 40% more when compared with the solanaceae family.



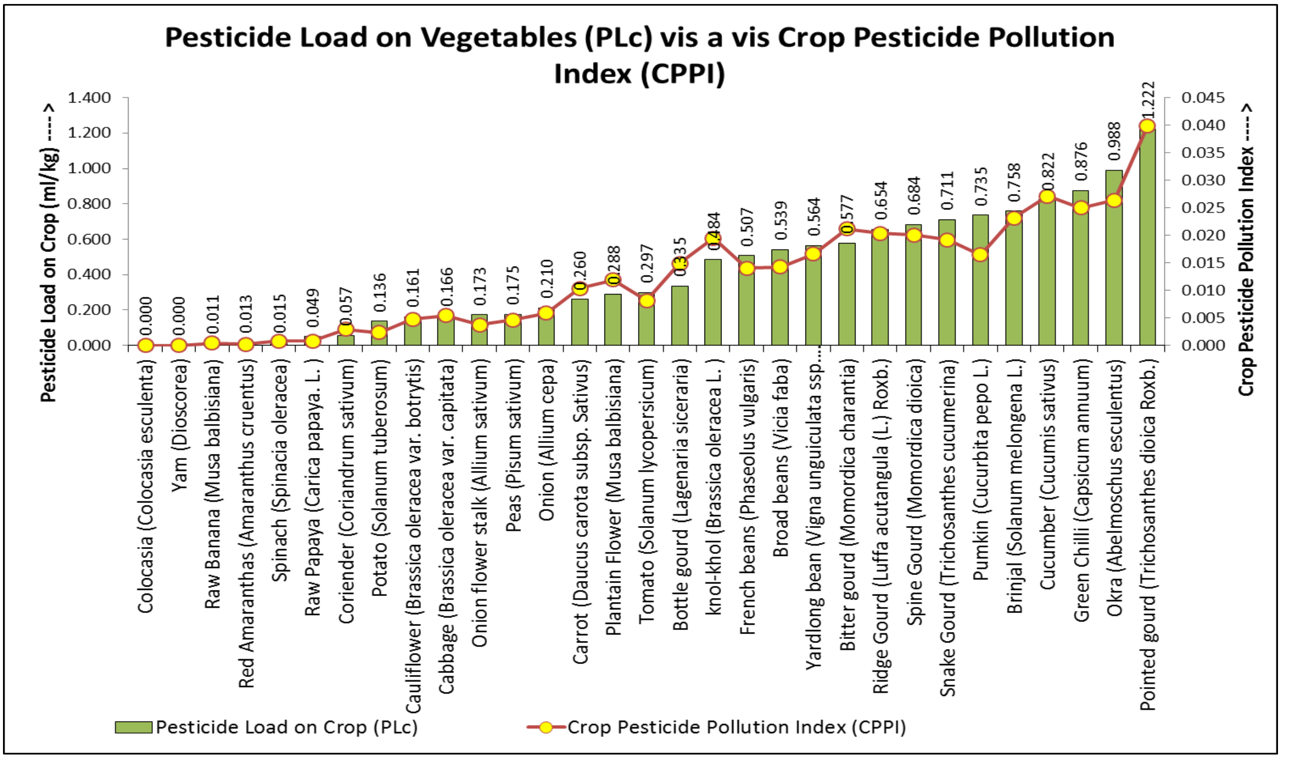
A higher SPPI value indicates high toxicity load on the soil, especially in relation to the microbial population and their functional dynamics. This is especially critical considering that vegetable crops are short duration crops that require well drained medium textured soils. The lack of sustainable soil managements and further negative impact on the soil microflora, raises a big question mark on the future sustainability of these vegetable farm lands.



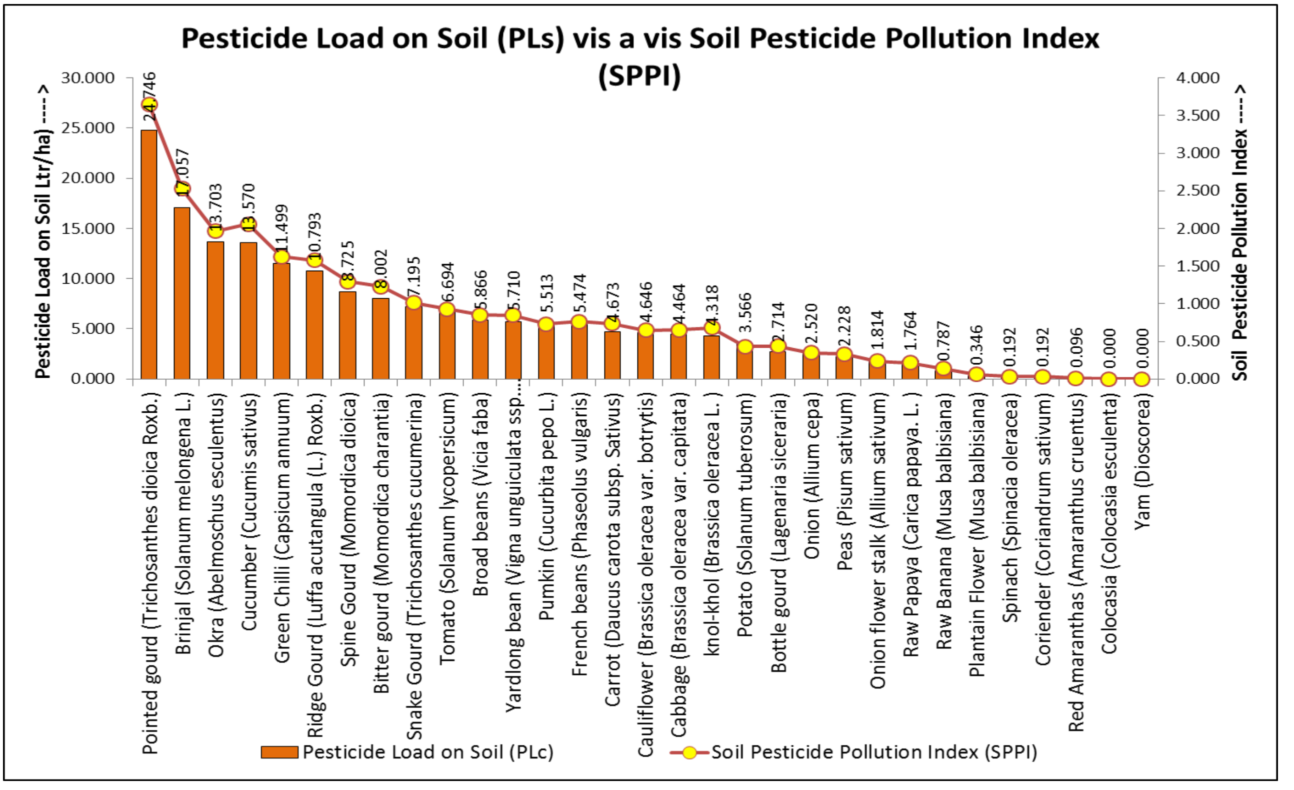
As compared to the SPPI, the CPPI values are comparatively lower. This is primarily due to the high volume production of these vegetables, which impacts the toxicity load per kg crop produced.



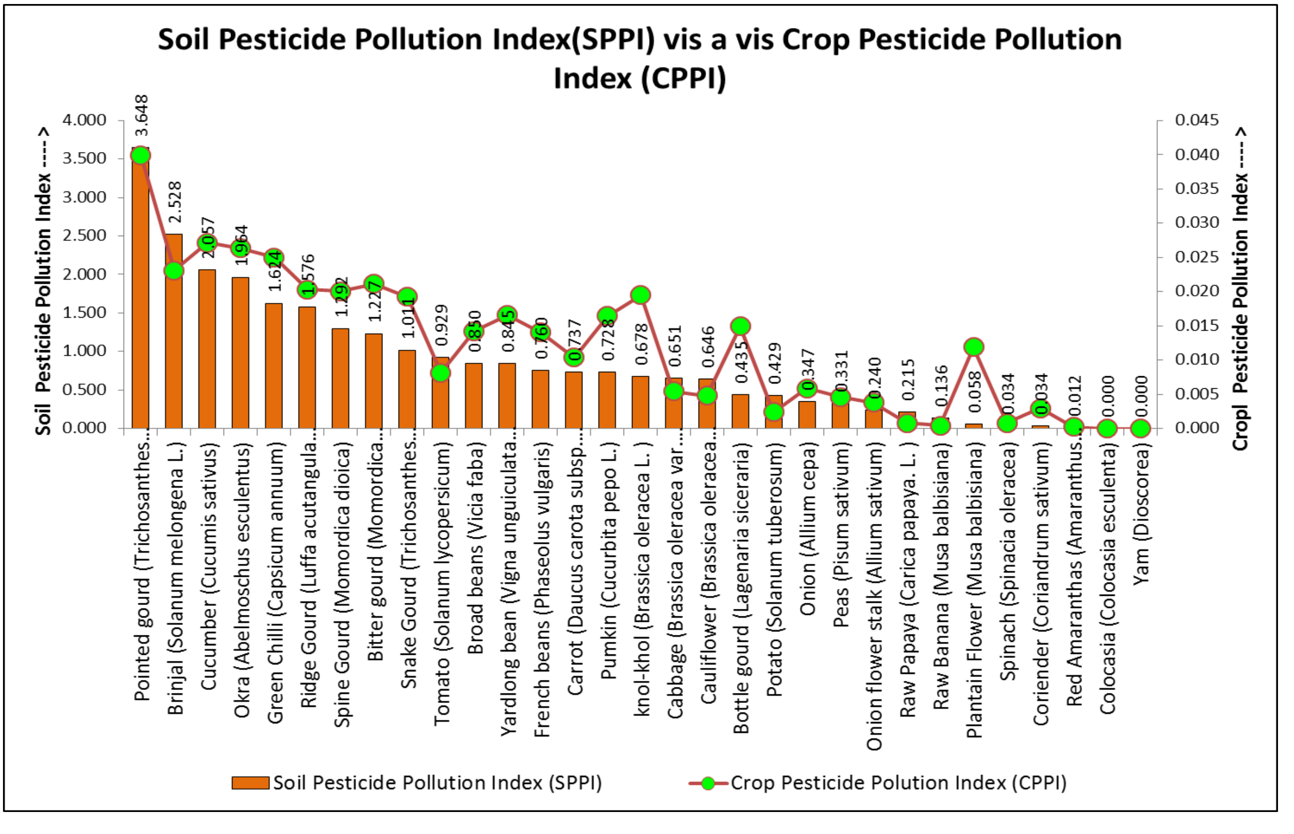
The graph demonstrates the Pesticide used (quantity used in ltr.) under different vegetable cultivation *vis-à-vis* the Pesticide Load (AI/kg Crop) on the respective crops. Higher usage *vis-à-vis* load is noted in respect of the vegetables belonging to the gourd family, apart from brinjal okra, green chilli and tomato.



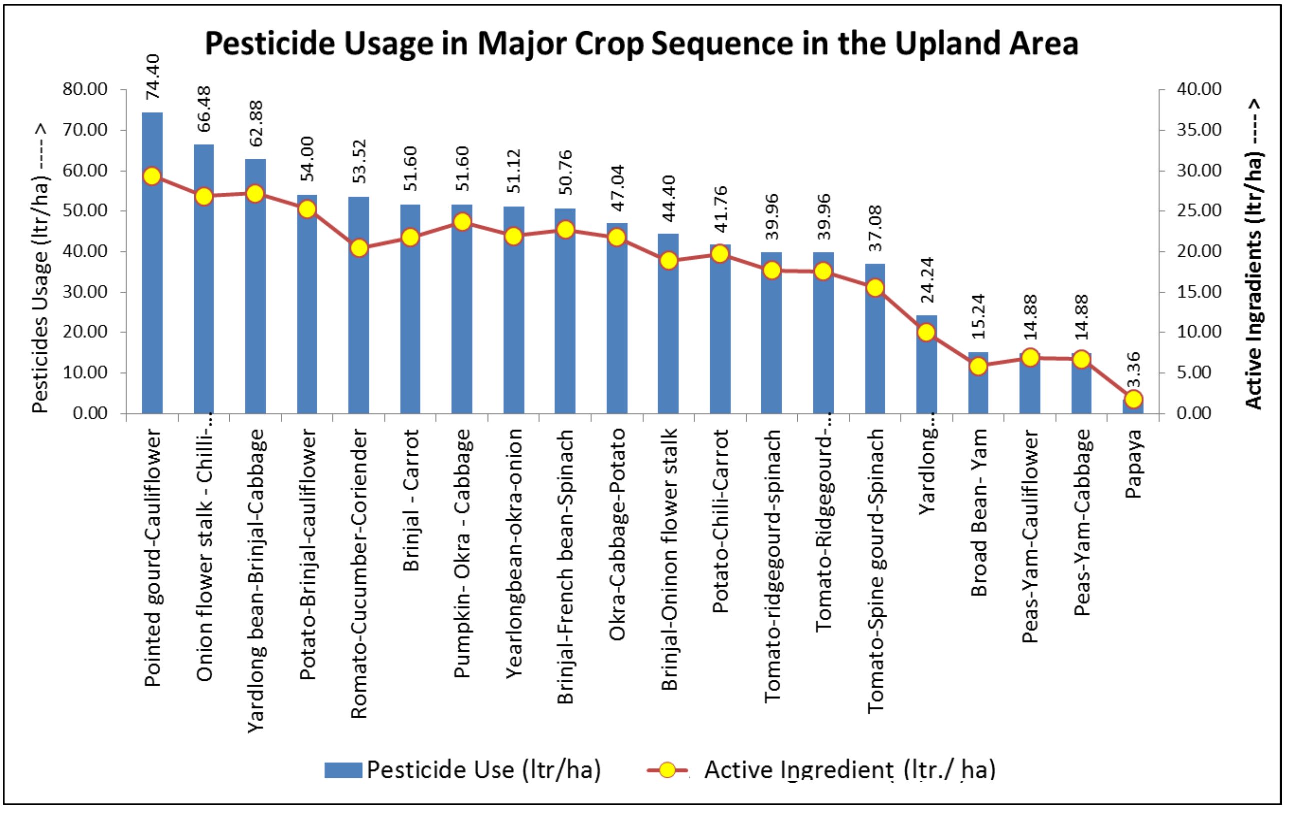
The graph demonstrates the Pesticide Load on crop (ml/kg) under different vegetable cultivation *vis-à-vis* the Crop pesticide Pollution Index w.r.t. the respective crops. Higher Pesticide usage *vis-à-vis* load is noted in respect of the vegetables belonging to the gourd family, apart from green chilli and okra.



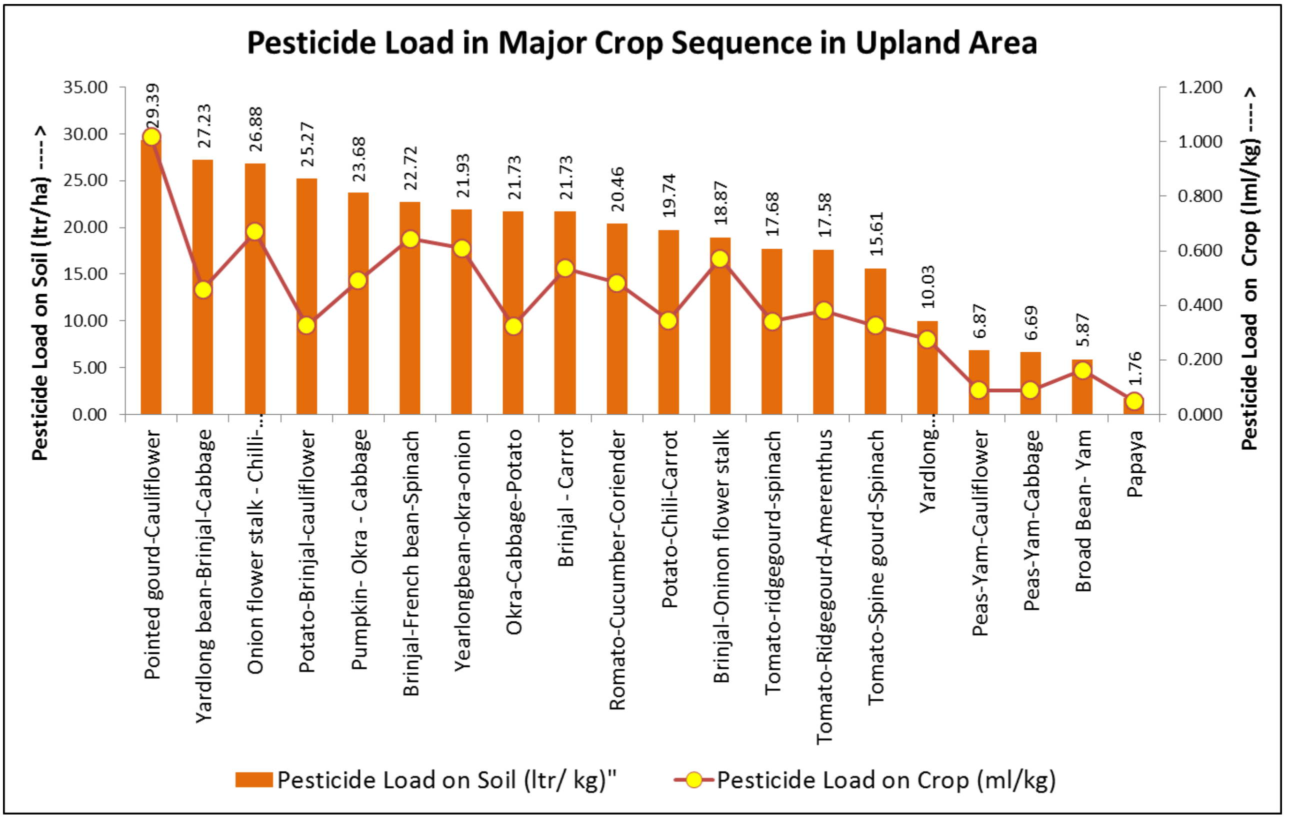
The project area represents the Gangetic alluvial zone – once the most fertile land, that has been eroding over a period of time making them more vulnerable. The farmers have refrained from investing in any Sustainable Practice considering that visible quantifiable returns may not be immediate. But the study shows that the issue has become emergent and unavoidable in order to safeguard the soil from any further degeneration.



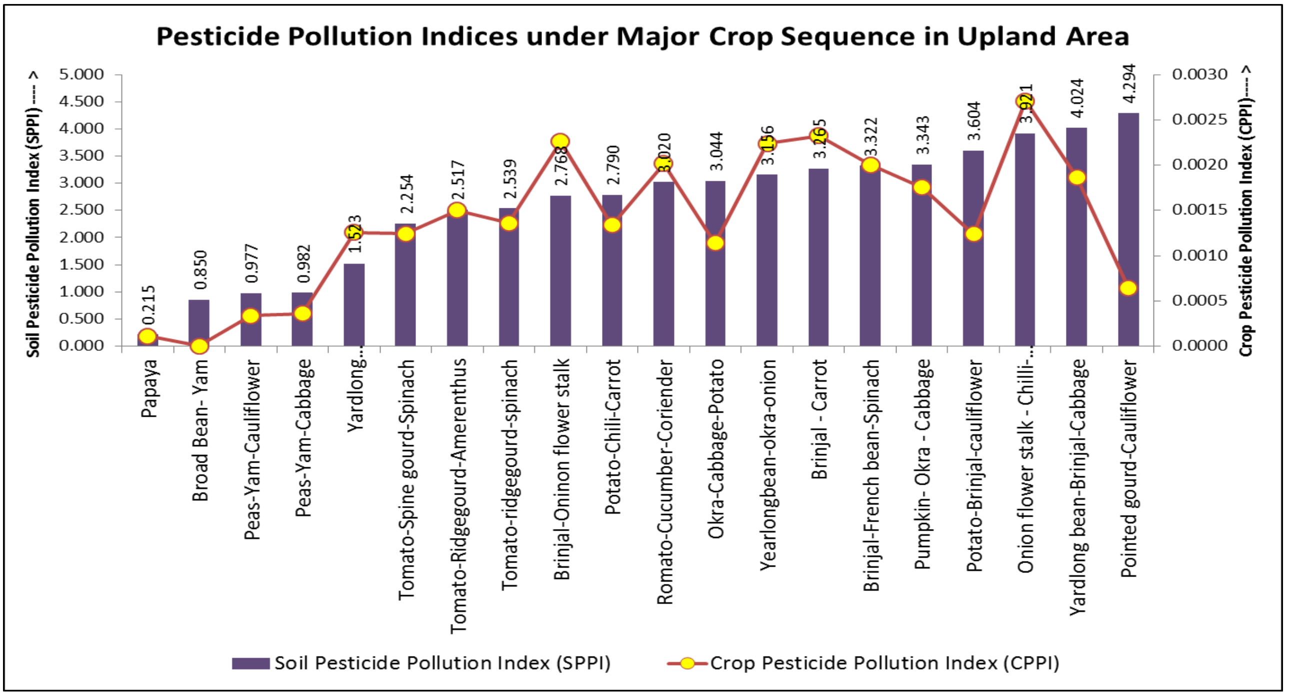
The graph demonstrates the interrelation of SPPI and CPPI under different vegetable cultivation.



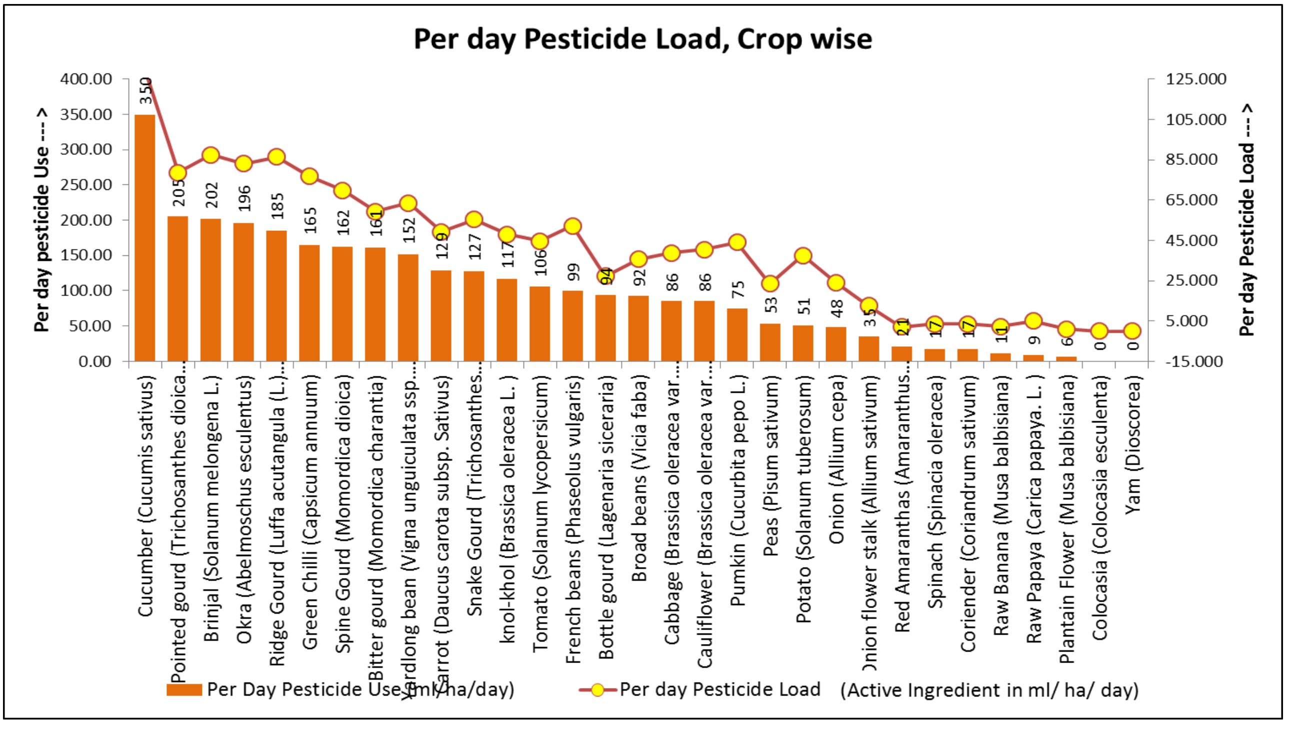
The graph demonstrates the Pesticide Use in Quantity (ltr./ ha) vis-à-vis Active Ingredient per hectare under the different Cropping Sequences followed in the Uplands of the Project Area .



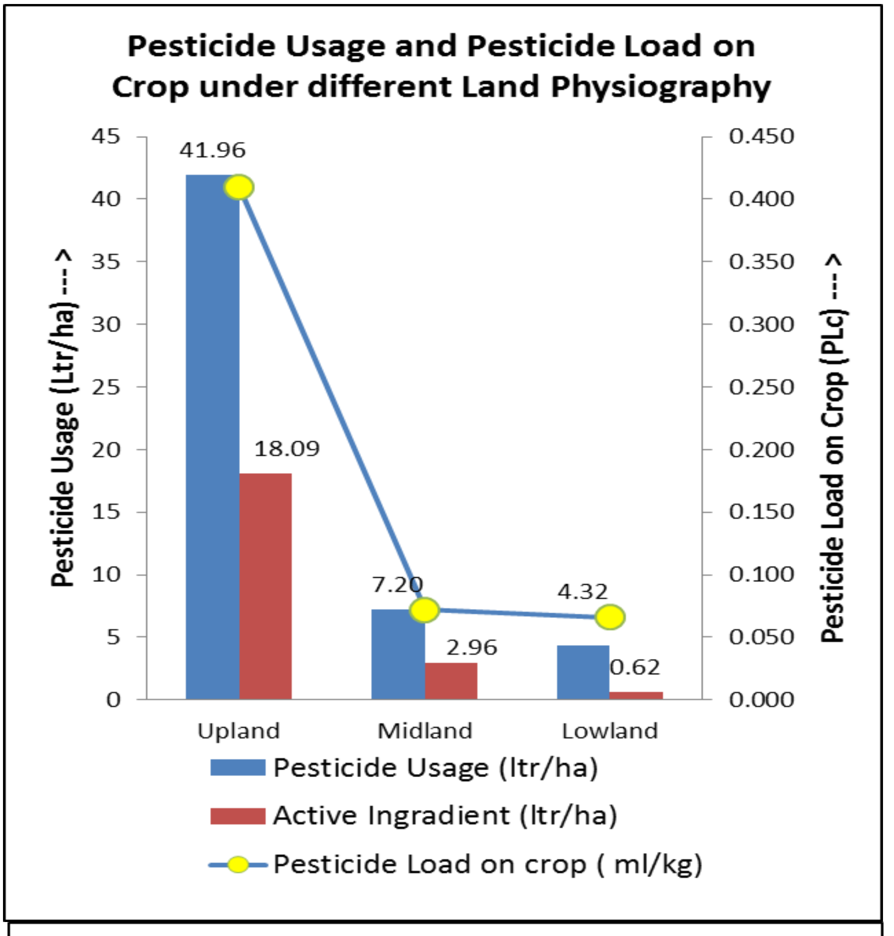
The graph demonstrates the PLs (Active Ingredient, ltr./ ha) vs. PLc (Active Ingredient, ml/ kg Crop) under the different Cropping Sequences followed in the Uplands of the Project Area .

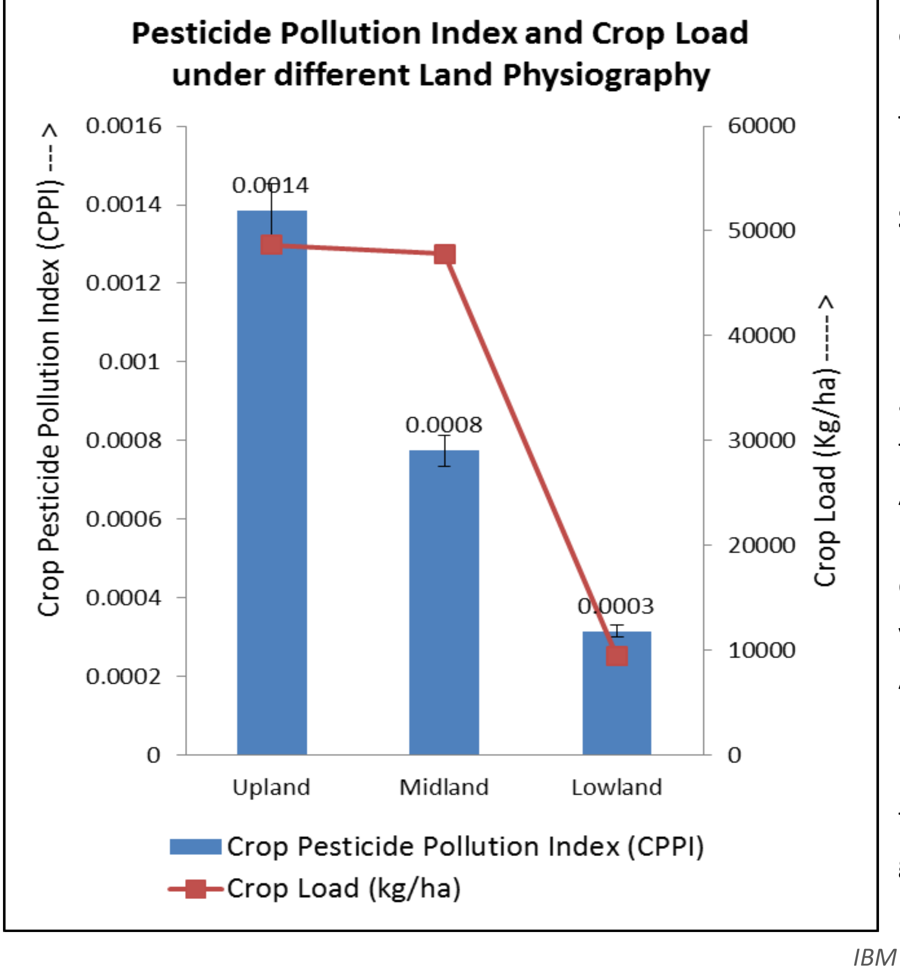


The graph demonstrates the SPPI vs. CPPI under the different Cropping Sequences followed in the Uplands of the Project Area. The graph indicates that though SPPI is high under the Pointed gourd- Cauliflower cropping sequence, the corresponding CPPI is on the lower side. SPPI & CPPI are both on the higher side in case of the onion flower stalk- chilli cropping sequence.



Per Day Pesticide Load (in terms of quantity & AI, ml/ha/day) is a very interesting way of understanding the actual toxicity load on a specific crop through consideration of its cropping period, pesticide spraying pattern and the total quantity used. This can vary from farmer to farmer depending upon how best one can adopt scientific practices and sustainable technologies that can extend the economic cropping period of a crop while naturally keeping the pest/ disease incidence under check.





The graphs represents the Crop Pressure in the varying land forms in the Project Area, vis-à-vis Pesticide Use in terms of quantity and AI (ltr./ha), Pesticide Load on Crop (ml/ha) and Crop Pesticide Pollution Index.

As indicated the uplands and the midlands have high crop pressure while the load is low in the lowlands. Moreover though the crop load is almost similar in upland and midland but the CPPI in midland is comparatively lower (by about 57%) than the value obtained for the uplands.

Thus the **Crop Pesticide Pollution Index (CPPI) and Soil Pesticide Pollution Index (SPPI) which** revealed the pesticide load in both crop and soil is an alternate way to indicate the Sustainability of an Agricultural System. This is because higher the value of CPPI and SPPI – more the vulnerability of an Agricultural System, which in turn will call for an intensified Approach towards the sustainability goal.

CHAPTER13: SOIL RESOURCE RECYCLING THROUGH NOVCOM COMPOSTING

The deteriorated soil quality and the slowly declining crop sustainability under chemicalized farming practice has established the need for a safe and sustainable farming approach which can serve as the best possible answer to that quest. Compost application forms an integral component of any sustainable farming practice as part of soil health management. Compost application in soil is basically aimed at creating a suitable environment for natural proliferation and activity of soil microbes, which being the prime drivers behind all soil ecological processes ultimately restore soil quality. Research has conclusively established that long term application of compost competes well in production with direct application of chemical fertilizer (Briggs and Conrtney, 1985). In this respect the quality of compost plays an important role for safe and sustainable farming. **The study was taken up in the Model Farms** towards the evaluation of Novcom Composting Technology as well as its end product in terms of its quality, stability and maturity for development of protocol for sustainable soil health management.

Method of compost preparation

Common weeds, water hyacinth, banana stump, crop residues and cow dung was used at 80:20 ratio for making compost in the study area.

Novcom solution : Biologically activated and potentized extract of Doob grass (*Cynodon dactylon*), Bel (*Sida cordifolia L*) and common Basil (*Ocimum bascilicum*).

Preparation of compost

At a selected upland and flat area chopped green matter was spread to make a base layer measuring 10 ft. in length, 5 ft. in breadth and 1 ft. in thickness. This layer was sprinkled thoroughly with diluted Novcom solution (5 ml/ ltr. of water) and over this layer, a layer of cow dung (3 inches in thickness) was made followed by a second layer of chopped green material, once again 1 ft. in thickness. The green matter layer was once again sprinkled with diluted Novcom solution (5 ml/ ltr. of water) and the process was continued till the total height reached to about 6 ft.

Pic. 1 : Demonstration of Novcom Compost in the Project Area.

After formation of each layer of green matter it was compressed downward from the top and inward from the sides for compactness.

On the 7th day compost heap was demolished and churned properly. The material was next laid layer wise and after making each layer diluted Novcom solution (5 ml/ ltr.) was sprinkled thoroughly as done on 1st day. After seven days the volume of the composting material decreased due to progress in decomposition process. Hence, to maintain the heap height to about 6 ft.; the length and breadth of the heap were reduced to 6 ft. x 6 ft. respectively. The heap was once again made compact as described earlier.

The same process was repeated on 14th day as on day 7 and to maintain heap height to about 6 ft., the length and breadth of the heap was further reduced to 6 ft. x 4 ft. respectively.

Total 250 ml Novcom solution is required for 1 ton of raw material (100 ml on day 1 followed by 75 ml each on day 7 and day 14 resp.). The composting process was complete and compost was ready for use after 21 days.

Pic. 2: Novcom Composting program using different raw materials

Temperature and volume record of compost heap was maintained regularly to identify the speed of the biodegradation process as well as identification of its compost maturity stage. The temperature variation curve (Fig. 1) showed that there was steady rise of temperature within composting heap from day 2, which reached the peak (72^0 C) on 6th day. The steep rise of temperature indicated initiation of prolific activity of microorganisms (*de* Bertoldi *et al*., 1983), which could be under the influence of energized Novcom solution. The average temperature between the successive turnings on 7th and 14th day gradually decreased and was below 45^0C from the 19th day and by 21st day the temperature curve was almost parallel to the x-axis, which confirmed the completion of composting process or simultaneously compost maturity.

Maintenance of a stable temperature of more than 145^{0}F (> 62.8 ^{0}C) within the compost heap for more than three consecutive days has been found to be effective towards destruction of most of the pathogens, insect larvae and weed seeds within the compost heap (Rynk *et al*., 1992). Hence the temperature curve of compost heap suggests that the process can ensure a safe end product for application in soil as well as human handling.

Evaluation of the compost samples :

All the compost samples appeared dark brown in colour with an earthy smell, deemed necessary for mature compost (Epstein, 1997). Average moisture varied from 47.57 to 65.09 percent, which may be placed in the high value range (40 to 50) as suggested by Evanylo, (2006).

Table 1 : Quality parameters of compost prepared in the Project Area

Sl. No.	Parameter	Range Value	Mean value	(±) S.E.
Physical Parameters				
1.	Moisture percent (%)	49.7 – 64.2	58.8	1.12
2.	pH_{water} (1 : 5)	6.09 – 8.09	7.43	0.21
3.	EC (1 :5) dSm^{-1}	1.68 – 3.30	2.23	0.28
4.	Organic carbon (%)	23.20 – 29.14	27.41	1.41
5.	Compost mineralization index	0.76 – 3.40	1.80	0.22
Fertility Parameters				
6.	Total nitrogen (%)	1.89 – 2.01	1.94	0.06
7.	Total P_2O_5 (%)	0.66 – 1.01	0.87	0.07
8.	Total K_2O (%)	0.59 – 1.11	1.02	0.10
9.	C/N ratio	12:1 – 17:1	14:1	0.51
Stability Parameters				
10.	CO_2 evolution rate (mgCO_2–C/g OM/day)	1.96 – 3.01	2.00	0.14
Microbial Parameters (total count)				
11.	Bacteria	(16–73) x10^{16}	57 x10^{16}	0.1x10^{16}
12.	Fungi	(19 – 38) x10^{16}	29 x10^{16}	0.3 x10^{16}
13.	Actinomycetes	(15–29) x10^{16}	17 x10^{16}	0.01 x10^{16}
Maturity & Phytotoxicity Parameters				
14.	Seedling emergence (% of control)	91 – 158	111	4.80
15.	Root elongation (% of control)	89 – 127	105	3.25
16.	Phytotoxicity bioassay	0.89 - 1.57	1.17	0.07
Compost Quality Index				
17.	**Compost Quality Index (CQI)**	**5.67 – 6.14**	**6.07**	**0.03**

pH value of the compost samples ranged between 6.09 and 8.09 with mean of 7.43, which was well within the stipulated range for quality compost. Electrical conductivity ranged between 1.68 and 3.30 with mean value of 2.23, indicating high nutrient status. The organic matter content of compost is a necessary parameter for determining compost application rate to obtain sustainable agricultural production. Organic carbon content in the compost samples ranged between 23.20 and 29.14 percent with mean value of 27.41, qualifying even the standard suggested value of >19.4 percent (AS 4454, 1999) for nursery application with few exceptions.

The total nitrogen content in the compost samples ranged between 1.89 and 2.01 percent, which was well above the reference range suggested by Alexander (1994) and Watson (2003). Mean value of total phosphate and total potash (0.87 and 1.02 percent respectively) were also higher than the minimum suggested standard. C/N ratio varied from 12.:1 to 17:1 indicating that all the compost samples were mature and suitable for soil application.

Microbial status of any compost is one of the most important parameter for judging compost quality because microbes are the driving force behind soil rejuvenation and play a crucial role towards crop sustenance by maintaining the soil–plant–nutrient dynamics. Microbial population in Novcom compost (total bacteria, total fungi and total actinomycetes count in the order of 10^{16} c.f.u.) was significantly higher (at least 10,000 times) than the population obtained in case of other compost samples.

Microbial respiration formed an important parameter for determination of compost stability (Gómez *et al.*, 2006). Mean respiration or CO_2 evolution rate of all the compost samples (1.96 to 3.01 mg/day) was more or less within the stipulated range (2.0 - 5.0) for stable compost as proposed by Trautmann and Krasny (1997). The phytotoxicity bioassay test, as represented by germination index provided a means of measuring the combined toxicity of whatever contaminants may be present (Zucconi *et al.,* 1981b). Test value indicated complete absence of any phytotoxic effect in all the compost samples as per the standard value of 0.8 to 1.0 suggested by Trautmann and Krasny (1997). At the same time germination index value of >1.0 as obtained in case of Novcom compost (1.17) indicated not only the absence of phytotoxicity (Bera *et al*, 2012) but moreover, it confirmed that Novcom compost enhanced rather than impaired germination and root growth (Trautmann & Krasny, 1997).

The overall compost quality was evaluated through assessment of the Compost Quality Index (Bera *et al.*, 2013b) and the value was found on the higher side.

CHAPTER 14 : A TANGIBLE DEMONSTRATION OF SAFE & SUSTAINABLE AGRICULTURE -*'CLEAN FOOD' DEVELOPMENT*

'Clean Food' is a first endeavor to comply the requirement for SDG-2 of the United Nations, more meaningfully SDG- Target 2.4 (*Sustainable food production and resilient agricultural practices*). This was a Milestone which most emphatically demonstrated **Inhana Rational Farming (IRF) Technology** of IORF as a Sustainable, Resilient and Productive Agricultural Technology which ensures Safe and Sustainable (Clean Food) Crop production without any time lag. 'Clean food' development is an exclusive outcome of a truly Economically and Ecologically Sustainable Agriculture which is extremely relevant in the pretext of the statement of the UN, "It is currently not clear or well defined what constitutes productive and sustainable agricultural practice".

The importance of Safe Food towards human health and immunity is un-debatable. Food can Boost Up Immunity only when it is Naturally Rich in Anti-oxidants, Minerals & Vitamins. But the Food Grown under Conventional Chemical Farming that is, with Fertilizer and Synthetic pesticides do not Serve the Objective. At the same time Organic Food is Safe but definitely not sustainable, catering to only a niche consumer class.

The Clean Food Concept was developed by IORF to fulfill the need of <u>SAFE FOOD that is Also SUSTAINABLE</u>. 'Clean Food' is the Tangible Demonstration of Sustainability

UNIQUENESS OF THE CONCEPT ?

Clean Food is the First & Only Offer in the direction of **'Safe & Sustainable' Food** that can enable :

- LARGE SCALE PRODUCTION of SAFE FOOD &
- PRODUCERS' PROFITABILITY, while Ensuring VALUE ADDED PRODUCT at AFFORDABLE PRICING

<u>SAFE FOOD FOR HUMAN HEALTH – SUSTAINABLE FOR ALL</u>

SCIENCE BEHIND CLEAN FOOD PRODUCTION

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 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 usage is to be reduced/ eliminated, then first pest need to be reduced and for that the ready food source need to be cut off**.

Clean Food Program

The Unique Approach under IRF Technology is based on this scientific background, and serves to activate Plants’ Metabolism & Photosynthetic Efficiency in order to curtail the accumulation of ready food source for the pests in the plants’ cell sap, so as to curtail the pest infestation and thereby the dependency on chemical pesticides.

This primary approach along with some pest management alternatives serve towards the development of Safe end product i.e., ‘Clean Food’.

WHAT IS CLEAN FOOD?

NO

Carcinogenic Chemicals
Heavy Metals
&
Growth Hormones

CLEAN FOOD MEANS : A 360 DEGREE CARE FOR THE FARMING COMMUNITY

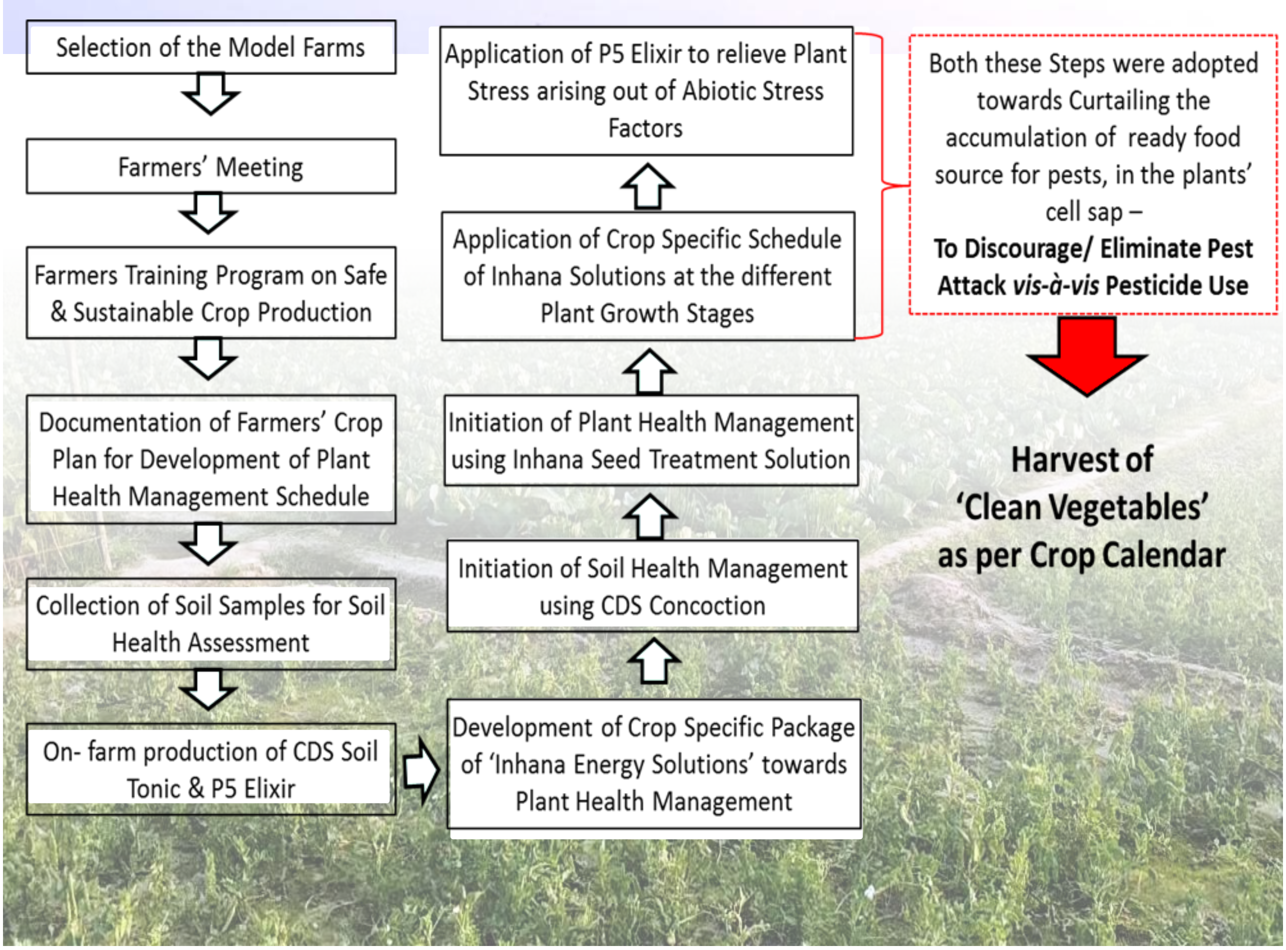
- Transfer of Complete Road Map towards Safe & Sustainable Crop Production
- Reduction/Elimination of the Requirement of Unsustainable Inputs i.e., Chemical Fertilizer & Pesticides
- Reduction in the Cost of Unsustainable Inputs for Crop Production
- Comprehensive Guidelines for Crop Management from Seed Treatment to Seed Production
- Health Protection of Farmers & Family Members
- Protection of Land Productivity
- Crop Sustainability even under Biotic & Abiotic Stress Factors

The Road Map for Clean Food Production?

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*).**

- 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.
- IRF Technology demonstrates how to nourish the main components of a crop production system i.e., Plants and Soil, in a comprehensive manner so that Safe Food can be produced in a Sustainable manner, that too without any time lag – **the prime criteria for attending Food Security.**
- **Clean Food production focused the need and demonstrated the pathway to develop 'Healthy Plants' – a component that is prerequisite for Sustainable Agriculture**, especially considering that in the present times More Crop has to be Produced from Less Land and the resources required for Soil Rejuvenation have become scarce.
- Clean Food production also demonstrated a unique and adoptable pathway for Soil Health Management, to **enable the Reduction of Nitrate Fertilizers and simultaneously initiate the process of Soil Health Regeneration** utilizing the available on-farm resources; in an economical manner.

ACTIVITY FLOW CHART TOWARDS CLEAN FOOD PRODUCTION

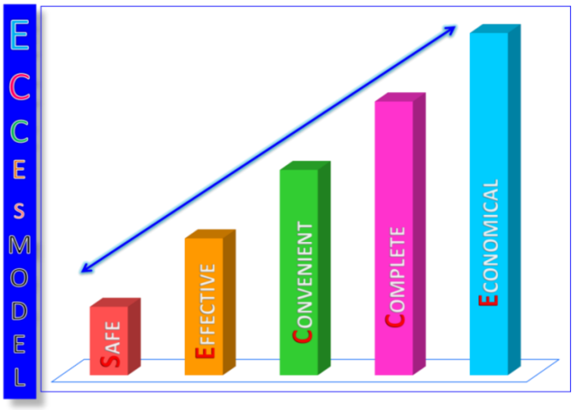


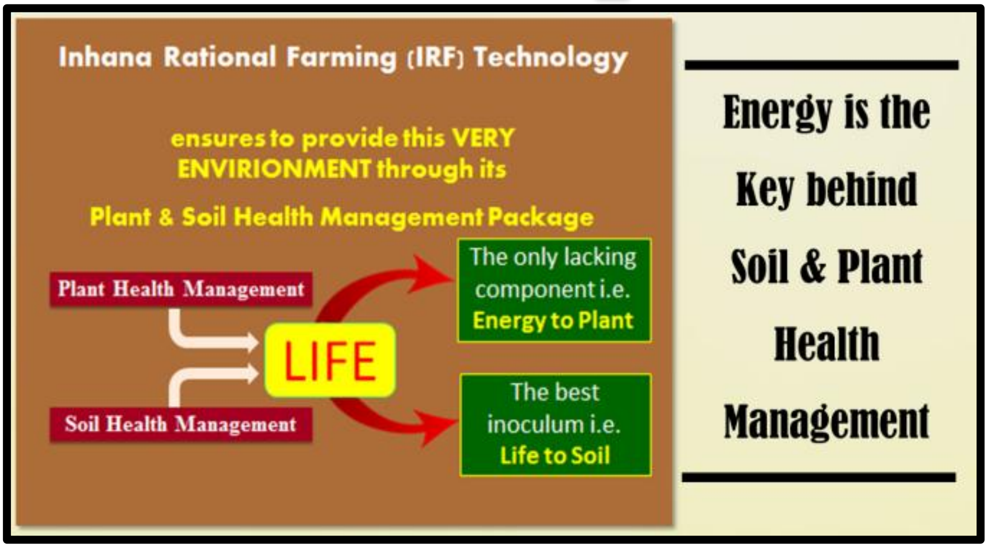
INHANA RATIONAL FARMING (IRF) TECHNOLOGY- An Outline

The limitations of the present system of crop production pointed out the relevance of climate smart agro-technology that can deliver 'More from Less' – meaning **enhanced crop production using less non-renewable resources and less energy inputs with lesser GHG emission.** Inhana Rational Farming (IRF) Technology was conceived from that basic need.

Today **IRF Technology is probably the World's only Ecologically & Economically Sustainable Crop Technology** which has demonstrated crop sustenance/ yield enhancement under low input farming- lesser non-renewable resources, lesser energy inputs; and lower GHG emission potential. But more importantly as an economically viable and easily adoptable pathway.

MORE IMPORTANTLY it fulfills all the **FIVE IRREVERSIBLE CRITERIA** that are Pre-requisite for **Long Term & Large Scale Sustainability of any Crop Production Management System**





FULFILLMENT OF THE SET MILESTONE

Although a detailed work plan was chalked out and initiated in the entire 100 hec. Project Area, **TWO MODEL FARMS** were selected in addition; with the following objectives :

- Undertake **SUSTAINABLE SOIL HEALTH MANAGEMENT**, which was not possible for the entire 100 hec. Project area, considering the acute resource scarcity, fuelled by criticall land fragmenetation and resource poorness of the farmers
- Secondly this area also served for critical scientific documentation of field data that will be utilized for various research publication post completion of the 1st phase of the IBM Sustainability Project.

TIMELINE OF ACTIVITIES

A. Farmers' Meeting & Discussion

Farmers' meeting and group discussion for creating awareness regarding the concept of Safe & Sustainable Agriculture and how 'Clean Food' production can open up a Pathway for Sustainable Crop Production under the Climate Change Impact, without raising the Cost of Production.

The different management aspects of Clean Food Production were also discussed and the farmers were appraised regarding the Sustainable Crop Technology (IRF Technology), that was to be adopted for attaining the objective of eliminating chemical pesticides and reducing Nitrate fertilizers- prerequisite for development of 'Clean Food'

Continuous awareness and Farming Skill Development Programs were conducted to enable steady and convenient transition of the farmers towards Safe & Sustainable Agriculture.

Training Program on the Interventions required for Clean Food Production by IORF & Krishi Vigyan Kendra (KVK, Nadia) Scientists

During this time IORF also collected details regarding farm demography, crop cultivation, plant nutrient management, chemical pesticide, insecticide and other chemical usage as well as other conventional practice for crop protection.

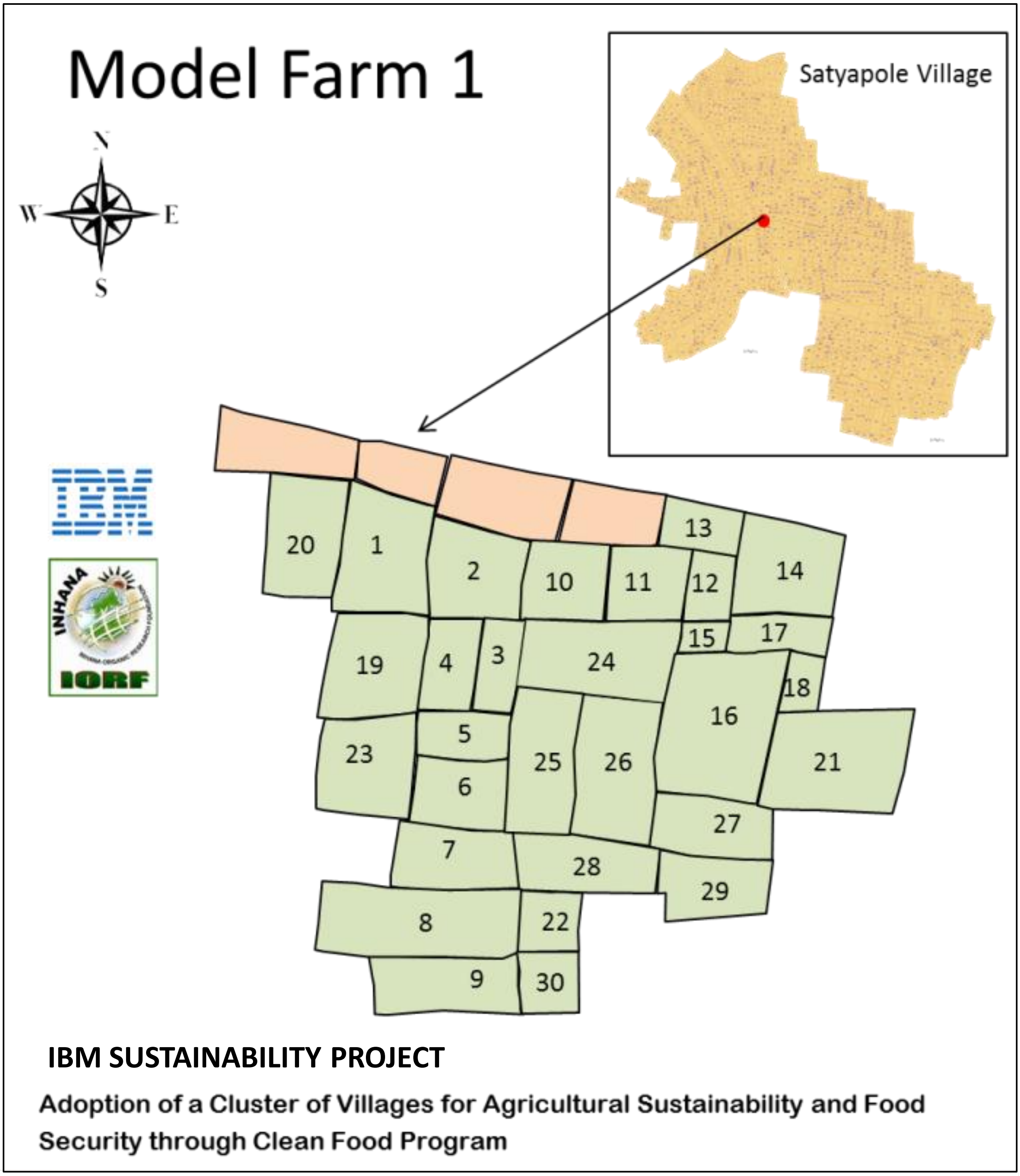


Fig. 1: More than 30 farmers were involved in Model farm 1, cultivating more than 15 different crops in 2.41 ha area indicating land fragmentation and crop diversity in the project area

MODEL FARM 1 – Crop Dynamics & Production Details

Sl No	Farmer name	Model Plot No	Area (ha.)	Crop	Total Harvest in 10 days period	Yield (kg./ha.) (as per 10 days harvest)
1	Toidul Mondal	1	0.05	Brinjal	140 kg	2800
2	Kasem Mondal	2	0.08	Guava	-	-
3	Ajit Mondal	3	0.05	Pointed Gourd	40 kg	800
4	Saidul Mondal	4	0.07	Onion Flower	-	-
5	Abdul Alim Mondal	5	0.10	Bottle Gourd	80 kg	800
6	Kalam Mondal	6	0.10	Potato	-	-
7	Soibul Mondal	7	0.05	Indian Plum/ Jujube	-	-
8	Asraf Mondal	8	0.27	Indian Plum/ Jujube	-	-
9	Pintu Mondal	9	0.20	Guava	-	-
10	Alam Mondal	10	0.07	Pea	-	-
11	Siraj Mondal	11	0.07	Mango Sapling	-	-
12	Soibul Mondal	12	0.05	Mango Sapling	-	-
13	Ekramul Mondal	13	0.05	Cauliflower	480 kg	9600
14	Sahawlam Mondal	14	0.10	Banana	18 kg	180
15	Moinuddin Mondal	15	0.04	Potato	-	-
16	Asraf Mondal	16	0.13	Potato	-	-
17	Toidul Mondal	17	0.04	Onion Flower	25 kg	625
18	Safikul Mondal	18	0.05	Cabbage + Bottle gourd	-	-
19	Moslem Mondal	19	0.10	Pea	-	-
20	Kutubuddin Mondal	20	0.10	Potato	-	-
21	Selim Mondal	21	0.07	Pea	-	-
22	Musaraf Mondal	22	0.08	Pointed Gourd	-	-
23	Didar Mondal	23	0.07	Mustard	-	-
24	Nwaj Mondal	24	0.10	Guava	-	-
25	Israfil Mondal	25	0.07	Onion Flower	-	-
26	Chaapic Mondal	26	0.08	Pointed Gourd	60 kg	750
27	Kalam Mondal	27	0.03	Pumpkin + Brinjal	40 kg brinjal	1340
28	Didar Mondal	28	0.03	Vacant	-	-
29	Rajjak Mondal	29	0.03	Pea	-	-
30	Patauddin Mondal	30	0.07	Chilli	-	-

MODEL FARM 1:

TOTAL AREA – 2.41 Hec. , **TOTAL PRODUCTION (10 Days Period)–** 0.883 Ton

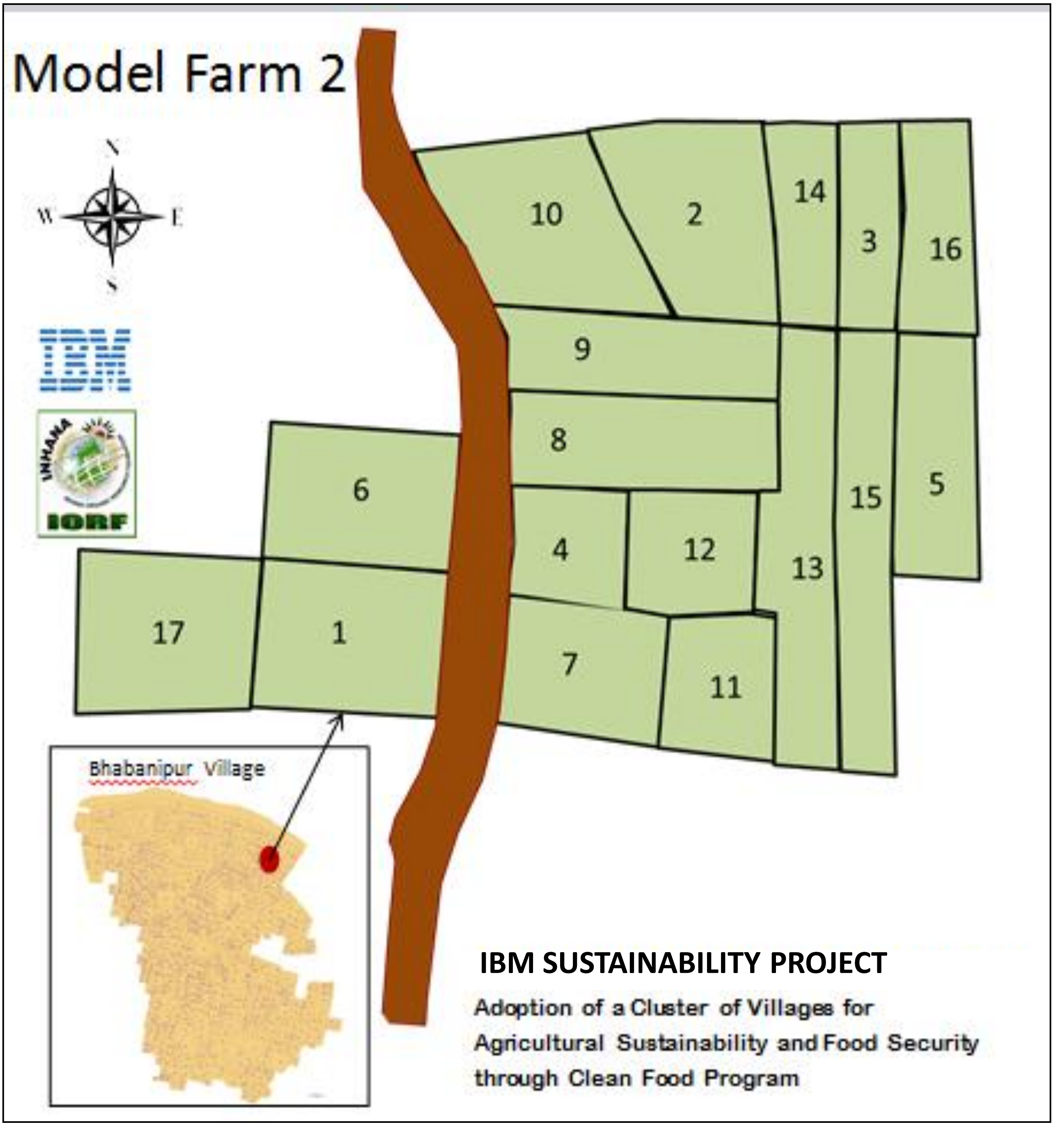


Fig. 2 : More than 17 farmers were involved in Model farm 2, cultivating more than 8 different crops in 1.65 ha area indicating land fragmentation and crop diversity in the project area

MODEL FARM 2 – Crop Dynamics & Production Details

Sl No	Farmers name	Model Plot No	Area (ha.)	Crop	Total Harvest in last 10 days period	Yield (kg./ha.) (as per 10 days harvest)
1	Sahil Mondal	1	0.12	Potato	-	-
2	Sahil Mondal	2	0.12	Guava	-	-
3	Jinnat Mondal	3	0.05	Cauliflower	160 kg	3200
4	Jinnat Mondal	4	0.04	Chilli	-	-
5	Jahangir Mondal	5	0.08	Cauliflower	560 kg	7000
6	Ajilul Mondal	6	0.12	Pointed Gourd	200 kg	1670
7	Sidhartha Mondal	7	0.08	Brinjal	20 kg	250
8	Siddik Mondal	8	0.12	Potato	-	-
9	Jakir Mondal	9	0.10	Potato	-	-
10	Siraj Mondal	10	0.13	Guava	-	-
11	Hajrat Mondal	11	0.10	Cabbage	600 kg	6000
12	Rajdip Mondal	12	0.08	Potato	-	-
13	Bablu Mondal	13	0.12	Indian Plum/ Jujube	-	-
14	Mozammel Mondal	14	0.12	Potato	-	-
15	Firoj Ali	15	0.12	Potato	-	-
16	Mojammel Mondal	16	0.08	Pointed Gourd	50 kg	625
17	Saidul Mondal	17	0.07	Chilli	140 kg	2000

MODEL FARM 2 : TOTAL AREA – 1.65 Hec.,
TOTAL PRODUCTION (10 days period) – 1.730 Ton

Pic. 1 : Regular field monitoring by personnel from Inhana Organic Research Foundation under IBM Sustainability Project.

B. Soil Quality Analysis of The Model Farms

The soil samples were collected Plot wise from the Model farms and analyzed for various quality parameters *viz.* Physical, Physicochemical, Fertility and Microbiological. Post Analysis different Soil Indices *viz.* Fertility Index, Physical index, Microbial Activity Potential & Soil Quality Index; were also calculated.

Pic. 2 : Soil Collection Team comprising Project Farmers, guided by IORF Technical Team lead the soil sampling activity along with utilization of Soil Core Sampler for on- field assessment of Soil Bulk Density under *IBM Sustainability Project*

- Physical Analysis revealed Silt loam to Silty clay loam texture. That means the soils are basically light textured with no limitation in terms of soil depth, coarse fragment, bulk density and aggregate stability.
- The soils were Slightly Acidic in nature, pH varying from 6.0 to 6.5. The organic carbon status varied widely between Low (0.5 to 0.75%) and Moderately High range (1.0 to 1.25%).
- Assessment of the Fertility Status of the soils in terms of Fertility Index (FI) revealed Moderately High (FI: 20-25) to High (FI: 25-30) Fertility.
- Microbiological Study in terms of Microbial Biomass Carbon (MBC) was found to be in the Low to Moderate range varying from 150 to 350. Fluorescein Diacetate Hydrolysis (FDAH) values were also Very Low (<60). And finally the Very Low (4.0 -10.0) values obtained in respect of the Microbial Activity Potential (MAP) indicated very poor soil microbial activity.
- The Analytical database and the Indices indicated that intensive chemical farming and lack of organic amendments has depleted the soil resource base; which increases the vulnerability in terms of future crop sustenance, especially under the climate change impact. Especially the Low to Very Low values obtained in respect of Soil Microbiology indicated stressful conditions in disturbed ecosystems, due to intensive usage of synthetic fertilizer and pesticides.

Pic. 3 : The Soil samples were Analyzed in IORF laboratory for 21 Quality parameters comprising, Physical, Physiochemical, Fertility and Microbiological assessments.

C. Initiation of On- Farm Activities

The Objective was to train the Project Farmers and inculcate sustainable practices in their present crop production system to enable Effective Resource Recycling and Better Utilization of the On-farm Available Resources; with an aim to reduce dependence on the off-farm Unsustainable Inputs like chemical fertilizers & pesticides.

Pic. 4: On- farm production of Novcom Compost using the available resources like water hyacinth, banana stumps, farm weeds etc. under Novcom Composting Method of IORF.

Pic. 5 : Preparation of different on-farm concoctions *viz*. Soil & Plant Tonic (CDS concoction) and Plant Elixir (P5 Concoction) for Soil and Plant Health Management.

D. SOIL HEALTH MANAGEMENT under IRF Technology

This activity aims to reactivate the soil- plant- microflora dynamics by providing an ideal environment and food source for natural regeneration of the population and functional abilities of the native soil microflora.

This was primarily done through application of on-farm produced Novcom Compost as well as Soil Tonic (CDS Concoction) prepared on- farm from cow based inputs and locally available organic resources. Different cultural practices *viz*. mulching, in-situ composting, etc. were also recommended to suit specific needs as well as to eliminate the use of herbicides.

On-field prepared Novcom Compost was incorporated in the soil @ 30 ton/ ha at the time of final land preparation i.e., 7 days before sowing. Nutrient content in terms of total NPK was in the ratio of 112: 33: 68 as obtained from compost analysis. Compost application was immediately followed by ground spraying of CDS Concoction @ 400 ltr./ ha.

The application of Novcom compost was also aimed at reducing the Nitrate Fertilizers. So for every Ton of Compost applied 4 kg of Nitrogen (approx. 8 kg of Urea was reduced)

What is Novcom Compost ?

Novcom Compost is a Stable, Mature and Non- phytotoxic compost and acts as an ideal exogenous soil inoculation; when applied in soil. It is produced under Novcom Composting Method. Novcom Composting Method, is the most suitable for large scale on- farm composting due to its process simplicity, speedy biodegradation, high quality end product and low economics.

The uniqueness of this method can be judged for its 5 Salient Features:

- Speediest Composting Method that produces quality compost within a short period of 21 days.
- Any type of Biodegradable material can be used as raw material.
- Requires no specific infrastructure
- Up to 200% appreciation of Nitrogen content in the final compost.
- Microflora in the order of 10^{16} c.f.u., which is at least 10,000 times higher than any other good quality compost

Pic. 6 : Application of Novcom compost in the Model farm.

E. PLANT HEALTH MANAGEMENT under IRF Technology

This is the most ignored but the most crucial component for Sustainable Agriculture, and therefore forms the focus point under IRF Technology. **The activity aims to energize, stimulate and reactivate plants' physiological, metabolic and biochemical functions**, which is vital for higher agronomic efficiency and higher immunity/ host defense mechanism of the plant system against pest and diseases; that contributes towards elimination/ reduction of chemical pesticides and fertilizers and crop sustenance even under the Climate Change Impact.

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.

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.

Pic. 7 : Seed treatment and seed transplanting as per the guideline of IRF Technology.

Pic. 8: Spraying of different organic concoctions and Inhana Plant Health management solutions as per the guideline of IRF Technology.

The following Customized IPHM Schedule was developed by IORF and followed post completion of the Nursery Schedule as per the recommended frequency of application

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)

Pic. 9: Spraying of Inhana Plant Health Management Solutions in the Model Farms.

Customized IPHM Schedule

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. 10 : Mulching with plastic, water hyacinth and straw along with hand weeding to eliminate the use of herbicides in the project area.

The Production of Safe & Sustainable 'Clean Food' (about 1800 ton from 100 ha area) was not only critically relevant in respect of SDG-2; more meaningfully SDG- Target 2.4 (*Sustainable food production and resilient agricultural practices*); but was especially meaningful in the pretext of the statement of the UN, "It is currently not clear or well defined what constitutes productive and sustainable agricultural practice".

Table 1 : Details of Vegetable Production under IBM-IORF Sustainability Project

Sl No	Vegetable Name	Area under Cultivation (ha)	Harvesting in last 45 days (ton)	% Share of Land	% Share of Crop Harvested
1	Cauliflower (Brassica oleracea var. botrytis)	8.5	90.5	11.26	23.96
2	Cabbage (Brassica oleracea var. capitata)	8.0	90.0	10.59	23.83
3	Onion flower stalk (Allium sativum)	10.6	47.0	14.04	12.44
4	Carrot (Daucus carota subsp. Sativus)	6.7	24.0	8.83	6.35
5	Pointed gourd (Trichosanthes dioica Roxb.)	13.3	7.5	17.61	1.99
6	Brinjal (Solanum melongena L.)	9.3	70.0	12.31	18.53
7	Pumkin (Cucurbita pepo L.)	1.0	12.0	1.32	3.18
8	Green Chilli (Capsicum annuum)	2.6	4.0	3.44	1.06
9	Peas (Pisum sativum)	13.3	20.0	17.61	5.29
10	Bottle gourd (Lagenaria siceraria)	1.0	0.8	1.32	0.20
11	Raw Papaya (Carica papaya. L.)	0.3	7.5	0.33	1.99
12	Raw Banana (Musa balbisiana)	1.0	4.5	1.32	1.19

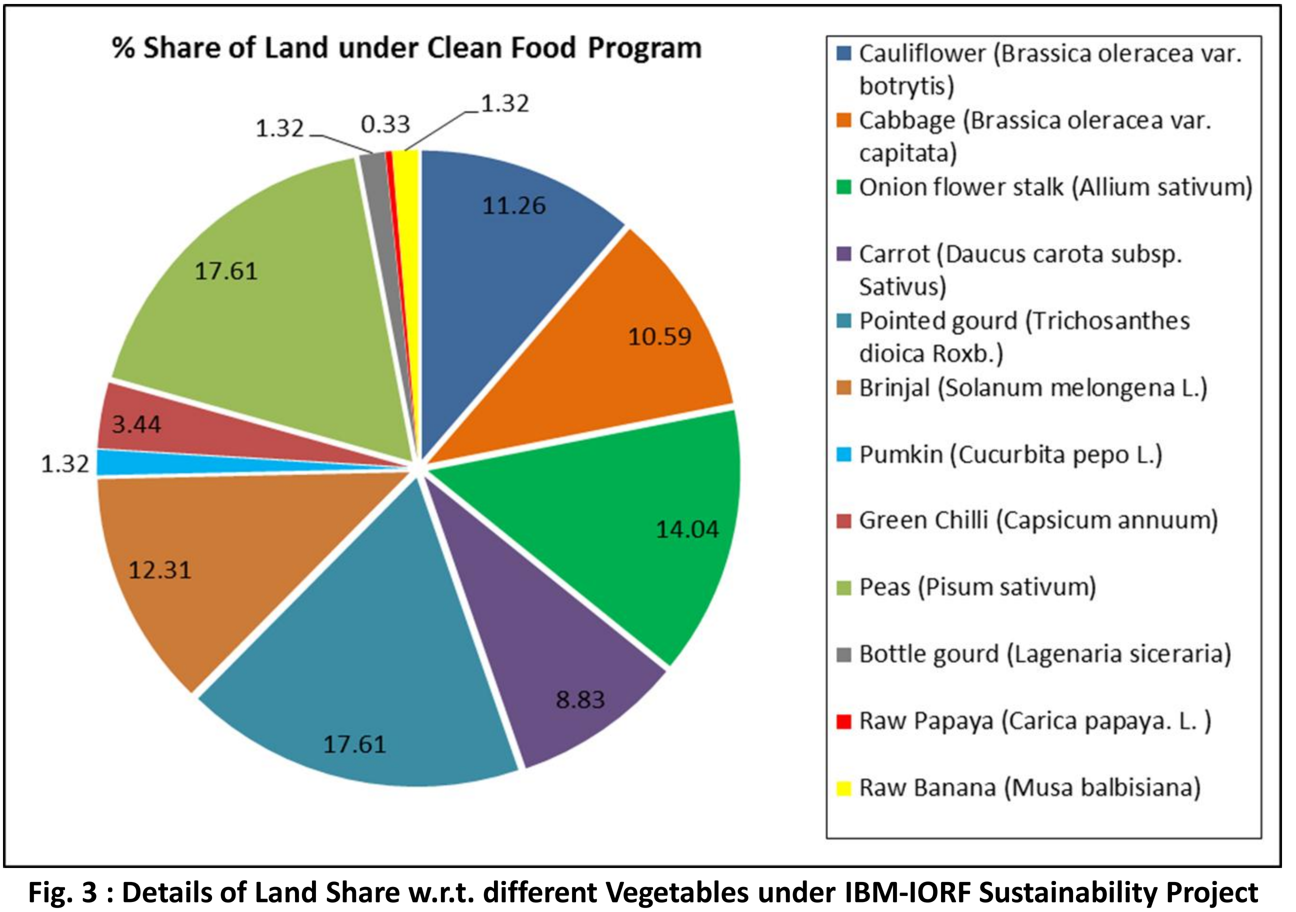


Fig. 3 : Details of Land Share w.r.t. different Vegetables under IBM-IORF Sustainability Project

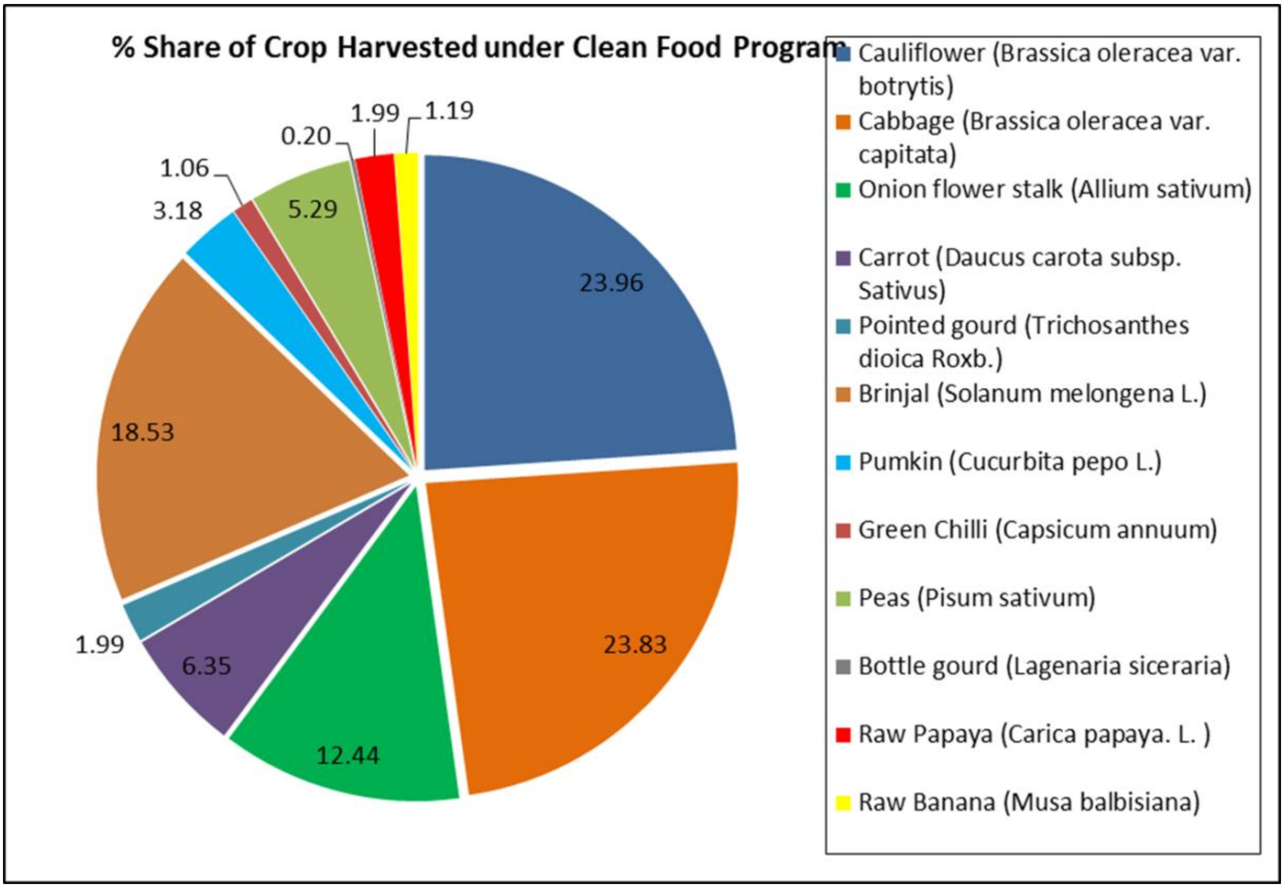


Fig. 4 : Details of Production Share w.r.t. different Vegetables under IBM-IORF Sustainability Project

Pic. 11: Continuous Farmers Training and intervention of IRF Technology were the criteria behind the development of Clean Food under IBM Sustainability Project

Background

A UK Study tests urine samples of children, finds organophosphate exposure in high levels (Indian Express, Published: 22nd July, 2018). Studies conducted by the Kerala Agricultural University indicated pesticide residues in 25% of the food products available in organic shops (Time of India, 2019). As per the last 5 years pesticide use trend in India, more than 25000 MT pesticides (technical grade) was consumed. Five major groups of chemicals viz. Organochlorine, Organophosphate, Carbamate, Synthetic pyrethroids and Nicotinoids cover more than 90% of the synthetic pesticides consumed in India.

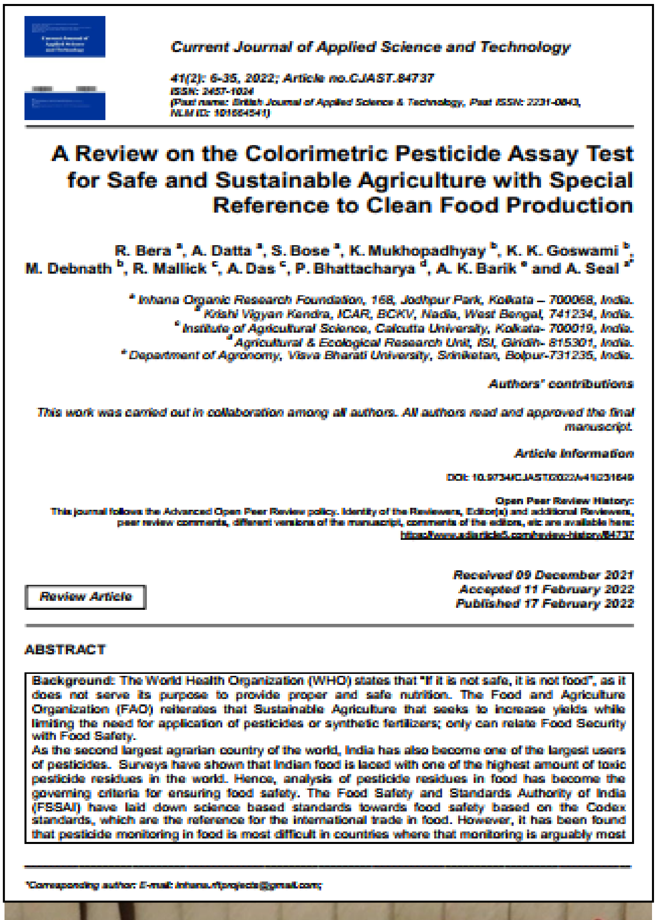
The World Health Organization (WHO) states that "If it is not safe, it is not food", as it does not serve its purpose to provide proper and safe nutrition. The FAO reiterates that Sustainable Agriculture that seeks to increase yields while limiting the need for application of pesticides or synthetic fertilizers; only can relate Food Security with Food Safety. The consumption and production of safe food have immediate and long-term benefits for people, the planet and the economy. While COVID-19 has not been transmitted by food, the pandemic has sharpened the focus on food safety-related issues and towards improvement of Health and Immunity. Hence, analysis of pesticide residues in food has become the governing criteria for ensuring food safety.

However, 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 this objective. 'ONLY HEALTHY PLANTS CAN PRODUCE HEALTHY FOOD'.

Pic. 1 : Standardization of Colorimetric Pesticide Assay Test in Inhana laboratory by Inhana Organic Research Foundation (IORF) and Krishi Vigyan Kendra (Nadia), ICAR.

The relevance of Sustainable Agriculture is manifolds, especially in the context of India where >90% farmers are marginal and resource poor, with a land holding size even <0.38 hec., are therefore highly unsustainable, more vulnerable to climate change, require compulsory usage of a large quantity of synthetic agrochemicals but receive very poor and inconsistent revenue.

However, it has been found that pesticide monitoring in food is 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 consumption, limits the scope for safety analysis even if the infrastructure and economics is not considered.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A Review on the Colorimetric Pesticide Assay Test for Safe and Sustainable Agriculture with Special Reference to Clean Food Production

R. Bera [a], A. Datta [a], S. Bose [a], K. Mukhopadhyay [b], K. K. Goswami [b], M. Debnath [b], R. Mallick [c], A. Das [c], P. Bhattacharya [d], A. K. Barik [e] and A. Seal [a*]

[a] *Inhana Organic Research Foundation, 168, Jodhpur Park, Kolkata – 700068, India.*
[b] *Krishi Vigyan Kendra, ICAR, BCKV, Nadia, West Bengal, 741234, India.*
[c] *Institute of Agricultural Science, Calcutta University, Kolkata- 700019, India.*
[d] *Agricultural & Ecological Research Unit, ISI, Giridih- 815301, India.*
[e] *Department of Agronomy, Visva Bharati University, Sriniketan, Bolpur-731235, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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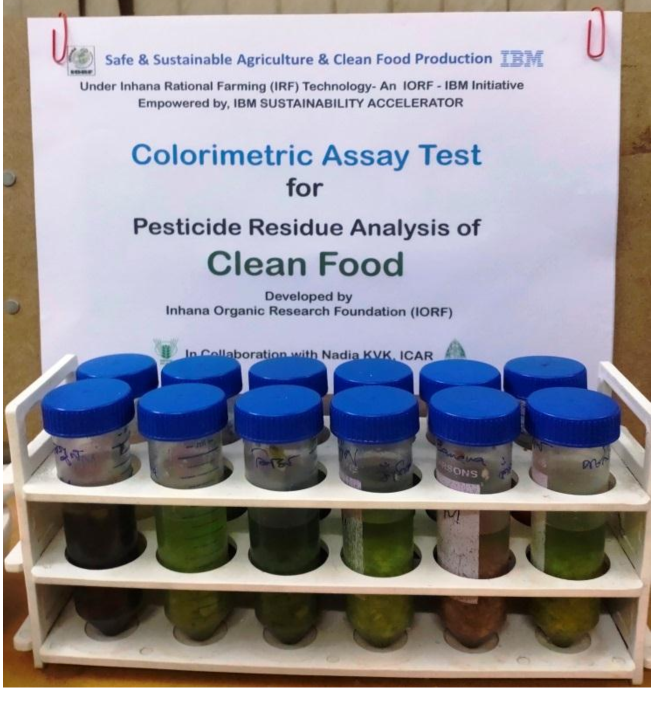
ABSTRACT

Background: 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 Food and Agriculture Organization (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.
As the second largest agrarian country of the world, India has also become one of the largest users of pesticides. Surveys have shown that Indian food is laced with one of the highest amount of toxic pesticide residues in the world. Hence, analysis of pesticide residues in food has become the governing criteria for ensuring food safety. The Food Safety and Standards Authority of India (FSSAI) have laid down science based standards towards food safety based on the Codex standards, which are the reference for the international trade in food. However, it has been found that pesticide monitoring in food is most difficult in countries where that monitoring is arguably most

*Corresponding author: E-mail: inhana.rfprojects@gmail.com;

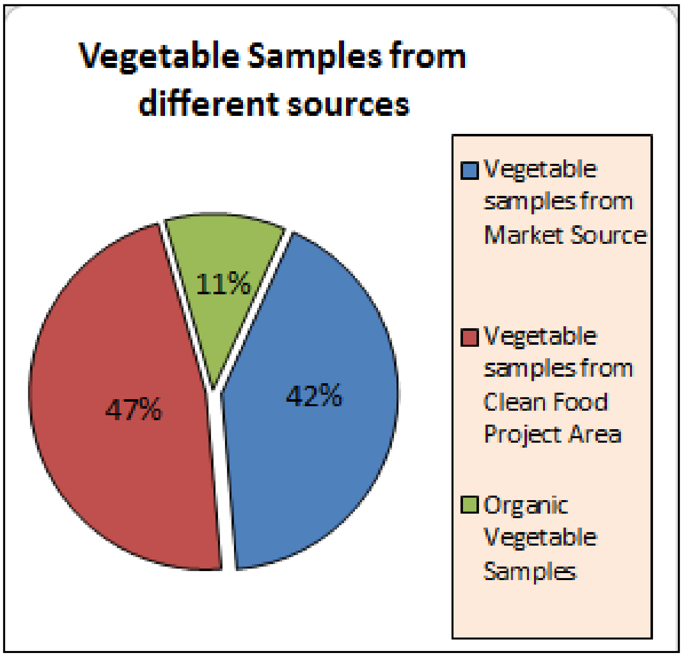


In this background an effective, simple, and affordable method is needed to enable pesticide residue analysis in situations of limited resources; more so for Safe & Sustainable Agriculture to comply the requirement for SDG-2 of the United Nations, more meaningfully SDG 2.1: Universal Access to Safe and Nutritious Food.

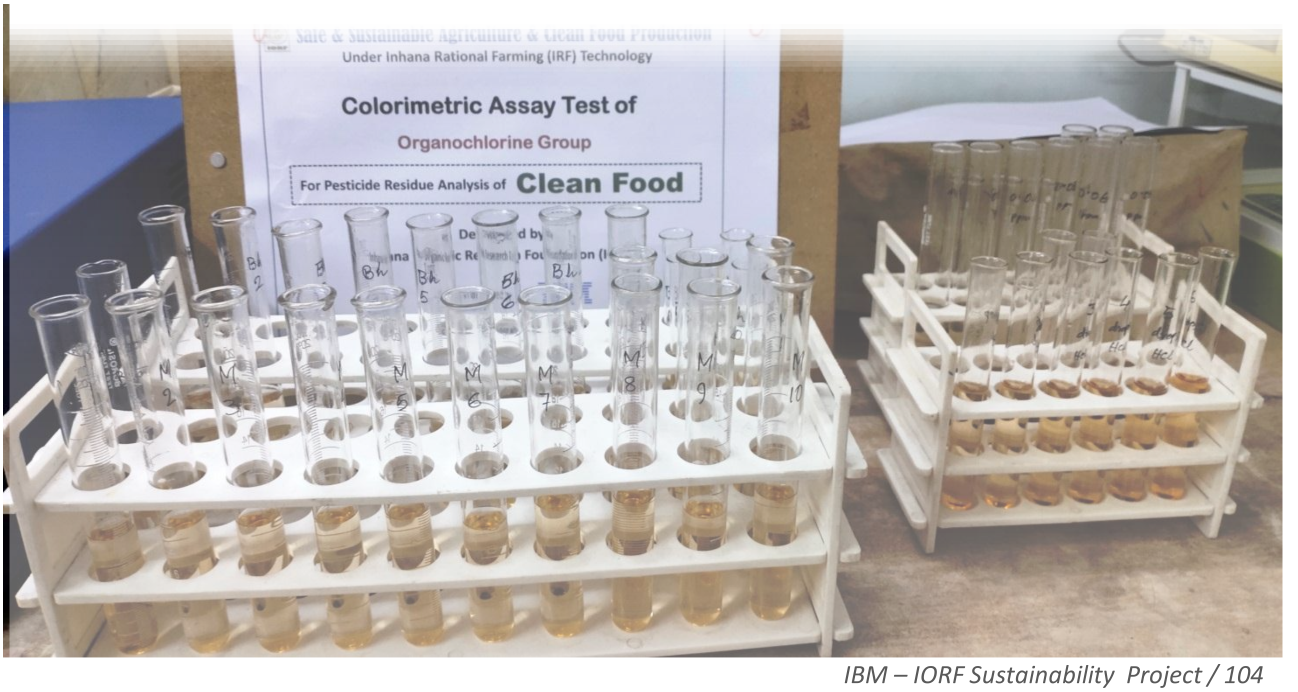
Why the Colorimetric Pesticide Assay Test ?

To mitigate both Cost and Time Constraints at a go, IORF identified the '**COLORIMETRIC PESTICIDE ASSAY TEST**'– a **Scientific yet an Economical Solution** that can be a real Game Changer in the Food Safety Arena and a 'Sustainability Tool' for Safe & Sustainable Agriculture.

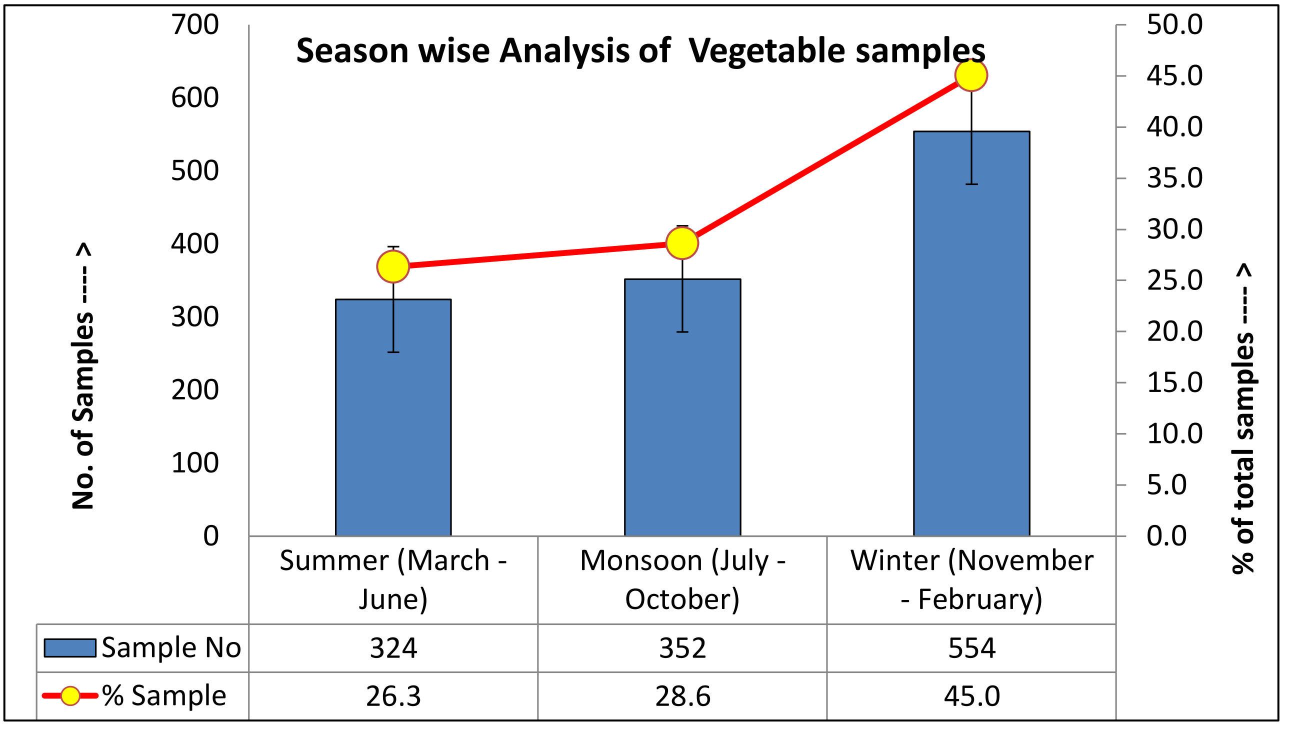
This test method although utilized round the globe to identify the pesticides residues both in a quantitative and qualitative manner, lack a standard protocol towards safety evaluation of vegetables in terms of detecting the presence/absence of the major pesticide groups. Another crucial point is how to measure in the most affordable and transparent manner. Then it has to be made available for small, marginal and resource poor farmers, who are more than 95% of the total farming community.



Inhana Organic Research Foundation (IORF), Kolkata in collaboration with Krishi Vigyan Kendra (Nadia), ICAR; took the initiative to develop a Protocol for Colorimetric Pesticide Assay Test of vegetables with the objectives of (i) Most Authentic and Speedy Measurement of the major groups of pesticides *viz*. organochlorine, organophosphate, synthetic pyrethroids, carbamates and neonicotinoids, that are used during vegetable production, (ii) 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) and (iii) Standardization of the Method



The standardization process involved the analysis of more than 1200 samples of 30 major vegetables produced in India. Vegetable samples were sourced from open markets, certified organic counters and from the farmers' field where the concept of Clean Food Program was 1st initiated by IORF in collaboration with KVK (Nadia), ICAR. Also the vegetable samples were sourced during different seasons i.e., winter (Period : November – February), monsoon (Period : July – October) and summer (Period : March – June).



	Summer (March - June)	Monsoon (July - October)	Winter (November - February)
Sample No	324	352	554
% Sample	26.3	28.6	45.0

Fig. 1 : Colorimetric Pesticide Assay Test : Analysis of vegetable samples as per season towards Standardization of the Protocol

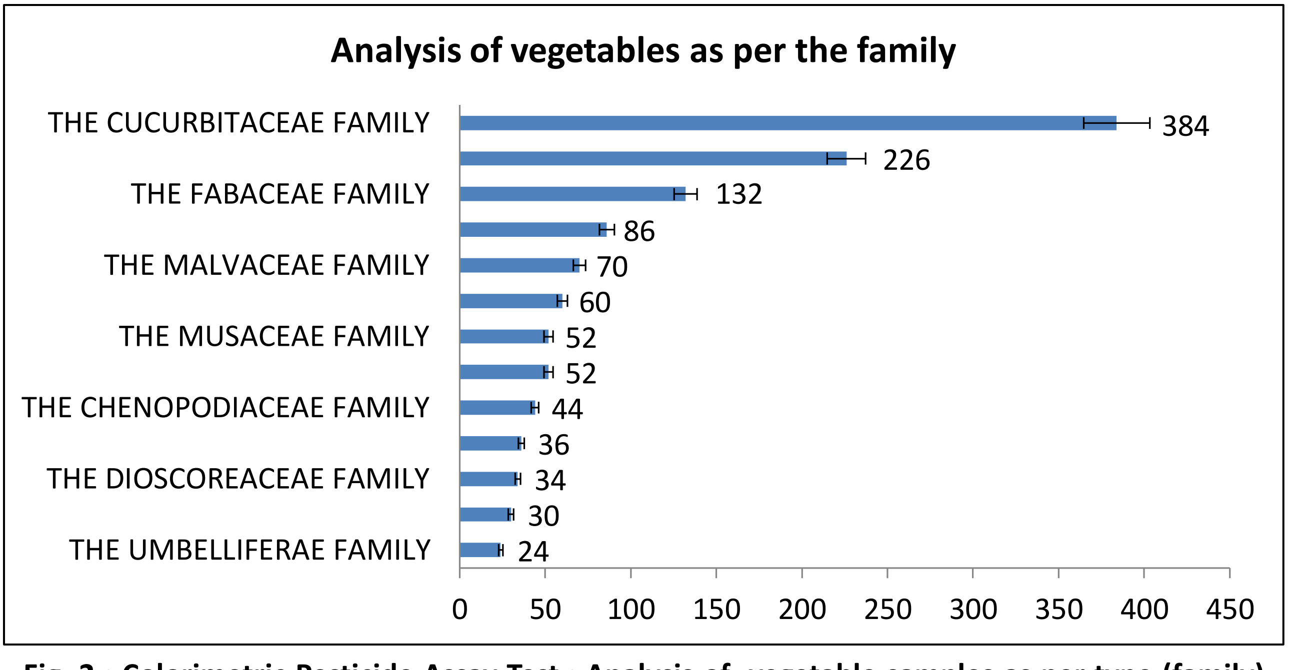


Fig. 2 : Colorimetric Pesticide Assay Test : Analysis of vegetable samples as per type (family) and collection source towards Standardization of the Protocol

Table 1. The Table indicates induction of the highest possible diversity during standardization of the Protocol.

Total No of Sample Analyzed	Summer (Period : March - June)				Monsoon (Period : July - October)				Winter (Period : November - February)				Grand Total
	Vegetable from Market Source	Vegetable from Clean Food Project	Organic Vegetables	Total	Vegetable from Market Source	Vegetable from Clean Food Project	Organic Vegetables	Total	Vegetable from Market Source	Vegetable from Clean Food Project	Organic Vegetables	Total	
THE SOLANACEAE FAMILY													
Brinjal (Solanum melongena L.)	12	8	2	22	10	12	2	24	12	18	2	32	78
Tomato (Solanum lycopersicum)	6	4	2	12	6	4	2	12	8	12	2	22	46
Potato (Solanum tuberosum)	6	4	2	12	4	0	2	6	8	12	2	22	40
Green Chilli (Capsicum annuum)	8	8	2	18	10	8	2	20	10	10	4	24	62
THE CUCURBITACEAE FAMILY													
Bitter gourd (Momordica charantia)	6	4	2	12	8	8	2	18	8	12	2	22	52
Cucumber (Cucumis sativus)	10	12	2	24	8	8	2	18	0	0	0	0	42
Pumkin (Cucurbita pepo L.)	4	6	2	12	6	6	2	14	8	10	2	20	46
Bottle gourd (Lagenaria siceraria)	4	4	2	10	6	6	2	14	6	6	2	14	38
Pointed gourd (Trichosanthes dioica Roxb.)	12	10	2	24	10	10	2	22	10	16	2	28	74
Ridge Gourd (Luffa acutangula (L.) Roxb.)	12	16	2	30	8	10	2	20	0	0	0	0	50
Spine Gourd (Momordica dioica)	8	8	2	18	10	12	2	24	0	0	0	0	42
Snake Gourd (Trichosanthes cucumerina)	8	8	2	18	10	10	2	22	0	0	0	0	40
THE FABACEAE FAMILY													
Broad beans (Vicia faba)	8	6	2	16	0	0	0	0	12	16	2	30	46
Peas (Pisum sativum)	0	0	0	0	0	0	0	0	10	14	2	26	26
French beans (Phaseolus vulgaris)	0	0	0	0	0	0	0	0	8	12	2	22	22
Yardlong bean (Vigna unguiculata ssp. Sesquipedalis)	0	0	0	0	8	8	2	18	8	10	2	20	38
THE BRASSICACEAE FAMILY													
Cabbage (Brassica oleracea var. capitata)	2	0	0	2	2	0	0	2	10	12	2	24	28
Cauliflower (Brassica oleracea var. botrytis)	2	0	0	2	2	0	0	2	12	16	2	30	34
knol-khol (Brassica oleracea L.)	0	0	0	0	0	0	0	0	10	12	2	24	24
THE MALVACEAE FAMILY													
Okra (Abelmoschus esculentus)	8	10	2	20	10	12	2	24	12	12	2	26	70
THE LILIACEAE FAMILY													
Onion flower stalk (Allium sativum)	0	0	0	0	0	0	0	0	8	14	2	24	24
Onion (Allium cepa)	6	6	2	14	0	0	0	0	8	12	2	22	36
THE ARACEAE FAMILY													
Colocasia (Colocasia esculenta)	0	0	0	0	6	8	2	16	8	10	2	20	36
THE UMBELLIFERAE FAMILY													
Carrot (Daucus carota subsp. Sativus)	0	0	0	0	0	0	0	0	8	14	2	24	24
THE CHENOPODIACEAE FAMILY													
Spinach (Spinacia oleracea)	6	6	2	14	4	4	2	10	8	10	2	20	44
THE DIOSCOREACEAE FAMILY													
Yam (Dioscorea)	0	0	0	0	6	8	2	16	8	8	2	18	34
THE CARICACEAE FAMILY													
Raw Papaya (Carica papaya. L.)	6	6	2	14	8	10	2	20	8	8	2	18	52
THE MUSACEAE FAMILY													
Raw Banana (Musa balbisiana)	4	4	2	10	4	4	2	10	2	2	2	6	26
Plantain Flower (Musa balbisiana)	4	4	2	10	4	4	2	10	2	2	2	6	26
THE AMARANTHACEAE FAMILY													
Red Amaranthas (Amaranthus cruentus)	4	4	2	10	4	4	2	10	4	4	2	10	30
TOTAL	**146**	**138**	**40**	**324**	**154**	**156**	**42**	**352**	**216**	**284**	**54**	**554**	**1230**

Thirty (30) most used pesticides in the vegetable fields were taken for the standardization procedure. Similarly for extraction from the test vegetables/fruits; the Standard QuEChERS method was adopted and standardized in present condition. For one vegetable sample, four individual studies/ analysis of the individual chemical groups were carried out.

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 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.

What all does the Newly Standardized Colorimetric Assay Test Offer ?

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 protocol can also be utilized for detecting the presence/ absence of toxic heavy metals such as Hg^{2+}, Cd^{2+}, Cu^{2+}, Pb^{2+} and a wide range of other toxic substance of known/unknown origin related to human health and safety**.

Moreover the Colorimetric Pesticide Assay Test Protocol opens up the scope for large scale and frequent food safety analysis due to the affordable cost (1/10th to 1/15th of the Conventional Cost of Residue Analysis) and significant reduction in the analysis time (1/10th of the time required for Residue Analysis using HPLC). Thus the Colorimetric Pesticide Assay Test can be a sustainable tool for any sustainable agriculture initiative to ensure safety in real time and in the most authentic and economic manner.

Pic. 2 : Development of Colorimetric Pesticide Assay Test Protocol for vegetables by Inhana Organic Research Foundation (IORF), Kolkata and Krishi Vigyan Kendra (Nadia), ICAR.

The Status of Food Safety in India and how 'Clean Food' Safety correlates

In India, the food safety is based on the guiding principle of risk analysis of the Codex Alimentarius Commission (CAC). As per the Food Safety and Standards (Contaminants, Toxins And Residues) Regulations (2011) developed by Food Safety and Standards Authority of India, the lowest limits of pesticide residue in vegetables is 0.1 ppm; excepting few cases. This was in accordance with codex Alimentarius maximum residual limit (0.1 ppm) in case of vegetables.

During 2008 to 2018, a total of 1,81,656 samples of the various food commodities were collected from various parts of the country and analyzed for the presence of pesticide residues, out of which 3,844 (2.1%) samples were found above MRL as prescribed under Food Safety Standard Authority of India (FSSAI), Ministry of Health and Family welfare. However Maximum Residual Limits (MRLs) of Insecticides in Organic Foods as per the Food Safety and Standards (Organic Foods) Regulations, 2017 are based on the standards of National Programme for Organic Production (NPOP) and Participatory Guarantee System (PGS-India) and lowest limit is mostly 0.01ppm in case of vegetables.

For authentication of Clean Food Safety, we also followed the Food Safety and Standards Authority of India (FSSAI) - Organic Standard of 0.01 ppm, as Tolerance limit. But the difference is that under FSSAI Organic Standard, the MRL of 0.01 ppm is the ceiling for individual pesticide, whereas under Clean Food Safety Standard the MRL of 0.01 ppm is the ceiling for the total presence of residues (*irrespective of the number of pesticides groups present*).

Hence, the Standard maintained for 'Clean Food' Safety is perhaps the Most Stringent in the Indian Food Safety Arena.

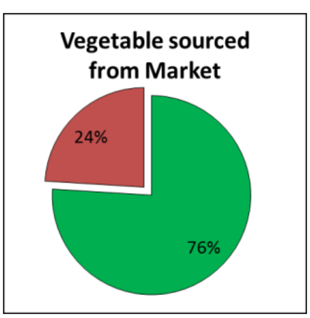
Pic. 3 : IORF Technical Team and KVK Official (Nadia), ICAR in the makeshift laboratory at the Project Site.

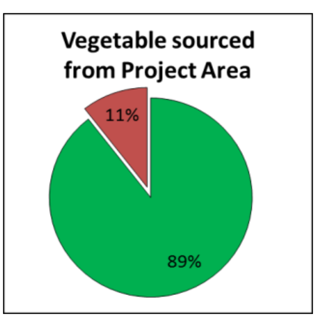
Table 2 : Colorimetric Pesticide Assay Test : Sample Percent that exceeded Maximum Residue Limit (MRL)

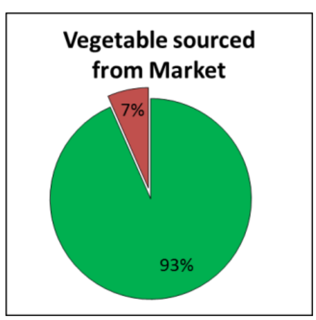
Total No of Sample Analyzed	Have atleast one group of pesticide residue > 0.01 ppm {Clean Food Standard]		Have atleast one group of pesticide residue > 0.10 ppm [FSSAI Standard]	
	Vegetable from Market Source	Vegetable from Clean Food Project	Vegetable from Market Source	Vegetable from Clean Food Project
THE SOLANACEAE FAMILY				
Brinjal (Solanum melongena L.)	61.76	44.74	32.35	23.68
Tomato (Solanum lycopersicum)	55.00	40.00	20.00	5.00
Potato (Solanum tuberosum)	44.44	31.25	16.67	6.25
Green Chilli (Capsicum annuum)	25.00	15.38	7.14	3.85
THE CUCURBITACEAE FAMILY				
Bitter gourd (Momordica charantia)	13.64	4.17	0.00	0.00
Cucumber (Cucumis sativus)	11.11	5.00	0.00	0.00
Pumkin (Cucurbita pepo L.)	5.56	0.00	0.00	0.00
Bottle gourd (Lagenaria siceraria)	6.25	6.25	0.00	0.00
Pointed gourd (Trichosanthes dioica Roxb.)	40.63	19.44	12.50	5.56
Ridge Gourd (Luffa acutangula (L.) Roxb.)	20.00	7.69	10.00	0.00
Spine Gourd (Momordica dioica)	16.67	5.00	0.00	0.00
Snake Gourd (Trichosanthes cucumerina)	16.67	5.56	0.00	0.00
THE FABACEAE FAMILY				
Broad beans (Vicia faba)	30.00	13.64	10.00	4.55
Peas (Pisum sativum)	30.00	7.14	10.00	0.00
French beans (Phaseolus vulgaris)	37.50	16.67	12.50	0.00
Yardlong bean (Vigna unguiculata ssp. Sesquipedalis)	12.50	5.56	0.00	0.00
THE BRASSICACEAE FAMILY				
Cabbage (Brassica oleracea var. capitata)	28.57	8.33	7.14	0.00
Cauliflower (Brassica oleracea var. botrytis)	25.00	6.25	6.25	0.00
knol-khol (Brassica oleracea L.)	20.00	16.67	0.00	0.00
THE MALVACEAE FAMILY				
Okra (Abelmoschus esculentus)	26.67	2.94	10.00	2.94
THE LILIACEAE FAMILY				
Onion flower stalk (Allium sativum)	25.00	0.00	0.00	0.00
Onion (Allium cepa)	7.14	0.00	0.00	0.00
THE ARACEAE FAMILY				
Colocasia (Colocasia esculenta)	7.14	0.00	0.00	0.00
THE UMBELLIFERAE FAMILY				
Carrot (Daucus carota subsp. Sativus)	50.00	14.29	12.50	0.00
THE CHENOPODIACEAE FAMILY				
Spinach (Spinacia oleracea)	16.67	5.00	0.00	0.00
THE DIOSCOREACEAE FAMILY				
Yam (Dioscorea)	14.29	0.00	0.00	0.00
THE CARICACEAE FAMILY				
Raw Papaya (Carica papaya. L.)	9.09	0.00	0.00	0.00
THE MUSACEAE FAMILY				
Raw Banana (Musa balbisiana)	10.00	0.00	0.00	0.00
Plantain Flower (Musa balbisiana)	10.00	0.00	0.00	0.00
THE AMARANTHACEAE FAMILY				
Red Amaranthas (Amaranthus cruentus)	16.67	0.00	0.00	0.00
TOTAL	24.81	10.90	6.98	2.77

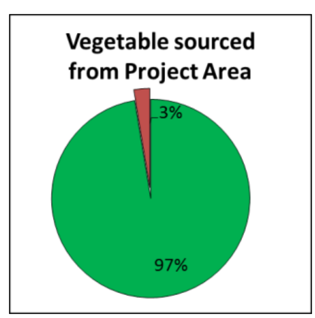
Sample Percent that had at least one group of Pesticide Residue >0.01 ppm [Clean Food Standard]

Sample Percent that had atleast one group of Pesticide Residue >0.10 ppm [In accordance with Stds. of CODEX ALIMENTARIUS FAO - WHO & FSSAI]









Clean Food Standard is in Accordance with FSSAI Organic Food Standard and 10 Times more Stringent than Standards of CODEX ALIMENTARIUS FAO-WHO & FSSAI

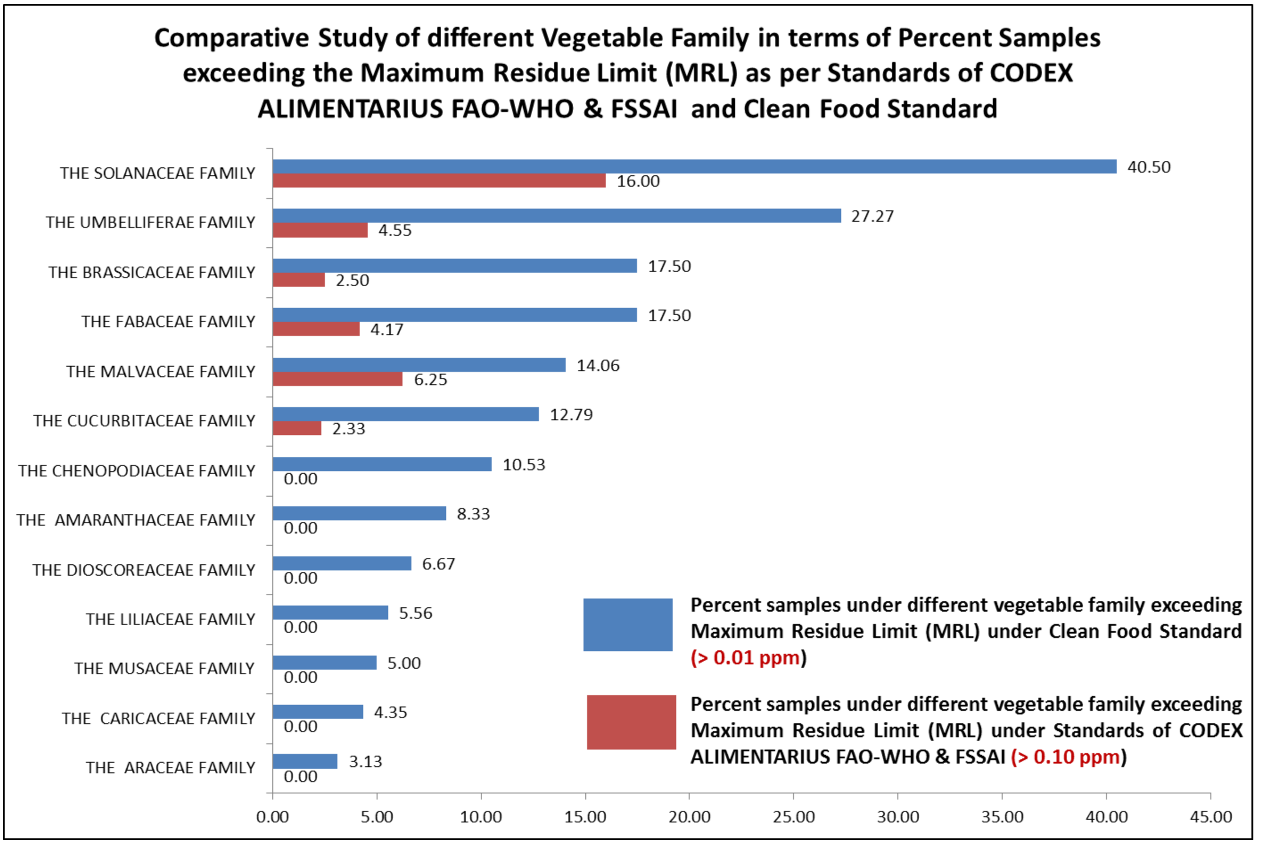


Fig. 3 : Comparative Analysis of different vegetable families in terms of MRL under different Standards (Before Project Initiation)

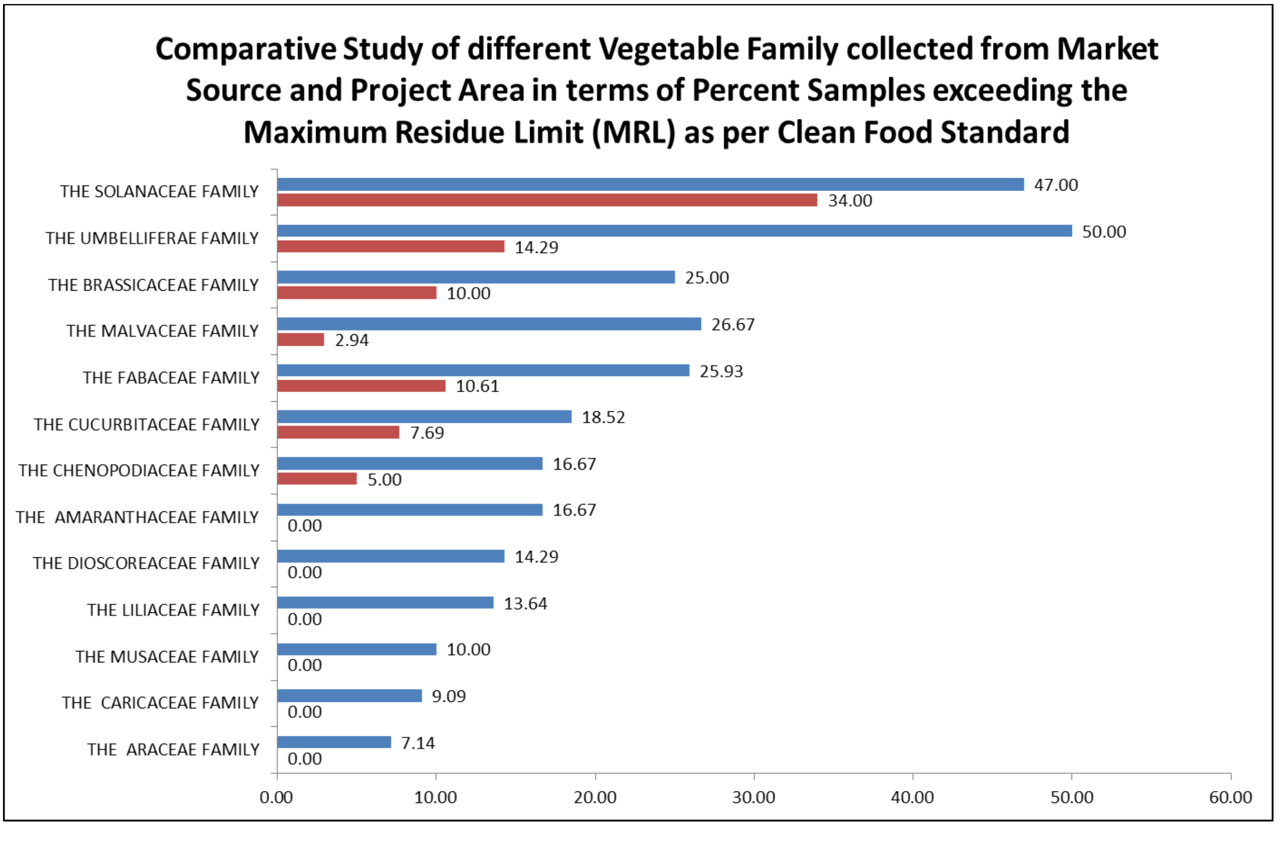


Fig. 4 : Comparative Analysis of different Vegetable Family from different Collection Source in terms of MRL under different Standards (Before Project Initiation)

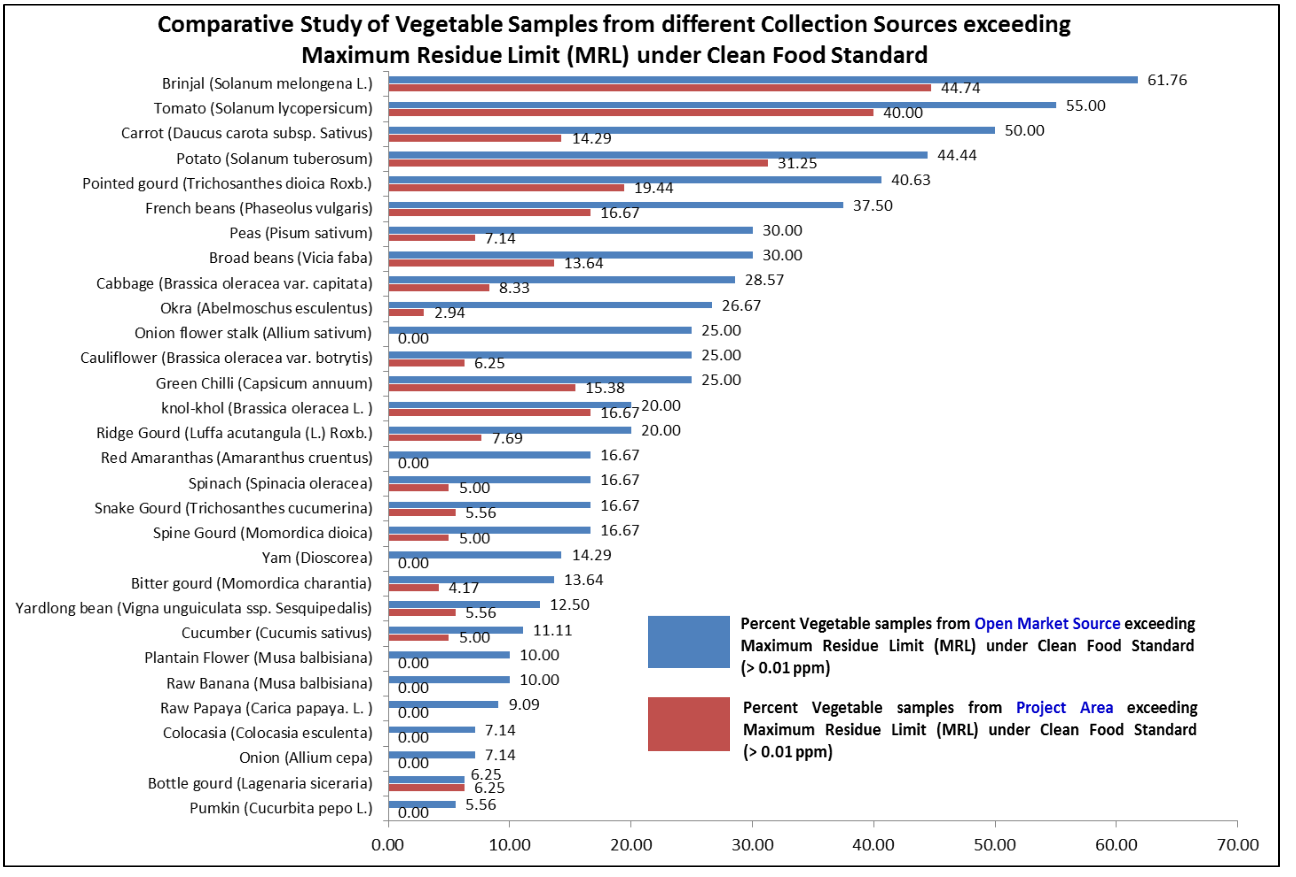


Fig. 5: Comparative Analysis of different Vegetable Family from different Collection Sources in terms of MRL under different Standards (Before Project Initiation)

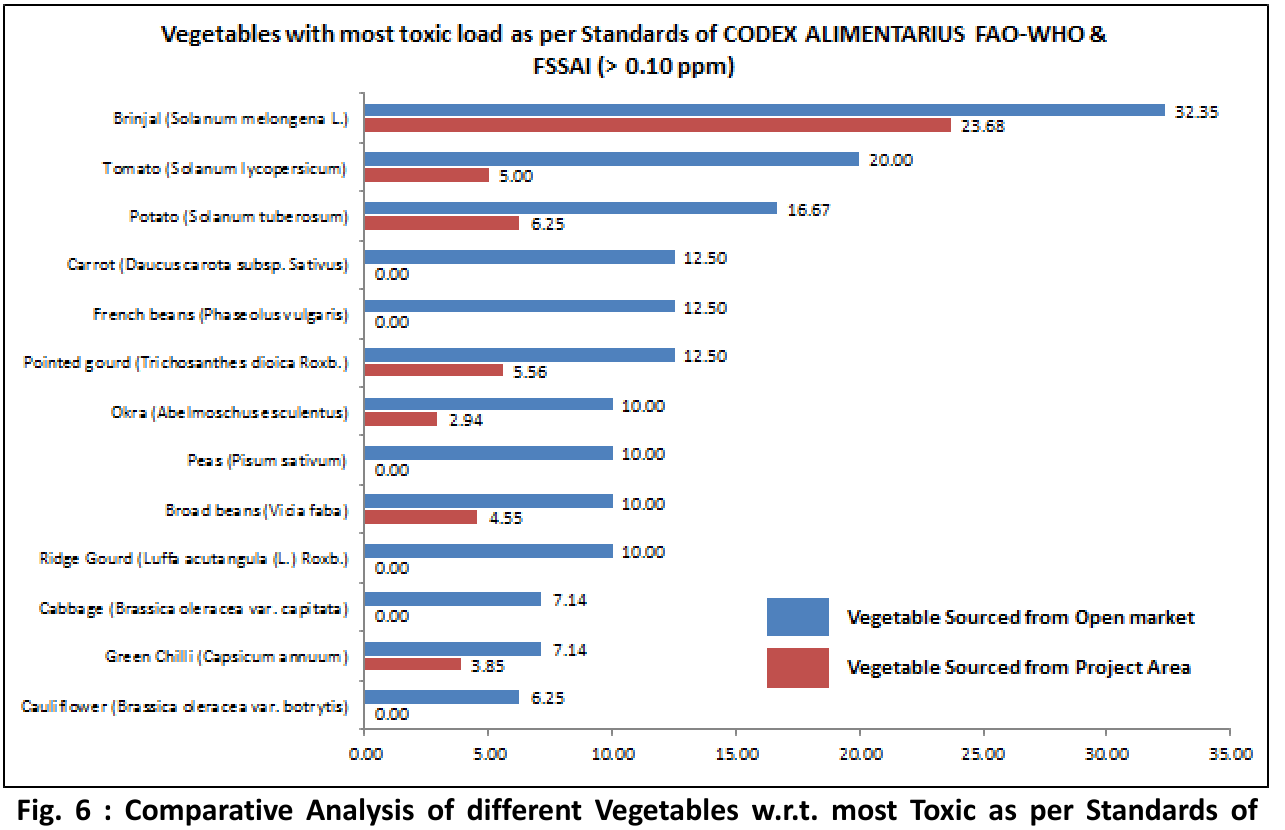


Fig. 6 : Comparative Analysis of different Vegetables w.r.t. most Toxic as per Standards of CODEX ALIMENTARIUS FAO-WHO & FSSAI (> 0.10 ppm) (Before Project Initiation)

Pesticide Residue Analysis Report of CLEAN FOOD

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Sample Collected by : Dr. K. Mukherjee, Nadia KVK

No : CATPR/ IL/2021/C101 Date : 20.12.2021

Name of Applicant : IORF Clean Food Project Team

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

Description of sample : Vegetables (12 samples)

Source of Sample : Model Farms (Nadia, West Bengal, India) under *IBM Sustainability Accelerator Project* 'Adoption of a Cluster of Villages for Agricultural Sustainability and Food Security through Clean Food Program'.

Mark on Sample : Approximately 500g each in sealed packed separately & signed by Dr. K Mukherjee

Sample Received on : 14.12.2021

Analysis Started on : 15.12.2021

Analysis Completed on : 20.12.2021

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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Colororimetric Assay test of Pesticide Residues / 1

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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 : Pointed Gourd						
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 : Onion Flower						
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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Colororimetric Assay test of Pesticide Residues / 2

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Colorometric Assay test of Pesticide Residues / 3

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm) Visual	Detection Limit (ppm) Spectro-photometer	Result Visual	Result Spectro-photometer
Sample 4: Chilli						
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: Bitter Gourd						
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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Colororimetric Assay test of Pesticide Residues / 3

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Colorometric Assay test of Pesticide Residues / 4

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm) Visual	Detection Limit (ppm) Spectro-photometer	Result Visual	Result Spectro-photometer
Sample 6: Green Peas						
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: Cabbage						
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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Colororimetric Assay test of Pesticide Residues /4

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Colorometric Assay test of Pesticide Residues /5

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm)		Result	
			Visual	Spectro-photometer	Visual	Spectro-photometer
Sample 8 : Pumkin						
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 9 : Cauliflower						
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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Colororimetric Assay test of Pesticide Residues / 5

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Colorometric Assay test of Pesticide Residues / 6

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm)		Result	
			Visual	Spectro-photometer	Visual	Spectro-photometer
Sample 10 : Bottle Gourd						
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 11 : Raw Papaya						
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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Colororimetric Assay test of Pesticide Residues / 6

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Colorometric Assay test of Pesticide Residues / 7

Sl No	Test Parameters (Pesticide Group)	Test methodology	Detection Limit (ppm)		Result	
			Visual	Spectro-photometer	Visual	Spectro-photometer
Sample 12 : Raw banana						
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

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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

Head, Inhana Laboratory

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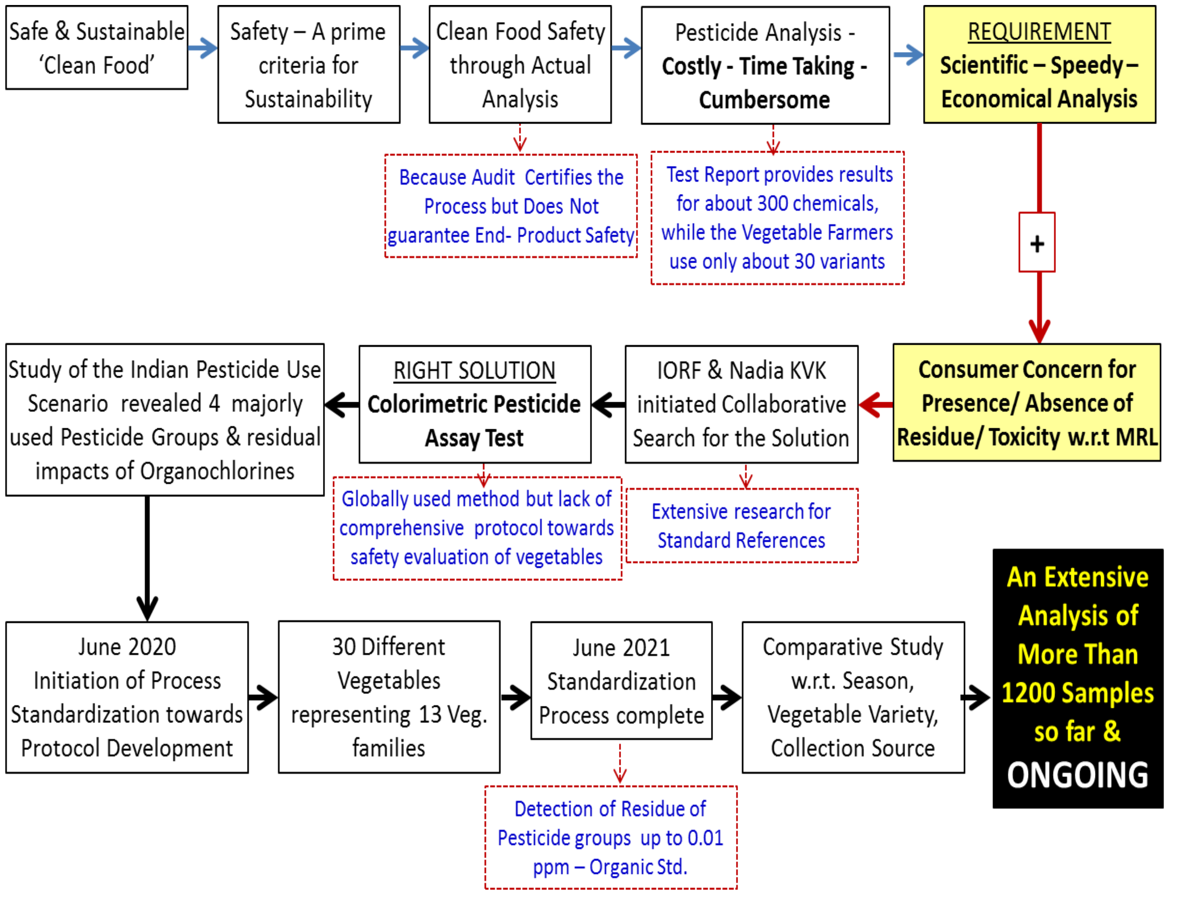
Pic. 4 : Pesticide Residue Analysis of vegetable samples using the Newly Standardized Colorimetric Pesticide Assay test.

Standardization of Protocol for Colorimetric Pesticide Assay Test- Activity Flow Chart



In A Nutshell

The Colorimetric Pesticide Assay Test can **Authenticate Safety In Real Time & in the Most Economic Manner** due to :

- The **AFFORDABLE COST (1/10th to 1/15th of the Conventional Cost of Residue Analysis)** and
- Significant **REDUCTION IN THE ANALYSIS TIME** (**1/10th of the time required for Residue Analysis using HPLC**).
- **Scope for Batch wise Safety Authentication for All Food Types especially the ones having a SHORT TIME GAP BETWEEN HARVEST AND CONSUMPTION.**
- **All of the Above Makes this Tool a REAL GAME CHANGER for SMALL & MARGINAL FARMERS**
- **Colorimetric Pesticide Assay Test can serve as a Unique Sustainability Tool with an Impact Area w.r.t SDG 2.1: Universal Access to Safe and Nutritious Food**

CHAPTER 16 : QUALITY ASSESSMENT OF 'CLEAN FOOD'

The Backdrop

Vegetables are the important sources of vitamins, minerals, and antioxidants, providing human health benefits. Vegetables contain low fats, less sugars, and sodium ions, which are the main focus of healthy diets. In this regards, WHO recommends consumption of more than 400 grams of fruits and vegetables per day to maintain good health and also reduce the risk of non-communicable diseases. Apart from the Environmental Factors, the Quality of a Vegetable greatly depends on the Crop Production systems and the Management Strategies adopted.

The International Year of Fruits & Vegetables 2021 was an initiative to raise awareness on the Important Role of Fruits & Vegetables in Human Nutrition, Food Security and Health as well as in Achieving the UN Sustainable Development Goals. The World Health Organization (WHO) also 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 World Food Safety Day, 2022 theme highlights the role that safe, nutritious food plays in ensuring human health.

That means Vegetables are the source of Nutrition for Human Health, but only when this Nutrition comes from a Safe Source- it can Sustain Life & Promote Good Health. And Only Safe and Sustainable Agriculture can Produce Safe Vegetables for its Nutrition to provide Actual Health Benefits and Immunity. That means Food can Boost Up Immunity only when it is NATURALLY RICH in Anti-oxidants, Minerals, Vitamins & other Qualities, but food grown under conventional chemical farming i.e., using Synthetic Fertilizers and Pesticides Cannot serve this objective. 'ONLY HEALTHY PLANTS CAN PRODUCE SAFE - NUTRITIOUS FOOD'.

The 'Clean Food' concept was developed by IORF to demonstrate an adoptable Solution for 'Safe & Sustainable Agriculture, with focus on Plant Health Management, the most crucial component for Healthy Plant development that can ensure Crop Sustainability even under the Climate Change Impact. Hence, Quality Analysis of 'Clean Food' was a priority in order to adjudge whether and to what extent does Safe & Sustainable Agriculture impact Food Quality.

Quality evaluation of Clean Vegetables was done in terms of three parameters which have crucial relevance towards human health :

1. Vitamin – C Content
2. Protein Richness
3. Antioxidant Richness

Quality analysis was done for the 12 Major Types of Vegetables grown by the farmers in the Project Area in order to review the impact of a Safe and Sustainable Crop Technology (IRF Technology) on the end product quality as compared to the Conventional Farming Practice.

The Process Undertaken

To conduct the analysis, for each Vegetable Type, 5 samples (each) were collected randomly from the Model Farms and the Conventional Farmers' field respectively, during the month of January - February.

The vegetables taken for the assessment are as follows :
Potato, Tomato, Brinjal, Carrot, Cauliflower, Cabbage, French Beans, Green Peas, Spinach, Okra, Green- Chilli and Red Onion

VITAMIN C – a Major Quality Parameter for Vegetables

Vitamin C is required for the biosynthesis of collagen, L-carnitine, and certain neurotransmitters and is also involved in protein metabolism. However, Vitamin C is an exogenous compound for humans, and must be supplied in food. This analysis was done in respect of the Vitamin-C rich vegetables grown in the study area viz. Cauliflower, Spinach, Tomato, Cabbage, Potato, Peas, Green Chilli and Okra, following the Titration Method using Indophenol, as per the Guideline of FSSAI Manual

Table 1 : Analysis indicated an improvement in the expression of this quality parameter in the 'Clean Vegetables' as compared to the conventionally grown vegetables.

Sl No	Vegetables	Under Conventional Farmers' Practice (CFP) (g/100g)	Under IBM-IORF Clean Food Project (ICFP) (g/100g)
1.	Cauliflower	64.5 – 85.3 (74.21 ± 3.32)	62.3 – 89.2 (78.49 ± 3.24)
2.	Spinach	49.4 – 57.2 (54.6 ± 2.12)	54.2 – 62.4 (57.62 ± 2.06)
3.	Tomato	21.3 – 26.2 (24.5 ± 1.46)	26.4 – 34.7 (29.11 ± 1.56)
4.	Cabbage	34.6 – 39.1 (37.1± 1.02)	35.4 – 43.1 (39.14 ± 1.04)
5.	Potato	11.80 – 13.80 (12.40 ± 0.304)	12.04 - 14.20 (13.30 ± 0.329)
6.	Peas	26.4 – 39.2 (34.10 ± 4.01)	28.2 – 43.4 (37.29 ± 3.04)
7.	Green- Chilli	0.19 – 0.27 (0.23 ± 0.02)	0.19 – 0.31 (0.24 ± 0.044)
8.	Okra	18.3 – 25.2 (19.56 ± 1.02)	17.28 – 29.01 (20.01 ± 0.092)

PROTEIN RICHNESS – of Major Relevance in respect of Plant- Based Proteins

Protein is not only a part of every cell in the body, but also helps the body to build and repair cells and tissues. Protein is made up of long chains of amino acids and there are nine essential amino acids that the human body does not synthesize, so they must come from the diet. Animal protein sources are complete — meaning they provide all the nine essential amino acids.

However, the Benefits of Plant-based Protein include increased intake of fibre as well as the fact that they do not contain some of the less-healthy compounds found in meat, including saturated fat and cholesterol.

Total Protein analysis was done in respect of the Protein rich vegetables grown in the study area viz. French- Beans, Green- Peas, Spinach, Brinjal, Potato, Carrot and Cauliflower, following Kjeldahl Method, along with Jones Factor as per the Guideline of FAO.

Table 2 : Comparative evaluation indicated an Almost At Par/ Slightly Higher Protein Content in the 'Clean Vegetables' vis-à-vis the conventionally grown vegetables.

Sl No	Vegetables	Under Conventional Farmers' Practice (CFP) (g/100g)	Under IBM-IORF Clean Food Project (ICFP) (g/100g)
1.	Beans	14.3 – 15.2 (14.65 ± 2.02)	14.13 – 15.31 (14.64 ± 2.06)
2.	Spinach	2.79 – 2.98 (2.85 ± 0.281)	2.74 – 3.06 (2.89± 0.202)
3.	Brinjal	1.04 - 1.12 (1.07 ± 0.012)	1.05 - 1.10 (1.07 ± 0.011)
4.	Green-Peas	4.83 - 5.27 (4.92 ± 1.01)	4.81 - 5.39 (4.98 ± 1.02)
5.	Carrot	0.80 – 0.96 (0.87 ± 0.010)	0.79 – 0.98 (0.88 ± 0.010)
6.	Cauliflower	0.73 - 0.86 (0.79 ± 0.021)	0.72 - 0.89 (0.81 ± 0.024)
7.	Potato	2.10 - 2.41 (2.21 ± 0.014)	2.11 - 2.46 (2.24 ± 0.013)

ANTIOXIDANT RICHNESS – an Indicator of 'Plant Health' & the Health Giving Aspects of the Vegetables.

The Phenolic Compounds are one of the most important natural antioxidants. Polyphenols are Secondary Metabolites of Plants and are generally involved in defense against aggression by pest/ pathogens. Therefore Higher Polyphenol Content in the end product is indicative of an Activated Host- Defense Mechanism within the Plant System.

These same natural Phenolic Compounds in the Plant Food provide the maximum health benefits, and are considered to be responsible for chemo-preventive effects.

Number of researches have indicated that organic crops have significantly higher antioxidant levels when compared to conventional crops, mainly due to the absence of synthetic pesticides, causing a higher exposure of the plants to stressful situations leading to an enhancement of natural defense substances such as phenolic compounds

This analysis was done in respect of the Antioxidant rich vegetables grown in the study area *viz*. carrot, potato, red onion, spinach, tomato, brinjal and cabbage.

The Total Phenolic Content in Vegetable Extracts was determined in triplicates by using Folin-Ciocalteau Colorimetric Method.

Table 3 : The comparative study indicated a relatively higher polyphenol content in the 'Clean Vegetables' *vis-à-vis* the Conventional Vegetables.

Sl No	Vegetables	Under Conventional Farmers' Practice (CFP) (g/100g)	Under IBM-IORF Clean Food Project (ICFP) (g/100g)
1.	Carrot	54.1 – 68. 8 (57.04 ± 4.31)	55.02 – 69.80 (61.02 ± 5.14)
2.	Potato	51.04 – 59.24 (54.04 ± 3.39)	52.13 – 59.04 (56.04 ± 3.49)
3.	Red Onion	84.02 – 95.24 (91.04 ± 4.19)	82.10 – 98.04 (96.03 ± 6.49)
4.	Spinach	234.1 – 242. 8 (238.4 ± 15.22)	235.4 – 244.2 (241. 2 ± 17.42)
6.	Tomato	14.85 – 18.58 (17.02 ± 2.01)	15.05 – 19.08 (17.32 ± 2.04)
7.	Brinjal	49.2 – 62.3 (57.14 ± 3.09)	50.2 – 63.2 (59.01 ± 3.19)
8.	Cabbage	104.1 – 108. 8 (102.04 ± 8.31)	105.4 – 114.2 (106. 2 ± 7.14)

This might be attributed to Plant Health Management, which forms an integral part of the Sustainable Crop Technology (IRF Technology) that has been adopted for driving the Safe & Sustainable 'Clean Food' Production .

Quality Assessment of 'CLEAN POTATO'

Potato is an important cash crop in the Project Area and occupies the first position both in respect of area as well as the quantity produced. Hence, detailed quality assessment was done for this particular crop to assess any qualitative differences in potato with variation in management practice. Potato samples were collected from the Model Farms and analyzed for Specific Gravity, Starch Content, pH, Titrable Acidity and Vitamin- C.

Quality parameter	Under Conventional Farmers' Practice (CFP)	Under IBM-IORF Clean Food Project (ICFP)
Specific gravity	1.041 – 1.110 (1.061 ± 0.011)	1.040 – 1.119 1.064± 0.012
Starch (g/ 100g tissue)	10.80 – 16.71 (11.65 ± 2.03)	10.66 – 17.52 (12.72 ± 2.01)
pH	5.98 - 6.12 (6.06 ± 0.012)	6.10 – 6.18 (6.14 ± 0.016)
Titrable acidity (%)	0.33 – 0.78 (0.53 ±0.113)	0.26 - 0.67 (0.43 ± 0.012)
Vitamin C (mg/ 100 mg tissue)	11.80 – 13.80 (12.40 ± 0.304)	12.04 - 14.20 (13.30 ± 0.329)

SPECIFIC GRAVITY of potato positively correlates with dry matter and starch content, and negatively with reducing sugar content, hence; higher specific gravity is an important indicative quality parameter. Relatively higher Specific Gravity of ‘Clean Potato’ indicated positive influence of Plant Health Management under IRF Technology.

STARCH, comprise 65-80% of dry matter content of potato and has direct influence on its technological quality, especially with regard to the texture of the processed products. Analysis indicated about 9.2% Higher Starch Content in ‘Clean Potato’ as compared to the conventionally grown counterpart.

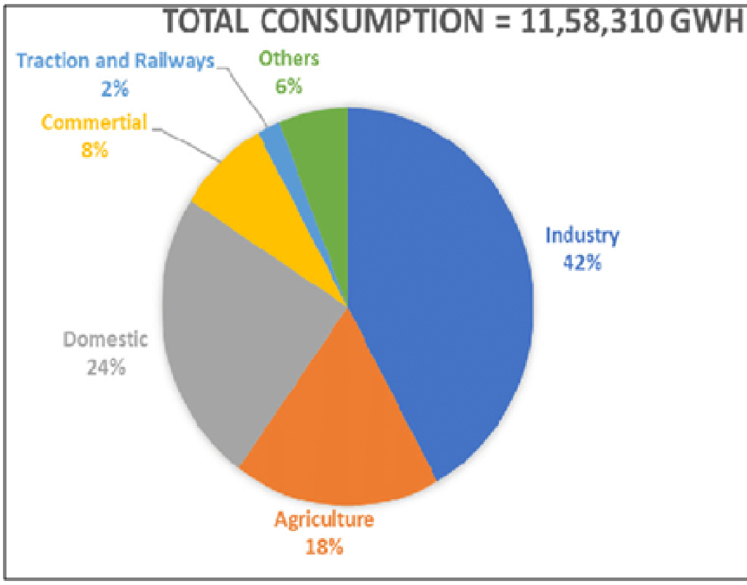
Factors that may interfere in a negative and/ or indirect way on the technological quality of tubers are pulp **pH and Total Titrable Acidity**. The pH index presents a negative correlation with reducing sugars accumulation and determines deterioration potential by fermentation and the activity of enzymes, predominantly on starch breakdown with maximum activity at pH 5.5. Total acidity on the other hand quantifies organic acids present in foods and also shows negative correlation with reducing sugars, which could contribute toward browning of the fried product. Hence a relatively Higher pH (6.14) value and Lower Titrable Acidity of ‘Clean Potato’ vis-à-vis conventional potato (0.43 percent) indicated a lower degradability and lower browning potential, when fried.

Potatoes are a steady reliable source of vitamin C (ascorbic acid). Vitamin C of ‘Clean potato’ was found to be about 7.3% higher, which indicated the positive role of a Safe & Sustainable Crop Technology (IRF Technology) on the ascorbic acid content as also indicated by several other scientists.

Pic. 1: Discussion & demonstration of ‘Clean Food’ produced under IBM Sustainability Project in Agriscience Fair organized by KVK (Nadia), ICAR.

Agriculture, is both a user and a supplier of energy in the form of bioenergy and food. 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 agrifood 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.



Agriculture Energy Consumption in 2020

19,6,913 GWH

Major challenge for the agricultural sector is to reduce environmental impacts while maintaining an economic activity

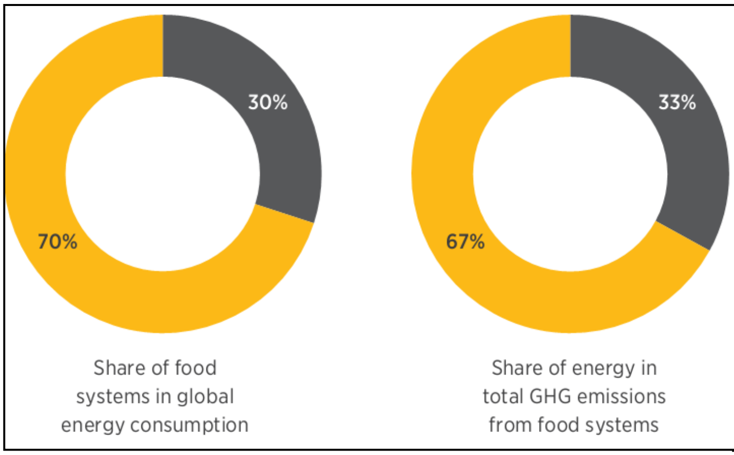
Ref.:https://indiaenergyportal.org/energy-consumption-in-india/

The lack of energy efficiency in the agricultural and food sector causes significant Greenhouse Gas Emissions. The UN 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)

The world's energy and food systems must be transformed to cope with growing demand; to become more inclusive, s secure, and sustainable; and to come into alignment with the 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change.

The transformation pathways of the two systems are deeply entwined: Agri-food systems consume about 30% of the world's energy, and a third of agri-food systems' emissions of greenhouse gases stem from energy use. The energy transition will directly affect the food system, and vice versa.



- About **30% of the world's energy** is consumed **within agri-food systems**.
- Energy is also responsible for **a third of agri-food systems' emissions of GHGs.**

Both systems must be transformed to meet current and future demand for food and energy in a fair, environmentally sustainable, and inclusive manner.

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. 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 an 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.

Food and energy systems also have a profound impact on society, economies and the environment, making them central to meeting multiple Sustainable Development Goals. **Over 2.5 billion people worldwide rely on agriculture for their livelihoods making the sector a key driver for development.**

Present patterns of energy use in agri-food systems point to regional disparities, lack of access to modern energy (especially in the developing world) and **continuing dependence on fossil fuels.**

The structure of energy consumption in food systems varies significantly between developing and developed countries. **In the latter, about 25% of total energy use occurs in the production stage (crop, livestock and fishery), 45% in food processing and distribution, and 30% in retail, preparation and cooking.**

The Global Energy and Food Systems are at an Important Crossroads

Both must cope with growing demand for energy and food from a growing population; both must transform to become more inclusive, secure and sustainable; and both must come into alignment with the 2030 Agenda for Sustainable Development and the Paris Agreement.

Reasons for unsustainable use of energy in the food system *(Source: Renewable energy for agri-food systems, 2021 by IRENA and the FAO, UN)*

- Maximum small and medium-sized agri-food enterprises **lack access to sustainable, reliable and affordable energy** to produce, store, process and consume food, resulting in significant food losses in post-harvest stages.
- Around **14% of food produced globally is lost** before even reaching the market (FAO, 2020a).
- The quality of food and cooking conditions are sub-optimal.
- Agri-food chains account for about 30% of global energy consumption, most of it in post-harvest stages and **in the form of fossil fuels**.
- **About 30% of that energy is wasted** through food losses at one point or another in the value chain (FAO, 2011).
- **Finally, energy use is responsible for about one-third of the greenhouse gas (GHG) emissions from food systems. (Source: Crippa et al. 2021).**

Agriculture Sector : 2nd Largest Source for GHG Emission

According to an estimate by FAO, in 2018; **global emissions due to agriculture** (*within the farm gate and including related land use/land use change*) 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.**

The use of synthetic nitrogen (N) fertilizers accounted for 8.3% of farm-gate emissions in 2019 (FAO).

Of the **16.5 billion tonnes of GHG emissions from global total agri-food** systems in 2019, **7.2 billion tonnes (43.6%) came from within the farm gate,** 3.5billion **tonnes (21.2%)** from land use change, and 5.8 **(35.2%)** billion **tonnes** from supply-chain processes.

Source: FAO. Emissions from agriculture and forest land. Global, regional and country trends 1990–2019. FAOSTAT Analytical Brief 25. https://www.fao.org/3/cb5293en/cb5293en.pdf, see also https://www.fao.org/3/cb7514en/cb7514en.pdf. Downloaded on 11-03-2022. (FAO, 2021).

Relevance of energy footprint in Food and Agriculture

The amount of energy used in agriculture has grown substantially, and currently, the agrifood chain accounts for 30 percent of the total energy used around the world.

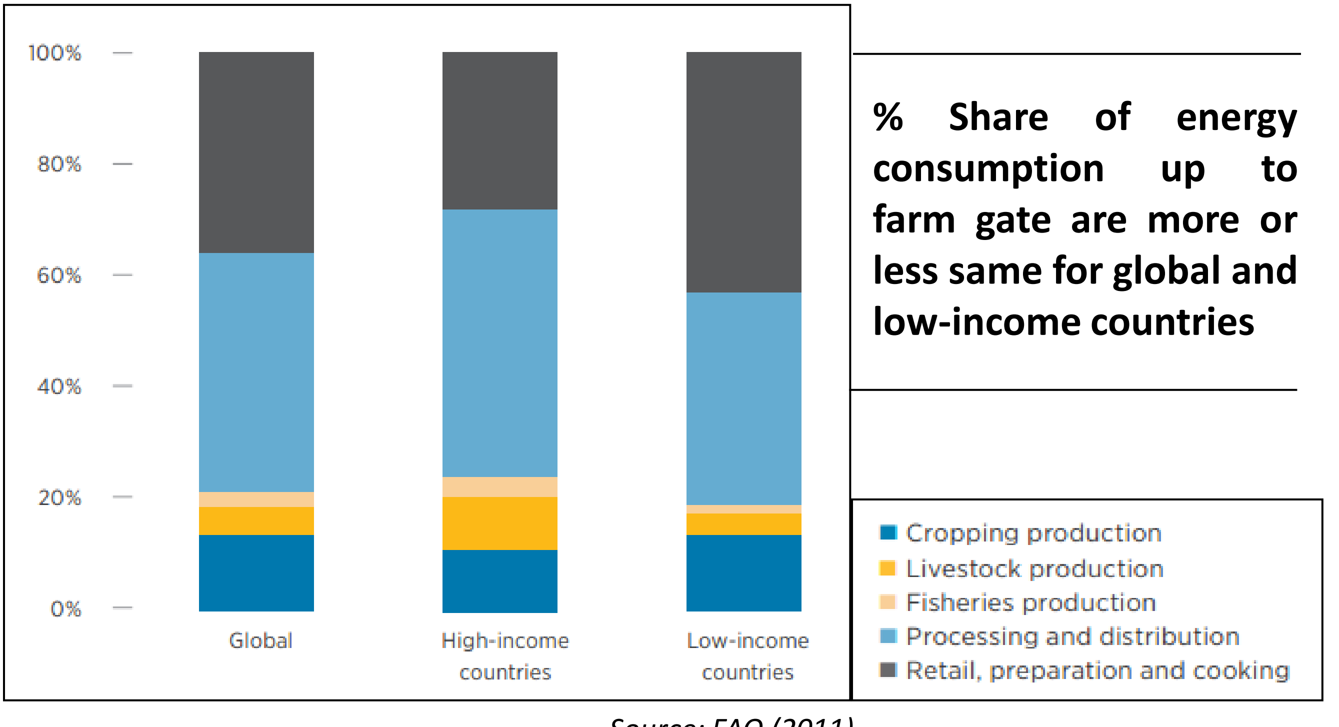
FAO analysis (Nov 2021) reveals carbon footprint of agri-food supply chain: Food processing, packaging, transport, household consumption and waste disposal are pushing the food supply chain to the top of the greenhouse gas emitters list, according to a new study led by the UN agriculture agency, presented at the COP26 climate conference in Glasgow.

KEY FACTS

- Current food systems use about 30 percent of globally available energy, and this energy accounts for about **30 percent of agri-food systems greenhouse gas emissions because modern food systems are heavily dependent on fossil fuels.**
- An estimated **one-third of the food** we produce is **lost or wasted**, and with it around **38 percent of energy** consumed in food systems.

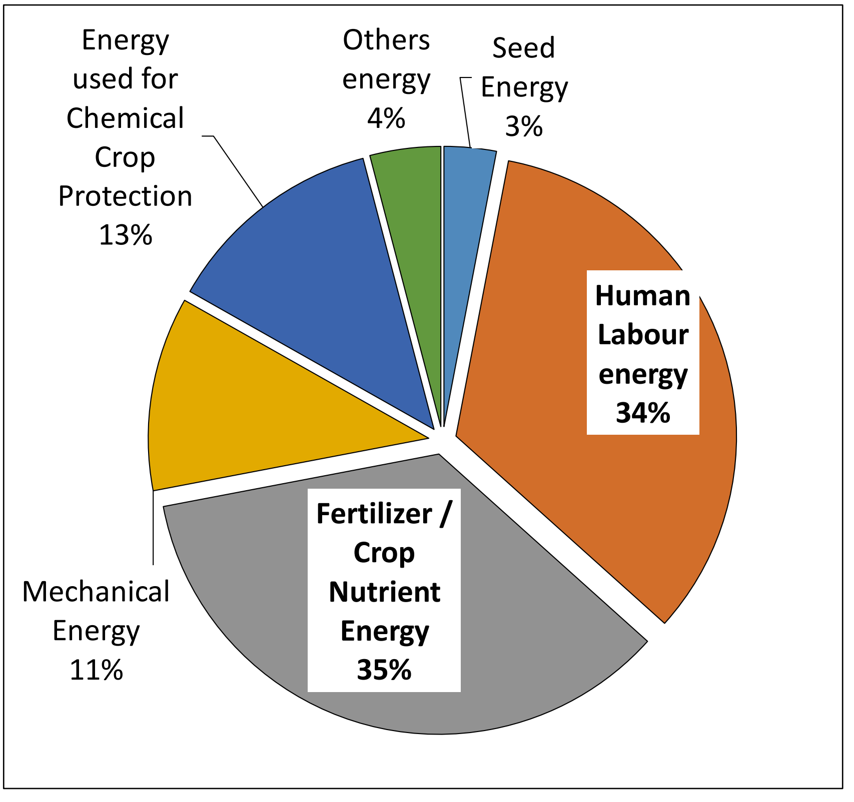
fao.org/energy/home/en/#:~:text=Finding%20green%20and%20resilient%20solutions%20that%20can%20support,from%20food%20system%20transformation%20without%20hampering%20food%20security.

Share of Total Energy Consumption Globally and in High and Low-Income countries, by Segment of Agri-food Chain



Source: FAO (2011)

Share of different Energy Inputs (Energy Input % Share) in Total Energy Usage for crop production under Conventional Farming Practice (CFP) of five Major Vegetable based Crop Sequences from eleven varieties of vegetable crops (majorly practiced by the farmers in the Clean Food Project Area, Nadia under IBM-IORF Sustainability Project.



Two Major Unsustainable Energy inputs i.e. **Chemical Pesticide & Chemical Fertilizers, are** recognized as the most important factor contributing to direct N_2O and other GHG emissions from agricultural soil comprise – **48% of Total Energy Inputs under Conventional Farmers or Chemical Farming or Industrial Agricultural Practice.**

Everything can be delayed, deferred , downsized except Food Production, rather there has to be **50 - 90% more Food Production by 2050** to feed the Growing Population. If higher Crop Production accounts further higher GHG Emission or Energy Usage **– Sustainability Will Be Severely Compromised or Affected.**

Most importantly More Output is required from Less or Same Inputs means Higher Energy Use Efficiency and that that too Clean Energy.

Energy Transition and Transformation of agri-food systems is crucial to meet the SUSTAINABLE DEVELOPMENT GOALS (SDGS).

Source: Renewable energy for agri-food systems, 2021 by IRENA and the FAO, UN

Renewable energy solutions deployed for food systems can increase incomes for farmers and other actors in the value chain, strengthen poverty alleviation efforts, improve health outcomes (through reduced use of traditional fuels for cooking and better access to water), and support gender empowerment and climate resilience and mitigation (IRENA, 2016a).

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).*

Challenges for Energy Transition in Agri-food Systems

- **The challenge** is to decouple the use of fossil fuels in food-system transformation and related innovations **without compromising food security.**

- With growing demand for energy and food, the transformation of both systems is necessary to align them more closely with global climate and sustainability goals.

The food sector is a major contributor to GHG emissions*(The world's food systems are responsible for more than one-third of global anthropogenic GHG emissions)while* also being deeply affected by climate change.

Energy-related activities within agri-food systems contribute to around one third of emissions from the food sector (Crippa et al , 2021). **Production stages (in fisheries, aquaculture, and agriculture, as well as emissions from inputs such as fertiliser) account for the largest share (39%). On-farm emissions arising from energy use increased globally by 25% from 1990 to 2018 (Tubiello et al., 2021).**

Which forms of Energy should be taken for Transition?

Component wise Input Energy Share under Conventional Farmers Practice documented under IBM-IORF Sustainability Project

	MJ/ha./yr.	% Share	
Seed Energy	2537	3%	
Human Labour Energy	28442	34%	} Major Unsustainable components, highly dependent on Fossil Fuels directly increases the GHG Footprint
Fertilizer / Crop Nutrient Energy	29878	35%	
Chemical Crop Protection Energy	10762	13%	
Mechanical Energy	9463	11%	
Others energy	3445	4%	
Total Energy (MJ/ha/Year)	**84527**	**100%**	

The challenge is to reduce the environmental impact of energy used through ENERGY TRANSITION in agri production system while maintaining crop security

The IBM-IORF Safe & Sustainable 'Clean Food' Project - **First Model for Safe and Sustainable Agriculture**

Where every Step has been Mentioned, Explicitly Defined, Safe is Validated & Sustainability is Tangible.

CLEAN FOOD PROGRAM was an initiative to provide Safe and Sustainable Food for Empowerment of Small and Marginal Farming Community, but Safe Food is made available to All at Affordable Cost; through the adoption of a Scientific - Smart Farming Practice, **Inhana Rational Farming (IRF) Technology**.

In the pretext of UN **statement "*It is currently not clear or well defined what constitutes productive and sustainable agricultural practice*".**

Clean Food Model practically demonstrated, **Safe Food Production, with Higher Crop Yield & Without Increasing Cost.**

IORF initiated the Clean Food Programme Considering the resource limitations :

- **In this program the objective was 100% Elimination of Chemical Pesticides with Soil/ Nutrient Management as per Conventional Farmers' Practice.**
- **It is actually a Resource Independent Model for Sustainable Agriculture aimed at development of Safe Food @ Conventional Cost.**
- **In this Model Inhana Plant Health Management (PHM) was used for Crop Health Management while Nutrient Management was done as per Conventional Farmers' Practice - Practiced in the large scale project field.**

Along with the Clean Food (CF) Model, IORF was initiated **Two Different Models for Clean Food, with LOW to NO usage of N- Fertilizers in the MODEL FARM.**

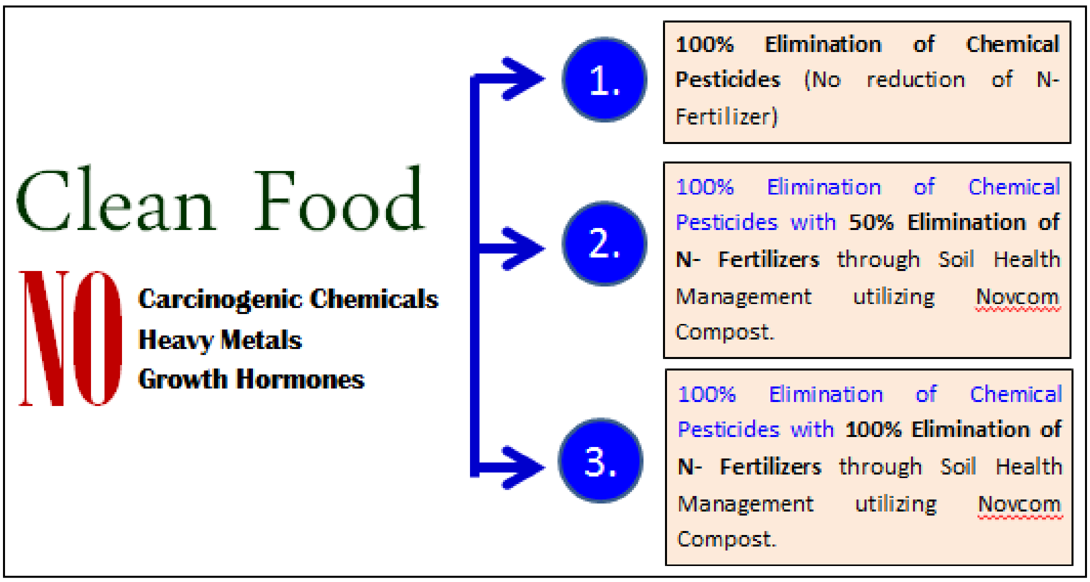
MODEL 1: Elimination of Chemical Pesticides with 100% reduction of N- Fertilizers, and Rejuvenation of Soil Health using Novcom Composting Technology.

- IPHM for Crop Health Management
- **100% elimination of N- Fertilizers**
- Application of **30 tons Of Novcom Compost/Crop/ha./year.**

Another Intermediate Integration Model was also taken up in the MODEL FARM

MODEL 2: Elimination of Chemical Pesticides with 50% Reduction of N- Fertilizers, and Rejuvenation of Soil Health using Novcom Composting Technology.

- IPHM for Crop Health Management
- **50% Reduced dose of N- Fertilizers**
- Application of 50% dose of Novcom Compost i.e. **15 tons. of Novcom Compost/Crop/ha./year**



ENERGY AUDIT OF 'CLEAN FOOD' PRODUCTION

Energy Analysis of agricultural ecosystems is a concrete approach to investigate and assess Energy Use Efficiency, environmental problems as well as to evaluate the Sustainability Quotient of any Crop Production System.

Assessment of energy requirements of different Cropping Sequences were done under 'Clean Food' production (in the Model Farm) w.r.t. three unique and adoptable Clean Food Models (*as depicted in the picture above*) ***vis-à-vis*** **Conventional Farmers' Practice.**

Along with individual crops, **five major cropping sequences**, commonly practiced in the project area were considered for the evaluation.

Crop Sequence 1: Tomato-Cucumber-Coriander

Crop Sequence 2: Potato-Brinjal-Cauliflower,

Crop Sequence 3: Potato-Okra-Cabbage,

Crop Sequence 4: Brinjal-French bean-Spinach

Crop Sequence 5: Pumpkin-Okra-Cabbage

The Evaluation was Done w.r.t Three Different Clean Food Models *vs.* Conventional Farmers' Practice

1. Conventional Farmers' Practice	2. Clean Food Program - 100 % Reduction of Chemical Pesticide (CF)	3. Clean Food Program with 50 % Reduction of N-Fertilizer ($CF_{50\%}$)	4. Clean Food Program with 100 % Reduction of N- Fertilizer ($CF_{100\%}$)

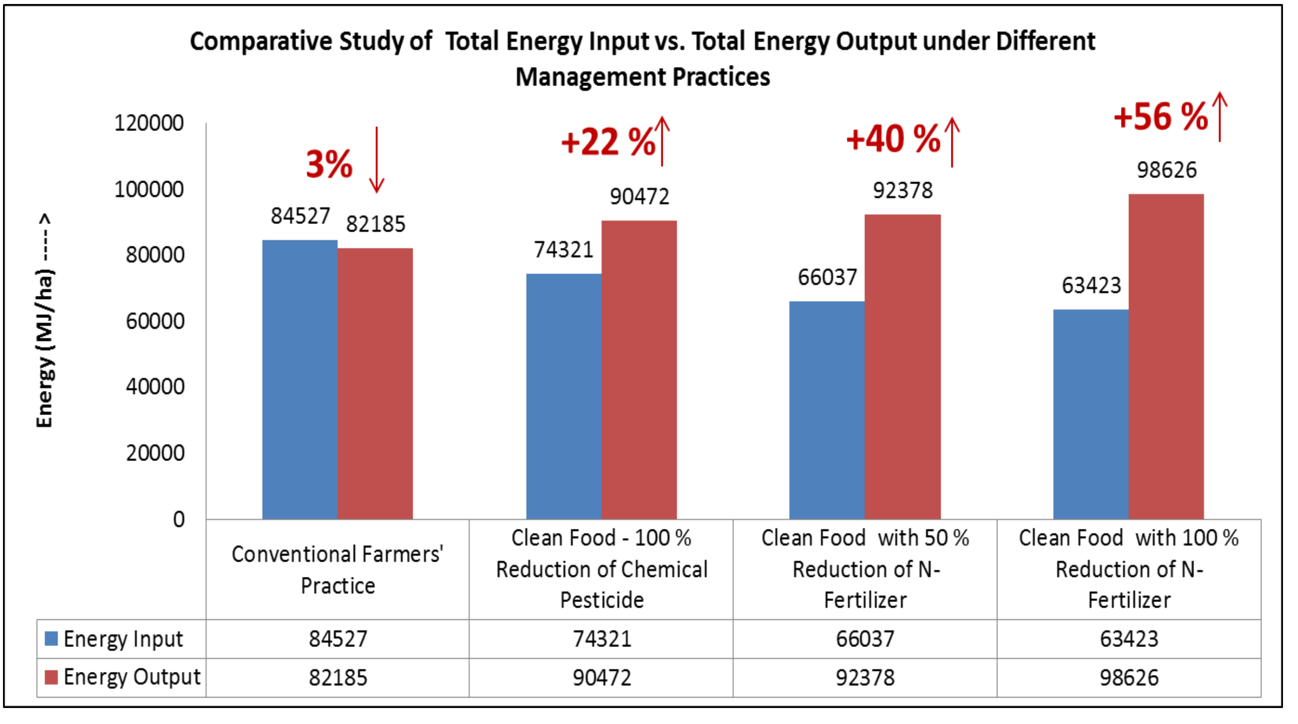
Component wise Input Energy Audit for Assessment of Total Energy Input under Conventional Farmers' Practice

Major Energy Inputs ((MJ/ha/year)	Sub Components/ Activities under the Major Energy Inputs	
Seed Energy	Seed Requirement	kg/ha
	Ref. Mittal & Singh	Seed Energy
Human Labour Energy	Seed treatment, Seed Bed Preparation and Nursery management	Mandays energy
	Seed Showing/Transplanting	Mandays energy
	Main Land Preparation	Mandays energy
	Cultural Practice	Mandays energy
	Irrigation	Mandays energy
	weeding	Mandays energy
	Harvesting & primary cleaning, package of farers practice	Mandays energy
	Nutrient management for Conventional farmers practice	Mandays Energy
Chemical Fertilizer Energy	Nutrient management for farers practice	N Energy (no org N)
		P_2O_5 Energy
		K_2O Energy
		SO_4 Energy

Major Energy Inputs ((MJ/ha/year)	Sub Components/ Activities under the Major Energy Inputs	
Mechanical Energy	Seed Bed Preparation and Nursery management,	Farm Instrument Embodied energy
	Seed Sowing/ Transplanting	Farm Instrument Embodied energy
	Main Land Preparation	Tractor embodied energy/Diesel Embodied Energy
	Irrigation	Electricity energy / Pump embodied energy
Chemical Crop Protection Energy	Seed Treatment	Chemical energy (MJ)
	Seed Bed Preparation and Nursery management	Chemical solution
	Pesticide energy under farmers practice	Insecticide Energy
	Pesticide energy under farmers practice	Fungicide Energy
	Plant Management (Chemical)	Total Energy
Other Energies	Miscellaneous	
Total energy Input(MJ/ha/year)		

Comparative Study of Total Energy Input vs. Total Energy Output under Different Management Practices

	1. Conventional Farmers' Practice (CFP)	2. Clean Food - 100 % Reduction of Chemical Pesticide (CF)	3. Clean Food with 50 % Reduction of N-Fertilizer ($CF_{50\%}$)	4. Clean Food with 100 % Reduction of N- Fertilizer ($CF_{100\%}$)
Energy Input (MJ/ha/yr.)	84527	74321	66037	63423
Energy Output (MJ/ha./yr.)	82185	90472	92378	98626



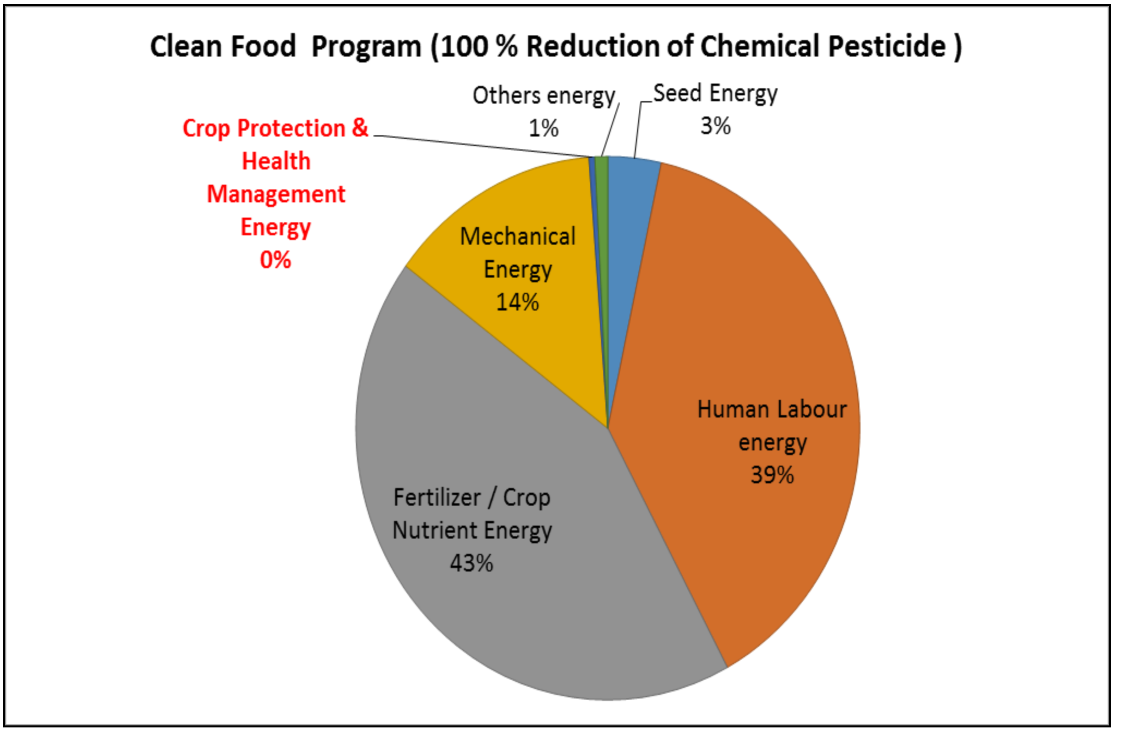
The Clean Food Models not only enabled LOWER ENERGY INVESTMENT due to Elimination/ Reduction of Non- Renewable Inputs and Adoption of Renewable Resources; they exhibited Higher Energy Output.

So while a 3% Deficit in Energy Output was recorded under CFP, Energy Output of varying from (+) 22% to (+) 56% was recorded under the different Clean Food Models.

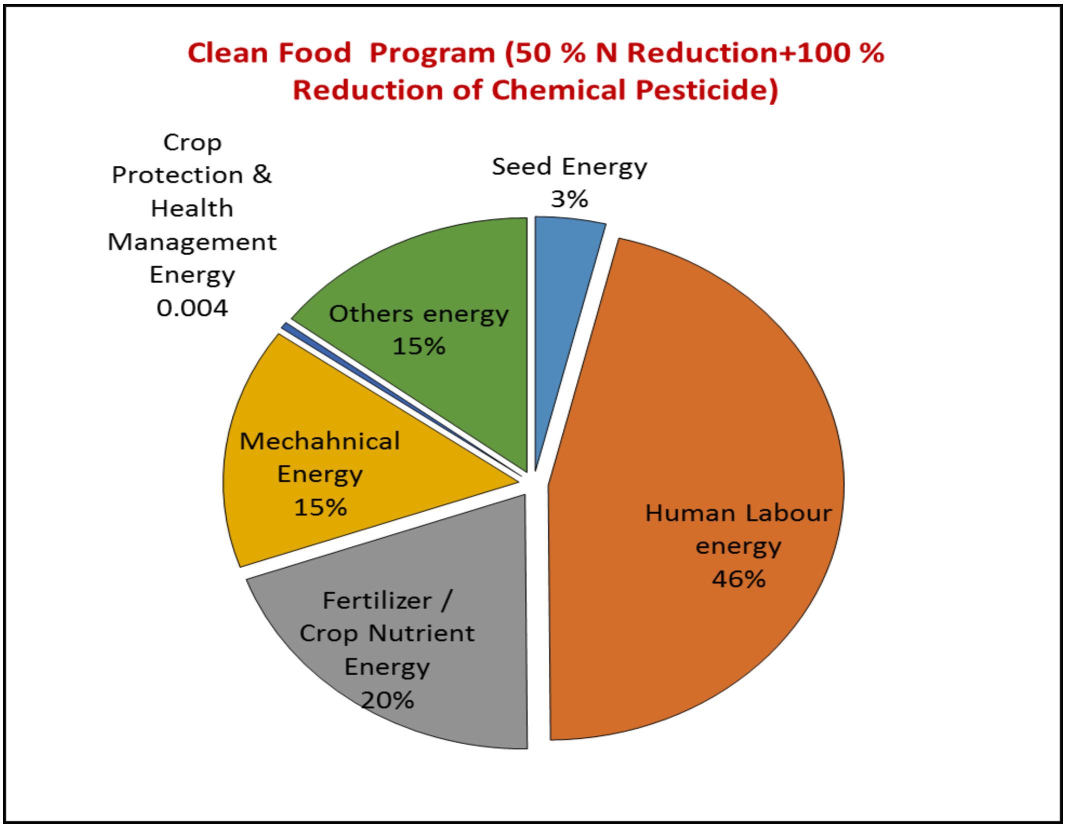
Share of different Energy Inputs (Energy Input % Share) in Total Energy Usage for crop production under different Mgt. Practices of five Major Vegetable based Crop Sequences (majorly practiced in the farmers field at IBM-IORF Clean Food Project Area, Nadia.

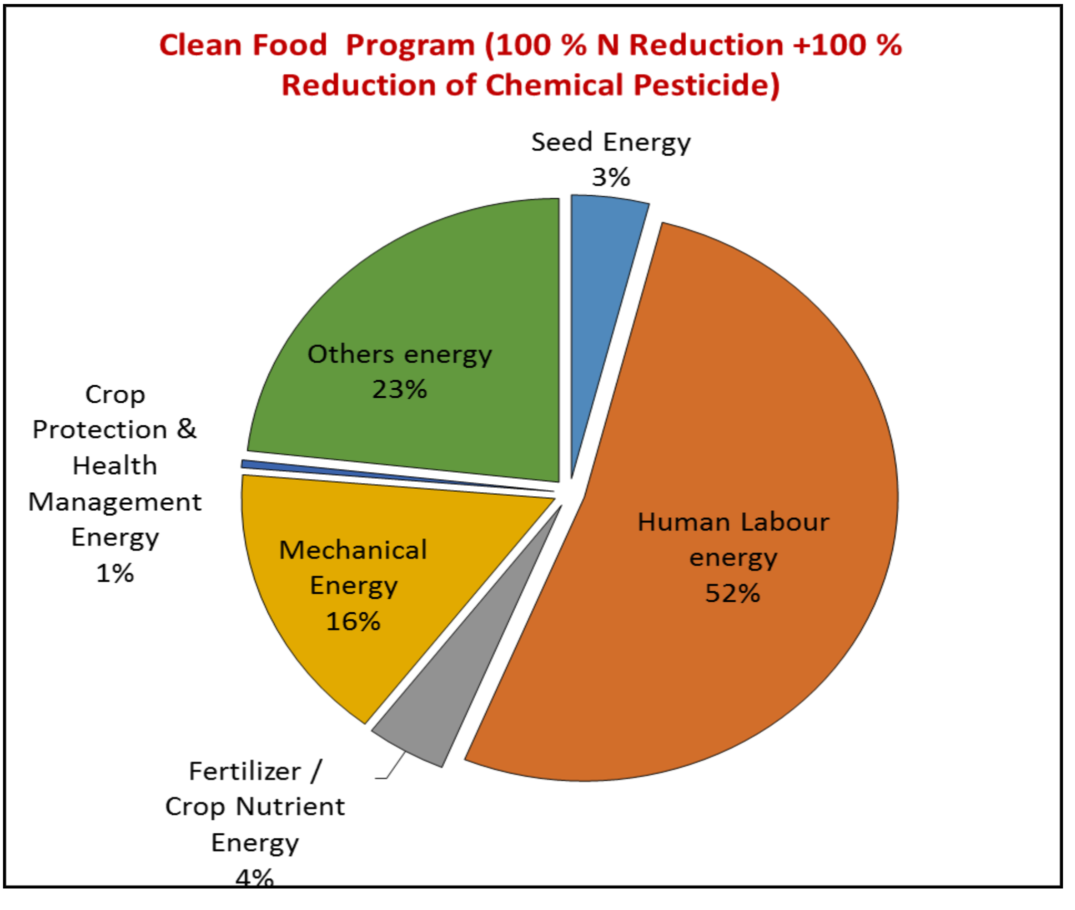
Component wise Input Energy Share under different Mgt. Practices	Seed Energy (MJ/ha/Yr)	Human Labour energy (MJ/ha/Yr)	Fertilizer / Crop Nutrient Energy (MJ/ha/Yr)	Mechanical Energy (MJ/ha/Yr)	Crop Protection Energy (MJ/ha/Yr	Other Energy(MJ /ha/Yr)	Total Energy (MJ/ha/Yr)
Conventional Farmers' Practice (CFP)	2537	28442	29878	9463	10762	3445	84527
Clean Food - 100 % Reduction of Chemical Pesticide (CF)	2537	28772	32002	10124	275	611	74321
Clean Food with 50 % Reduction of N- Fertilizer ($CF_{50\%}$)	2537	30402	13006	10124	275	9693	66037
Clean Food with 100 % Reduction of N- Fertilizer ($CF_{100\%}$)	2537	33130	2624	10124	275	14733	63423

Distribution of Energy Use under Conventional Farmers' Practice and Different 'Clean Food' Models



Distribution of Energy Use under Conventional Farmers' Practice and Different 'Clean Food' Models





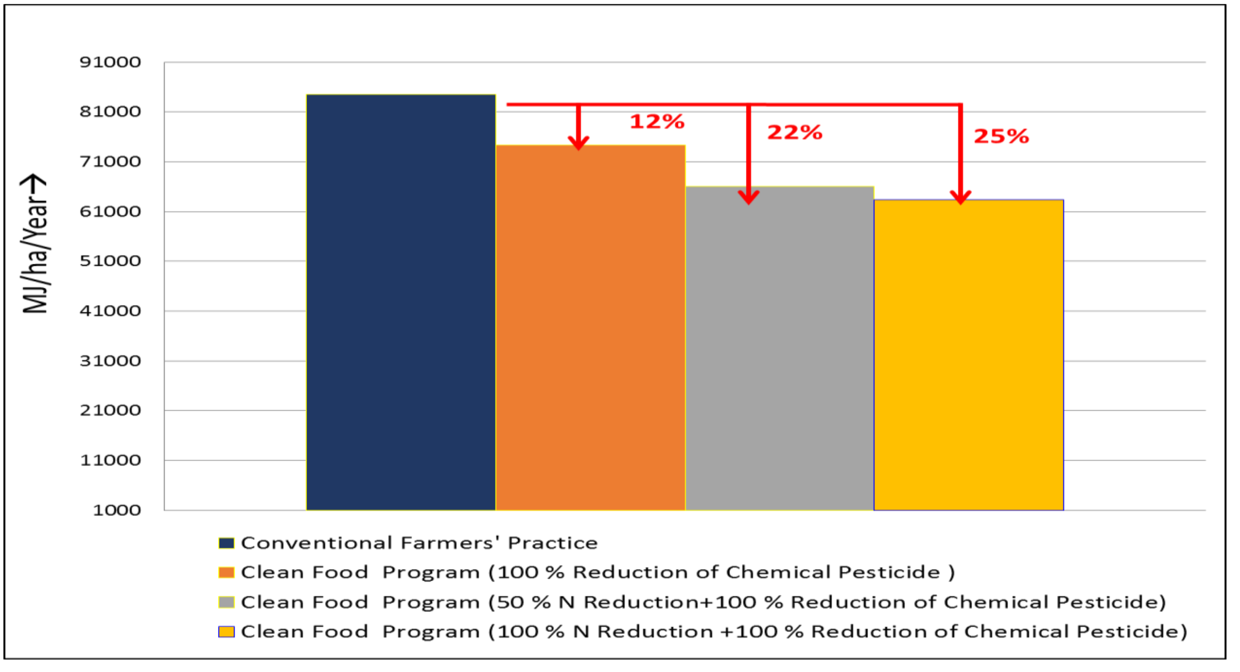
Total Energy Input vs. Total Energy Output under Different cropping Sequences *vs.* Different Management Practices

Crop Sequence	CFP	CF	CF_{50}	CF_{100}
Total Energy Input (MJ/ha)				
Tomato-cucumber-coriander	72941	63978	57599	57871
Potato-brinjal-cauliflower	99431	87644	75910	70886
Potato -Okra-cabbage	96996	87601	76727	71403
Brinjal-French bean-Spinach	68860	58465	53573	53367
Pumpkin-okra-cabbage	84406	73916	66376	63588
Average	**84527**	**74321**	**66037**	**63423**
Total Energy Output (MJ/ha)				
Tomato-cucumber-coriander	33900	36024	36900	41040
Potato-brinjal-cauliflower	135600	151727	153900	162870
Potato -Okra-cabbage	142313	160466	162383	172890
Brinjal-French bean-Spinach	45300	46240	49523	53055
Pumpkin-okra-cabbage	53813	57905	59183	63276
Average	**82185**	**90472**	**92378**	**98626**
Energy Productivity (Kg/MJ)				
Tomato-cucumber-coriander	0.58	**0.70**	0.80	0.89
Potato-brinjal-cauliflower	0.78	**0.95**	1.12	1.26
Potato -Okra-cabbage	0.69	**0.84**	0.97	1.10
Brinjal-French bean-Spinach	0.64	**0.77**	0.91	0.98
Pumpkin-okra-cabbage	0.57	**0.71**	0.80	0.88
Average	**0.66**	**0.81**	**0.93**	**1.03**
Energy Use Efficiency (EUE)				
Tomato-cucumber-coriander	0.46	**0.56**	0.64	0.71
Potato-brinjal-cauliflower	1.36	**1.73**	2.03	2.30
Potato -Okra-cabbage	1.47	**1.83**	2.12	2.42
Brinjal-French bean-Spinach	0.66	**0.79**	0.92	0.99
Pumpkin-okra-cabbage	0.64	**0.78**	0.89	1.00
Average	**0.97**	**1.22**	**1.40**	**1.56**

NOTE :
CFP : Conventional Farmers' Practice; CF : Clean Food Program (100 % Reduction of Chemical Pesticide), CF_{50}: Clean Food with 50 % Reduction of N- Fertilizer; CF_{100} : Clean Food Program with (100 % Reduction of N- Fertilizer

In terms of Energy Input the highest consumption was noted under Potato-Brinjal-Cauliflower sequence in respect of Conventional Farmers' Practice (CFP). **In case of Clean Food production, Elimination of Chemical Pesticides led to a 12% lower energy investment (on an average)** as compared to Conventional Farmers' Practice. However, this **Energy Investment became 25% lower when N- Fertilizer was completely eliminated ($CF_{100\%}$) during Clean Food production .**

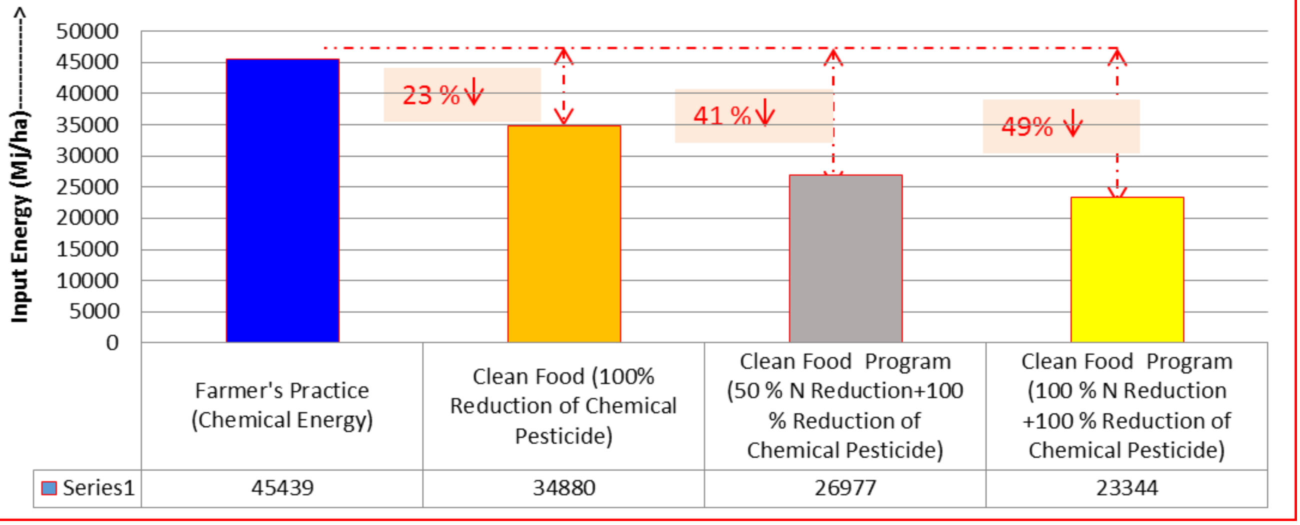
Avg. **Total Energy Input** used in some major Vegetable based Crop Sequences under different Management Practices



Total Avg. Energy Inputs used for Crop & Nutrient Management (Two Major Unsustainable Inputs under Conventional Farmer's practice) in some Vegetable Based Crop Sequences with different Clean Food Models.	Total Energy Input (MJ/ha/Year)	**Total Crop Nutrient Energy Input** (MJ/ha/Year)	**Total Crop Protection Energy Input** (MJ/ha/Year)
Conventional Farmers' Practice (CFP)	**84527**	**32002**	**13818**
Clean Food Program (100 % Reduction of Chemical Pesticide) (CF)	**74321 (12% Less compared to CFP)**	**32002**	**3258 (76% Less compared to CFP)**
Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide) ($CF_{50\%}$)	**66037 (22% Less compared to CFP)**	**23718 (26% Less compared to CFP)**	**3258 (76% Less compared to CFP)**
Clean Food Program (100 % N Reduction +100 % Reduction of Chemical Pesticide) ($CF_{100\%}$)	**63423 (25% Less compared to CFP)**	**20085 (37% Less compared to CFP)**	**3258 (76% Less compared to CFP)**

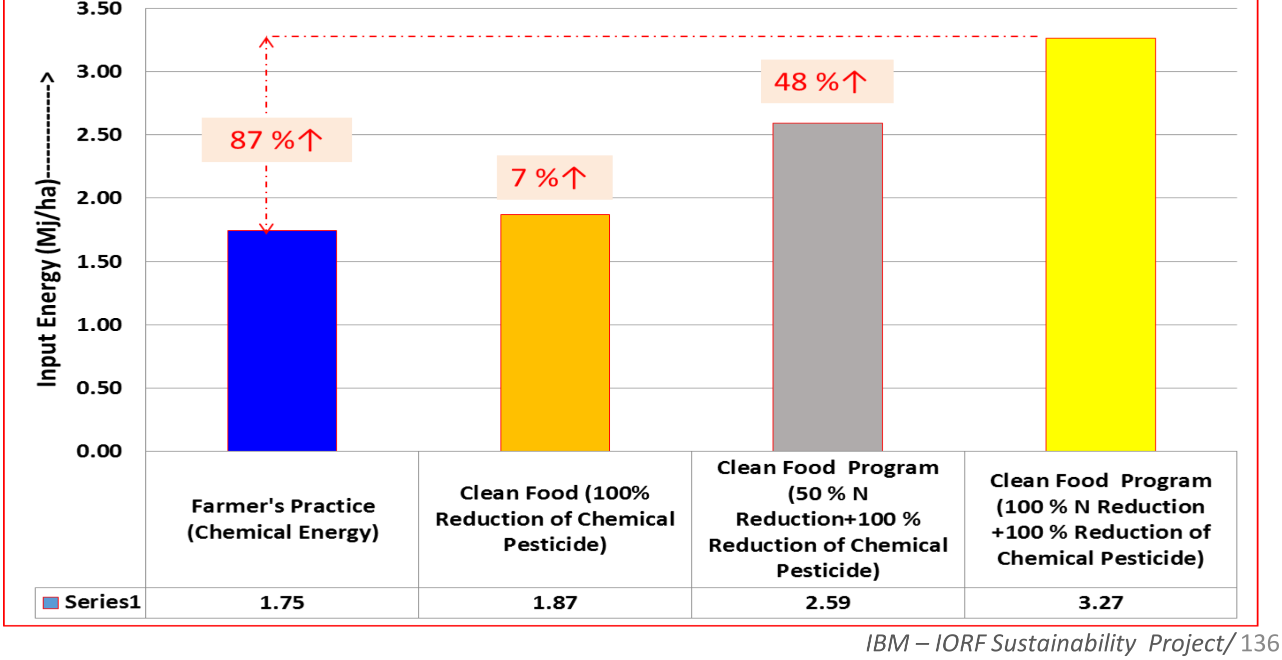
Evaluation of the Total Energy Use w.r.t. two Major Unsustainable Inputs i.e., fertilizers and pesticides revealed **23% Lowering of Energy Use as compared to conventional farmers' practice on 100% removal of one unsustainable component i.e., chemical pesticides**. And Energy Investment became close to **50% lower when both the Chemical Pesticides and N-fertilizers were ELIMINATED from the crop production system**.

Total Energy Inputs used for Crop & Nutrient Management (Two Major Unsustainable Inputs under Conventional Farmer's practice) in some Vegetable Based Crop Sequences.



Evaluation of **Nutrient Energy Productivity** (i.e. agricultural output produced using per unit of energy); revealed **87% Higher Value under 'Clean Food' production,** with **100% removal of N- fertilizer and Chemical Pesticides;** as compared to conventional farmers' practice .

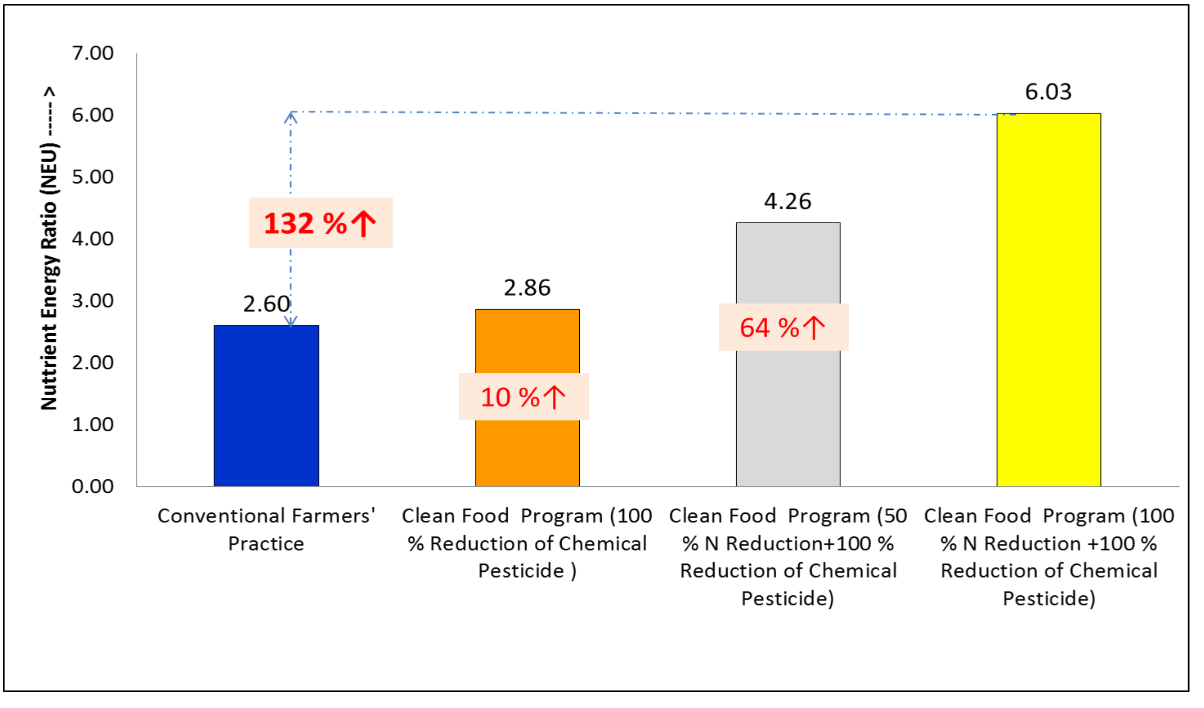
Comparative Assessment of Nutrient Energy Productivity under Different Management Practices in some Vegetable Based Crop Sequences.



Comparative Study of Nutrient Energy Ratio

One of the major objectives of sustainable agriculture is 'MORE FROM THE LESS i.e., MORE PRODUCTION FROM LESS INPUT. This can be measured using the Nutrient Energy ratio which is the ratio of Energy Output (MJ/ha) and Nutrient Energy Input (MJ/ha). Comparative Study of **Nutrient Energy Ratio** under Conventional Farmers' Practice and different 'Clean Food' Development Models showed **highest value (6.03)** in the case of 'Clean Food' Program **with 100% N Reduction, which was 132 % higher than Conventional Farmers' Practice.**

Comparative Assessment of Nutrient Energy Ratio under Different Management Practices in five majorly practiced Vegetable Based Crop Sequences.



The results indicated that adoption of Sustainable Soil and Plant Health Management under Inhana Rational Farming (IRF) Technology helped to minimize the unsustainable inputs on one hand and helped to increase the crop productivity on the other. The cumulative impact of these two factors influenced a phenomenal jump in the Nutrient Energy Ratio, which indicated higher sustainability quotient of the farming model adopted under IBM Sustainability Project.

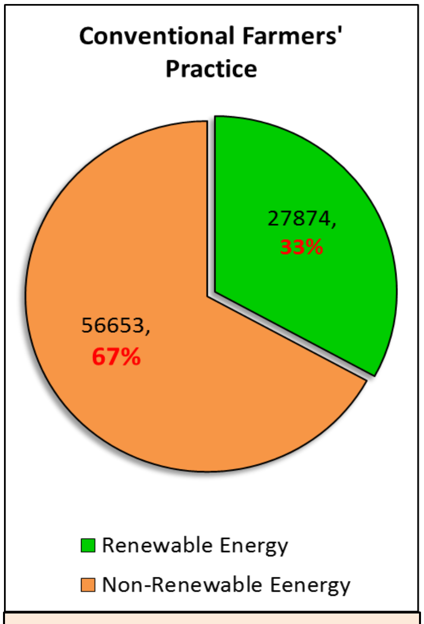
Comparative Assessment of Total Avg. Energy Inputs used for Crop & Nutrient Management (Two Major Unsustainable Inputs under Conventional Farmer's practice) in some Vegetable Based Crop Sequences with different Clean Food Models.

Different Mgt. Practices	Total Avg. energy Input (based on FP) (MJ/ha)	Total Nutrient energy Input (based on FP) MJ/ha)	Crop Protection & Growth/ Crop Health Mgt. Energy MJ/ha)	Crop & Nutrient Management (Two Major Unsustainable Inputs under Conventional Farmer's practice) MJ/ha)	Total Avg. Crop (kg/ha.)	Energy per Kg. Crop (MJ/kg crop)
Conventional Farmers' Practice	**84527**	**32002**	**13818**	**45820**	**55875**	0.82
Clean Food Program (100 % N Reduction)	**63423**	**20085**	**3258**	**23343**	**65604**	0.36
% Transition	**25**	**37**	**76**	**49**	**17**	**57**

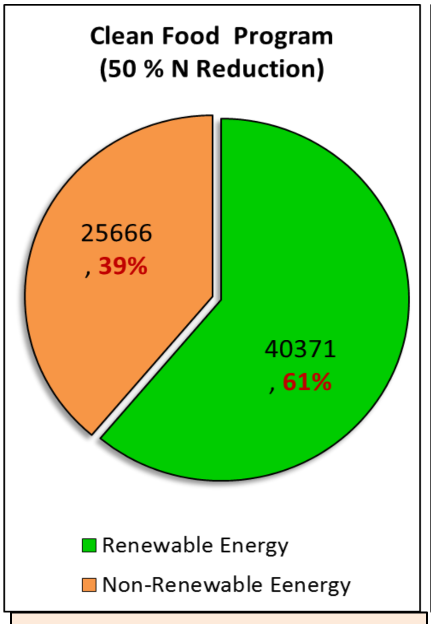
The world is committed to achieve **carbon neutrality by 2050**. And **ENERGY TRANSITION** (*i.e., the shift from an energy mix based on fossil fuels to renewable energy sources that produces very limited, if not zero, carbon emissions*) forms the TOOL for this Target Achievement. **'Clean Food' Production with 100% Reduction of both N- Fertilizer and Chemical Pesticides conclusively demonstrates 57% ENERGY TRANSTITION enabled by the interventional IRF Technology as well as IMPROVEMENT OF ENERGY PRODUCTIVITY, a benchmark criteria for SUSTAINABLE AGRICULTURE.**

Indirect Energy Use contributed by the two major Unsustainable Inputs of Conventional Farming i.e., the N- Fertilizers and Chemical pesticides; **and GHG emission are directly proportional,** and the GHG Abatement potential under a crop management system forms the best indicator of **SUSTAINABILITY**. **Thus 'Clean Food' Production with 100% Reduction of both N- Fertilizer and Chemical pesticides will have the HIGHEST SUSTAINABILITY QUOTIENT.**

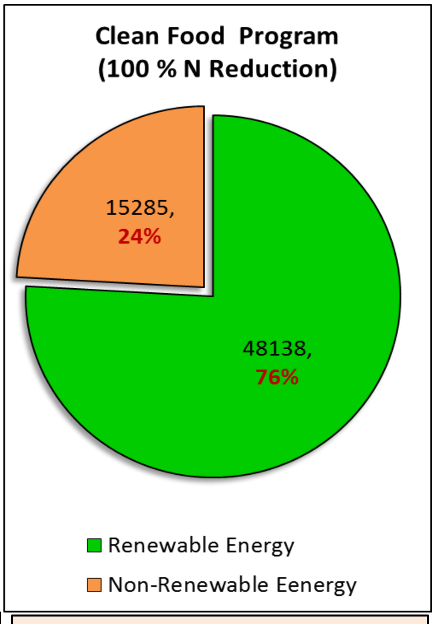
Use of Renewable and Non-Renewable Inputs under Conventional Farmers' Practice vis-a-vis different Clean Food Development Models.



Energy Ratio of Renewable & Non-Renewable inputs : **0.49**



Energy Ratio of Renewable & Non-Renewable inputs : **1.57**



Energy Ratio of Renewable & Non-Renewable inputs : **3.15**

Use of Renewable and Non-Renewable Inputs

Today's agricultural production relies heavily on the consumption of non-renewable inputs leading to direct negative environmental effects primarily due to GHG Emission. In order to understand better the direction of agricultural energy use, it is important to investigate the tendency of energy forms. For this purpose, we studied the renewable and non-renewable energy forms used in the IBM-IORF Sustainability Project.

Decrease in the requirement of agro-chemicals (complete elimination of chemical pesticides and decrease in nitrate fertilizers) under Clean Food program led to reduction in the use of non-renewable energy, considering that high quantities of fossil fuel is required for production of the agrochemicals.

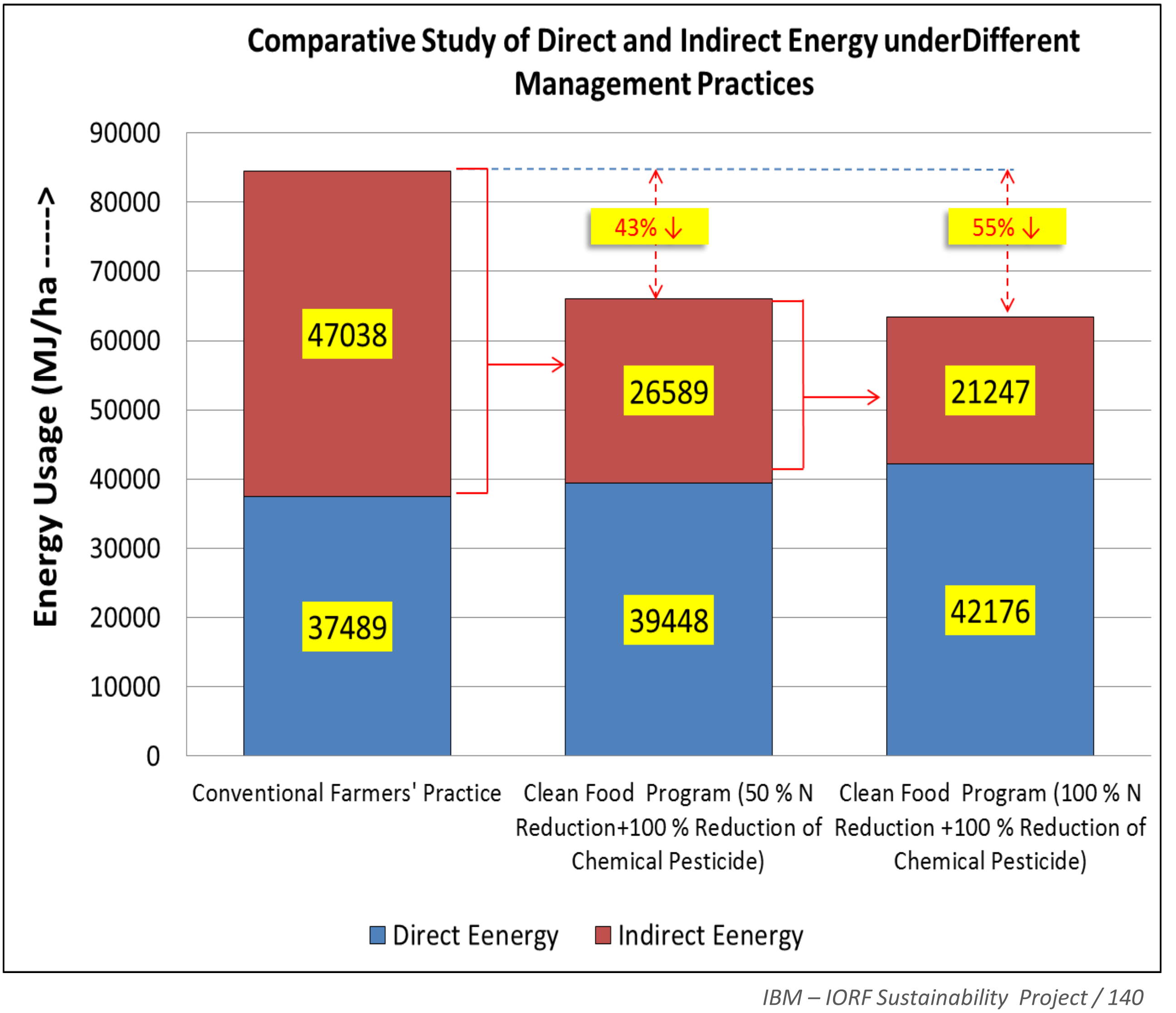
The Comparative Study of Usage of Renewable and Non-Renewable Inputs in Conventional Farmers' Practice and under the different 'Clean Food' development models clearly indicated a significant increase in the use of renewable energies under 'Clean Food' production. In the case of Conventional Farmers' Practice where only 33 % of total energy input is renewable in nature, in case of Clean Food Program with 50 % N Reduction, 61 % of the total energy input is renewable and the same increased up to 76 % in case of Clean Food Program with 100 % N Reduction.

Thus Energy ratio of Renewable and Non-renewable inputs was highest in case of Clean Food Program with 100% N Reduction (3.15) followed by Clean Food Program with 50% N Reduction (1.57) and the lowest in case of Conventional Farmers' Practice (0.49).

Comparative Study of Direct and Indirect Energy

Sustainable agriculture is an alternative for solving fundamental and applied issues related to food production in an ecological way (Lal, 2008). It has its roots in a set of values that reflects an awareness of both ecological and social realities. Agricultural sustainability could be measured in terms of energy usage and energy requirements in agriculture, being divided into two groups, i.e., direct and indirect. Direct energy is consumed directly in crop production i.e. human labour, animal labour, fossil fuels, and electricity etc. The sources of these energy are human, animal, petrol, diesel and water required to perform different tasks in the crop production processes such as field preparation, cultural practices, irrigation, harvesting, threshing and transportation. However, the energy that is used in manufacturing, packaging and transportation of different farm inputs such as seed, fertilizers, farmyard manure, pesticides and other chemicals and machineries are called indirect energy.

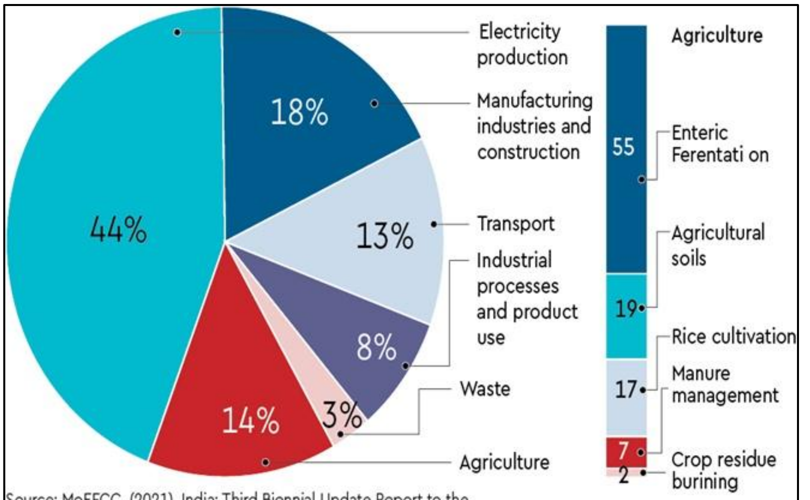
In crop production there is little scope of lowering the direct energy usage, but there is a huge scope for reduction of the indirect energy inputs under 'Safe and Sustainable' Agriculture. In the IBM-IORF Sustainability Project adoption of IRF Technology enabled about 55% reduction in the use of indirect energies under 'Clean Food' production with 100% N reduction and about 43% in the case of Clean Food production with 50% N Reduction program, as compared to



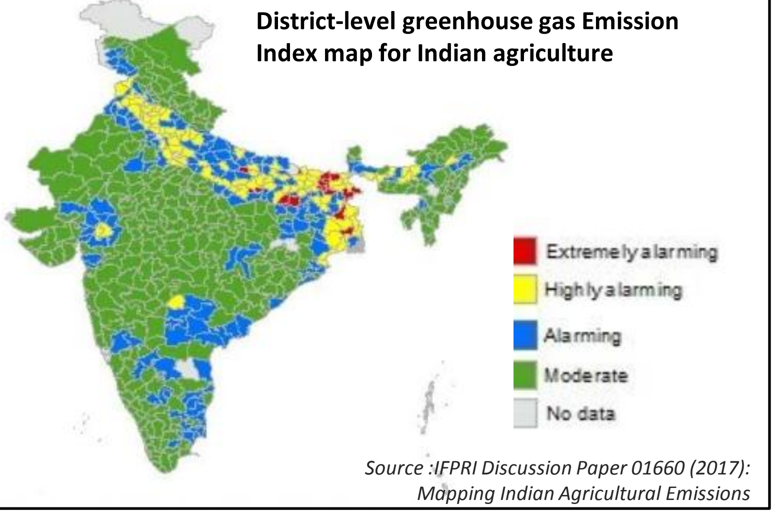
Agriculture is an important sector of the economy in India, contributing about 20% of national gross domestic product, and providing a livelihood for nearly two-thirds of the population. However, the advent and increased use of Chemical Inputs especially chemical fertilizers and pesticides, post green revolution; has over the years made Indian agriculture more greenhouse gas (GHG)-intensive.

According to the Global Carbon Atlas, India ranks third in total greenhouse gas emissions, with ~2.6 billion tonnes (bt) CO_2 equivalent, preceeded by China (10 bt) and the US (5.4 bt), and followed by Russia (1.7 bt) and Japan (1.2 bt). India ranked 7th in the most affected countries due to extreme weather events, incurring losses of $69 billion (in PPP) in 2019 as per German watch. Today, providing food and nutritional security to the growing population of the world, projected to be 9.3 billion by 2030, while limiting emission of greenhouse gases, is a global challenge. With a population of 1.3 billion, it is evident that the food system in India will be central to the global challenge of providing sufficient nutritious food while minimizing GHG emissions. The United Nations Framework Convention on Climate Change (UNFCCC) therefore aims at stabilizing the concentrations of greenhouse gases in the atmosphere and developing policies to reduce their emissions so as to minimize the impact of climate change on agriculture.

On the flip side **Agriculture is the only sector that can serve as an important climate change mitigation strategy**, both by reducing GHG emissions to the atmosphere, and by sequestering atmospheric carbon into plant biomass and soil. **Reduction of Unsustainable Inputs like chemical fertilizers and pesticides is the first step in this direction**, **but crop Sustainability/Improvement will have to be ensured in order to activate GHG Adaptation strategy.** Moreover integrated soil management will also be an essential criteria. **That means to activate the climate change mitigation strategy Agriculture has to most definitely be both Safe & Sustainable.**



Source: MoEFCC. (2021). India: Third Biennial Update Report to the United Nations Framework Convention on Climate Change.



District-level greenhouse gas Emission Index map for Indian agriculture

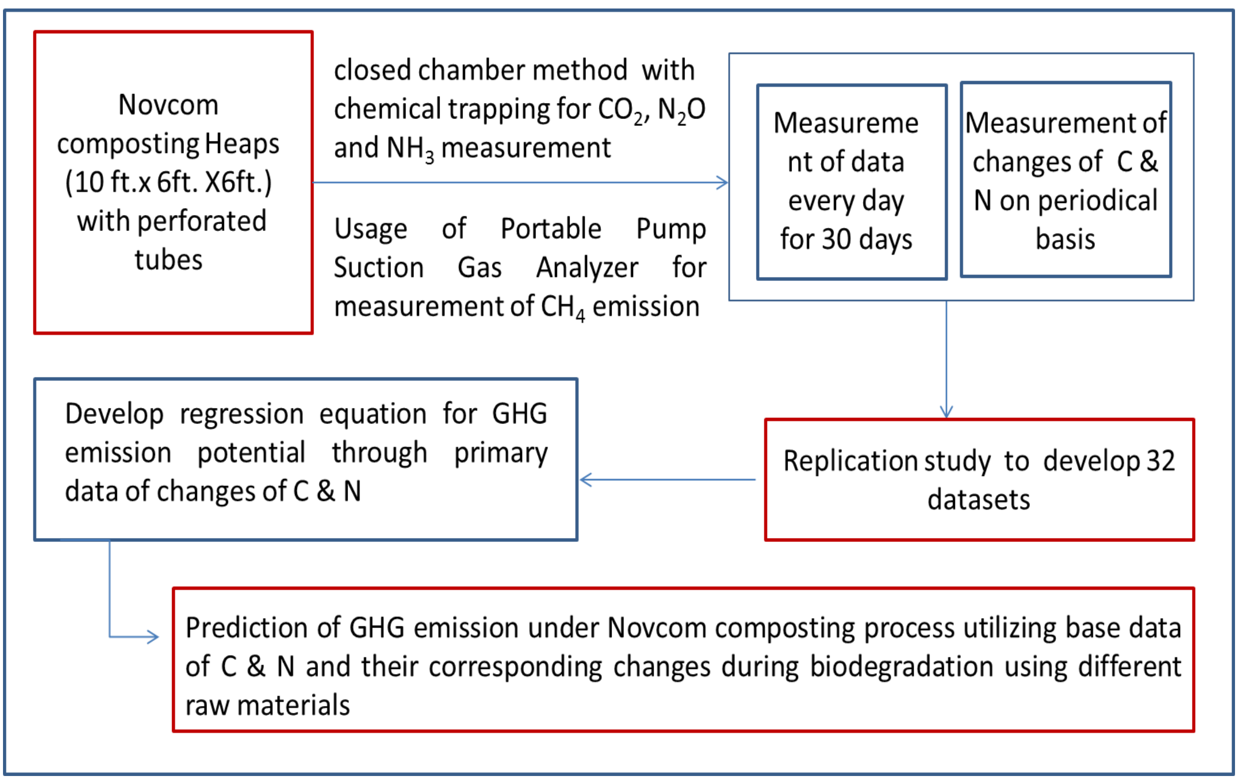
Source :IFPRI Discussion Paper 01660 (2017): Mapping Indian Agricultural Emissions

India's Intended Nationally Determined Contributions (INDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) place emphasis on mitigation from agriculture, and various mitigation strategies (particularly concerning methane, CH_4, and nitrous oxide, N_2O) have been proposed (Smith et al., 2014, 2008). Quantification of GHG emissions from the production of different food commodities helps farmers, researchers and policymakers to understand and manage these emissions, and identify mitigation responses that are consistent with the food security and economic development priorities of countries (Hillier et al., 2011; Whittaker et al., 2013).

Hence, quantification of Agriculture GHG emissions is the first step to estimate emissions, and identify mitigation responses that are consistent with the food security and economic development priorities especially in respect of the small and marginal land holders. But there are hardly any such evaluation in the Indian Agriculture Sector

The IBM-IORF 'Clean Food' Project primarily demonstrated **'Safe and Sustainable' Food production with elimination of the chemical pesticide (and reduction/ elimination of N-fertilizer in Model Farm)**- enabled through the induction of IRF Technology. The support from IBM project gave the impetus to record the GHG emission/ mitigation under Sustainable Agriculture *vis-à-vis* conventional crop production.

Research Flow



Flowchart of the Methodology Adopted for GHG estimation under Novcom Composting Technology

Measurement of different Greenhouse Gases (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 leading *to* mitigation of GHG from source. However, implementation of a reliable technology to deal with these wastes is considered as a pillar for sustainable development of any nation (Iqbal, 2020). **The amount of emitted gases under any composting process is highly influenced by the type of treated wastes and operational conditions, but most importantly by the adopted composting technology, which would have a direct impact in reducing the rate of emissions, mainly N_2O and CH_4 (Dhamodharan *et al*. 2019, Sayara and Sánchez, 2021).** 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 (Dhamodharan *et al*. 2019). 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 (Jiang *et al*. 2015; Wang *et al.* 2016; Yang *et al*. 2015). The rate of gaseous emissions generally vary as per the adopted composting method, but the emitted amount is considerably less than that recorded from the landfill sites and under waste-to-energy processes (Friedrich and Trois, 2011; Saer *et al*. 2013; Wang and Nakakubo, 2020).

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 (Vallero, 2019) 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, 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 (Allen *et al.* 2016). Meanwhile, GWP_{20} 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). According to J. Trancik, 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 Celcius (Moseman and Trancik, 2021).

Pérez-Domínguez *et al*. (2021) 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 (Ocko *et al.* 2017)

In the Sixth Assessment Report of IPCC (AR6) (IPCC, 2021) , there is discussion regarding the use of a range of emission metrics, including GWP20 and GWP100 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 (EFCTC, 2021).

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.**

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 (Abernethy and Jackson, 2022).**

In the study we used two different timescales for evaluating GHG emission in order to estimate the maximum impact of the GHG gases on the environment. In case of N_2O, we considered the usual 100 years' time frame. But **for 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 1.5°C goal of Paris Agreement.

Evaluation of Novcom compost in terms of carbon offsetting

Landfill is considered to be one of the major contributors of the total annual global CH_4 emissions, equivalent to **734 kg CO_2-eq** (tonne wet waste treated)$^{-1}$ (Bijaya K. Adhikari, 2013,Matthews and Themelis, 2007; US EPA , 2006). Composting lowers GGE to values of 0.03-8.0 kg CH_4 (tonne wet waste treated)$^{-1}$ and 0.06 - 0.6 kg N_2O (tonne wet waste treated)$^{-1}$, for a total averaging **200 kg CO_2-eq** (tonne wet waste treated)$^{-1}$ (Friedrich and Trois,2011; Hermann et al., 2011 ; Rogger et al., 2011 ; Martínez-Blanco et al., 2010; Lou and Nair, 2009 ; IPCC, 2006). **GHG emission from Novcom compost was measured in detail under the IBM Sustainability Project in order to evaluate its efficiency in offsetting GHG as compared to the other biodegradation processes.**

Pic 1 :. The beakers were replaced with new beakers after every 24 hours and titrated; the same process was continued for 21 days.

Pic 2 : Daily replacement of the Beakers on the compost heap developed under Novcom Composting Technology, done in presence of IORF Lab – Persons.

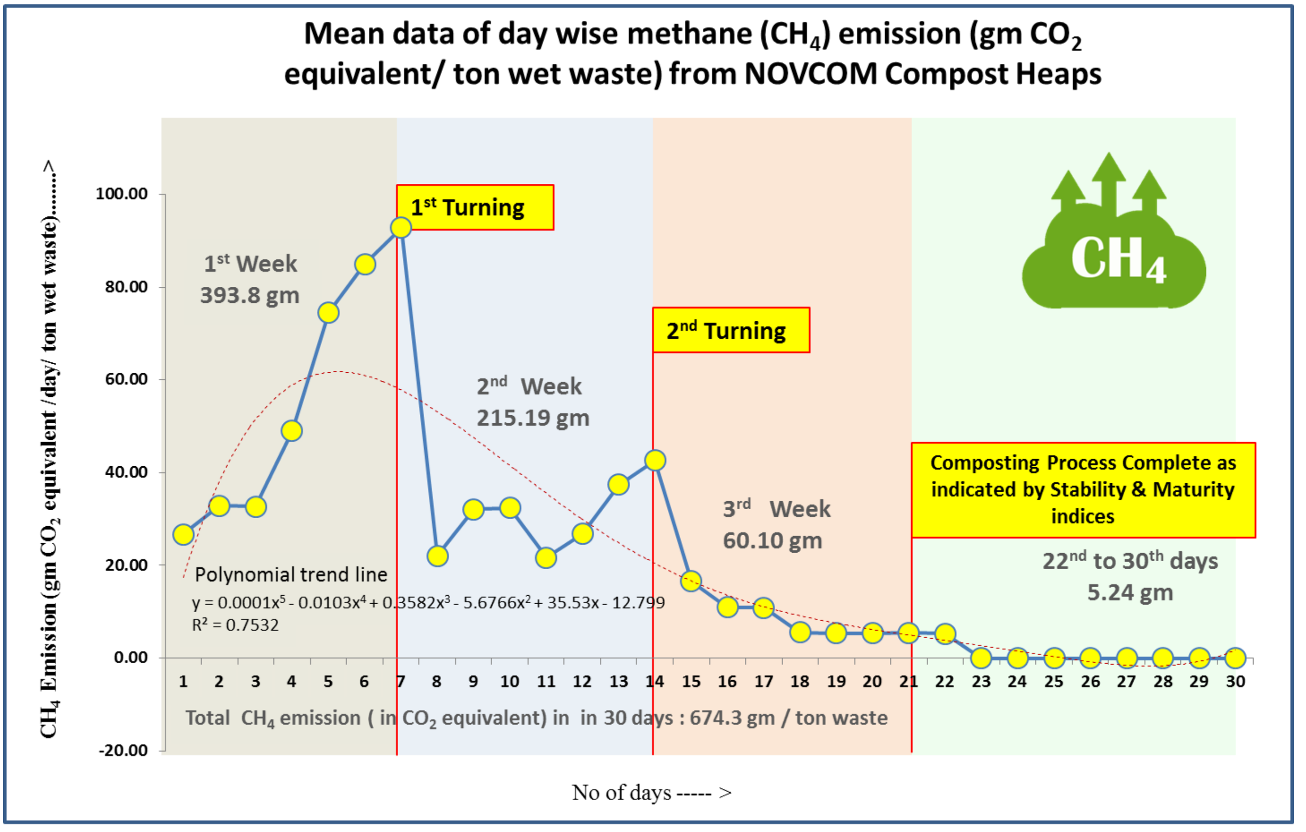


Fig 1 : Evaluation of Day wise Total methane (CH_4) Emission (in CO_2 equivalent) from compost heap under Novcom Composting Technology

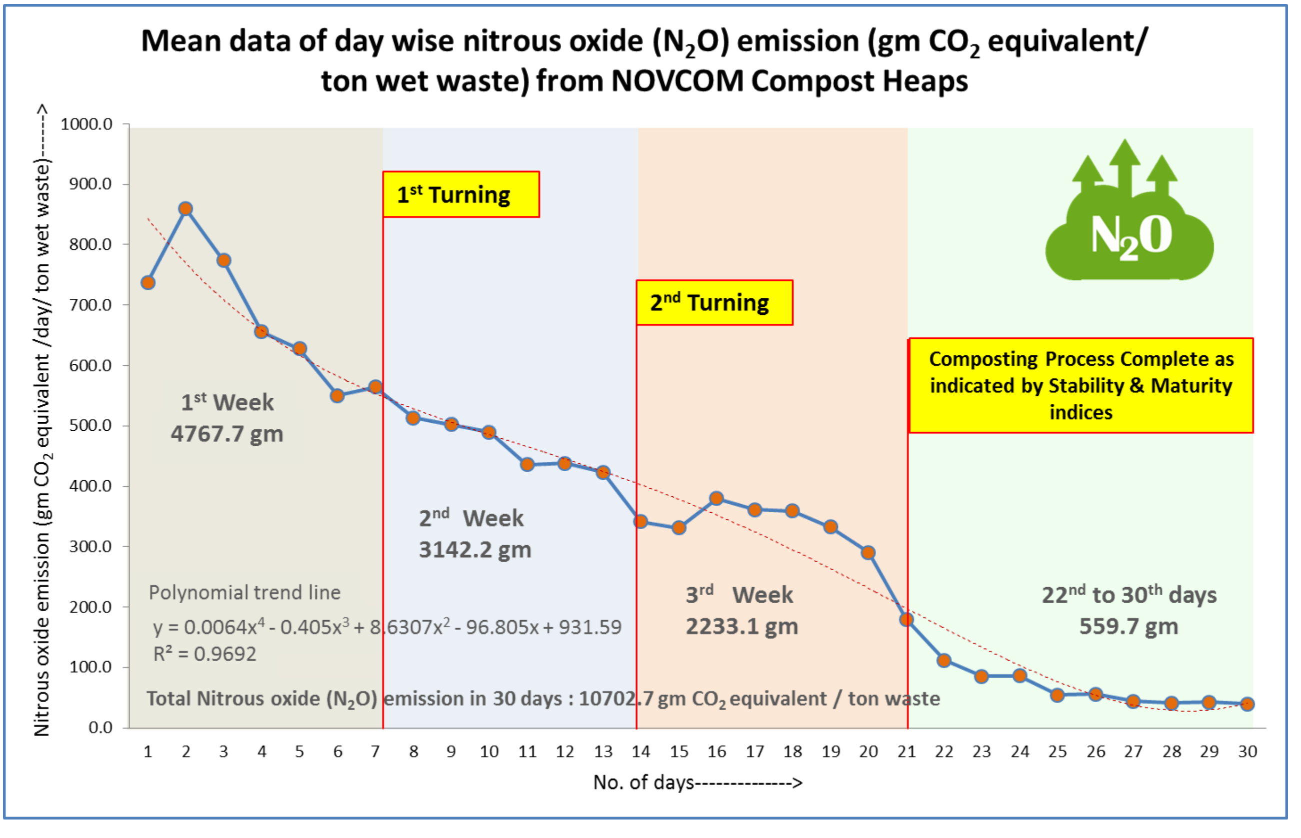


Fig 2 : Evaluation of Day wise Total Nitrous Oxide (N_2O) Emission (in CO_2 equivalent) from compost heap under Novcom Composting Technology

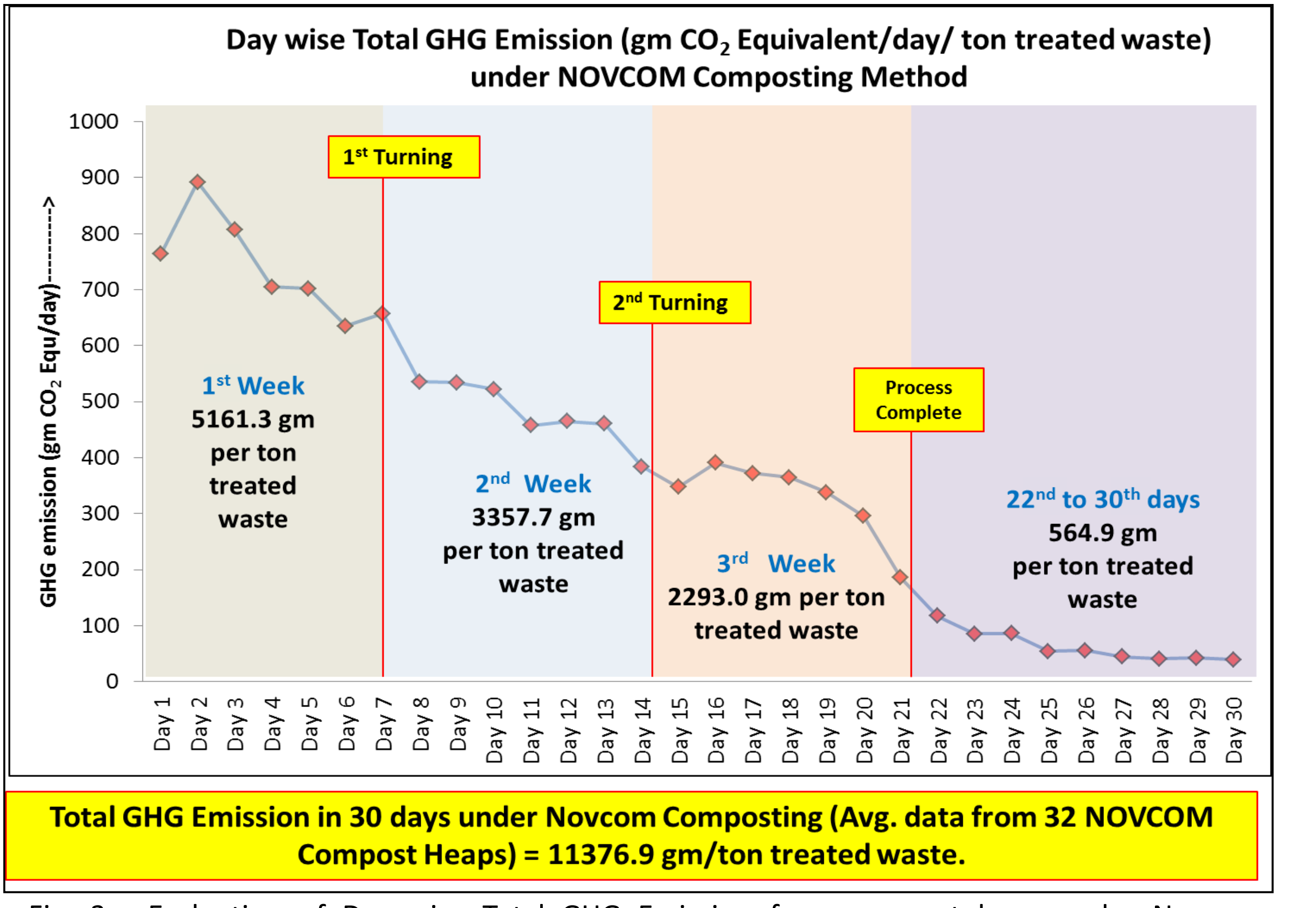


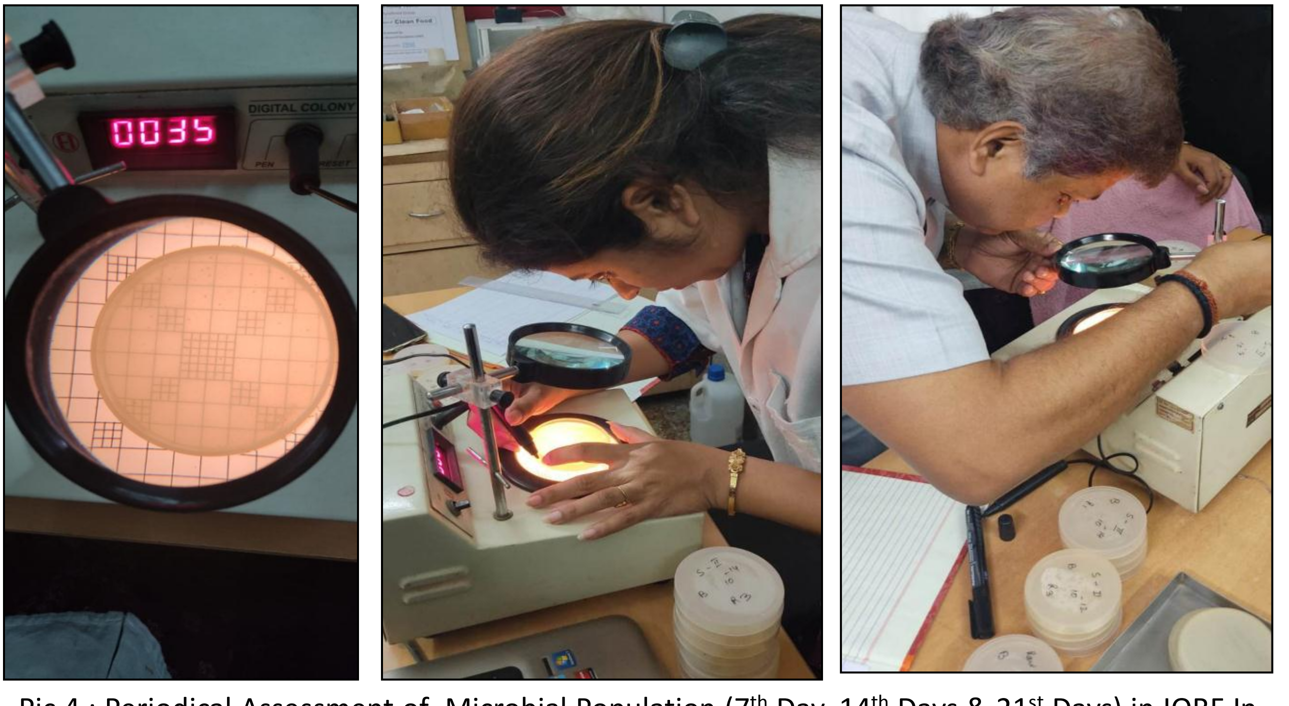
Fig. 3 : Evaluation of Day wise Total GHG Emission from compost heap under Novcom Composting Technology.

Pic. 3: Monitoring, Analysis & Evaluation of the GHG tapping methodology from compost heap developed under Novcom Composting Technology, jointly by IORF & Nadia KVK, ICAR.

The study reveals that this aerobic composting method enabled quality compost generation within a short period of 21 days, corroborated by the phytotoxicity and maturity studies along with scientific literature support. **However, the most relevant finding is the 17 times lower GHG emission (11.4 kg CO_2 equivalent/ ton treated waste) under Novcom Composting Technology** as compared to the scientifically documented GHG emission values under any other biodegradation methods.

Investigation revealed that the biodegradation process under Novcom Composting Technology is expedited by the Novcom Solution which creates a favourable environment for intensified and successional generation of a very high and diversified microflora population in the order of 10^{16} c.f.u/ gm moist compost within the composting heap. **The phenomenon facilitates speediest bioconversion which in turn helps to minimize the possibility of N_2O emission due to transformation of this greenhouse gas into a more stable form during the process of biodegradation.** Generation of favourable environment within the composting heap also ensured the **absence of any anaerobic pockets that are majorly responsible for CH_4 gas generation.** The fact is substantiated by the lowest methane emission value (0.7 kg CO_2 equivalent/ ton treated waste) under Novcom Composting Technology as compared to emission values documented under any other aerobic biodegradation methods.

The most significant finding was that, Novcom Composting Technology can offset more than 6000 kg CO_2 equivalent per ton of treated waste from landfill waste (highest as per the available scientific literatures), which can facilitate an EFFECTIVE BUSINESS MODEL towards NET ZERO COMMITMENT.



Pic 4 : Periodical Assessment of Microbial Population (7th Day, 14th Days & 21st Days) in IORF In-house Laboratory, following National & International Standards for organic soil input/compost analysis.

GHG AUDIT OF 'CLEAN FOOD' PRODUCTION

Apart from GHG evaluation under compost production following Novcom Composting Technology, assessment was also taken up in respect of **Five 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 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 Five Major Cropping Sequences, followed in the area are as follows:

- Crop Sequence 1: Tomato-Cucumber-Coriander
- Crop Sequence 2: Potato-Brinjal-Cauliflower,
- Crop Sequence 3: Potato-Okra-Cabbage,
- Crop Sequence 4 : Brinjal-French bean-Spinach
- Crop Sequence 5 : Pumpkin-Okra-Cabbage

GHG evaluation under the different cropping sequences was done in respect of the Different 'Clean Food' Models *vs*. Conventional Farmers' Practice

1. Clean Food (100 % Reduction of Chemical Pesticide)	**2. Clean Food with 50 % Reduction of N- Fertilizer**	**3. Clean Food with 100 % Reduction of N- Fertilizer**

TABLE 1: GHG Emission (kg CO_2 eq.) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under Conventional Farmers' Practice (CFP) in 2021-22

Conventional Farmers' Practice	Crop Seq 1	Crop Seq 2	Crop Seq 3	Crop Seq 4	Crop Seq 5	Avg. of 5 Crop Sequences
Total GHG Emission from Nutrient Sources (Chemical NPK) kg CO_2 eq /ha./year	3764	6503	6789	3593	5542	**5238**
Total GHG from Chemical pesticides (kg CO_2 eq/ha./year)	389	488	419	429	460	437
Total GHG for Chemical Fertilizers & Pesticides under Conventional Farmers' Practice (CFP) kg CO_2 eq **/ha./year**	**4153**	**6991**	**7208**	**4022**	**6002**	**5675**
Total Crop under Conventional Farmers' Practice (kg.ha.)	42375	77625	66938	44250	48188	55875
GHG (Chemical Fertilizers & Pesticides under Conventional Farmers' Practice, CFP) **per kg Crop** (kg CO_2 eq/ per kg. crop)	**0.10**	**0.09**	**0.11**	**0.09**	**0.12**	**0.10**

GHG Mitigation Potential under Clean Food Program

Comparative study was done to evaluate the GHG emission potential under Conventional Farmers' Practice, Clean Food Program (100 % Reduction of Chemical Pesticide), Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide) and Clean Food Program (100 % N Reduction+100 % Reduction of Chemical Pesticide) with adoption of IRF Technology. **IPCC methodology (IPCC, 2019) and Cool Farm Tool (Hillier, 2013) was used for the purpose. Five major crop sequences** viz. Tomato-Cucumber-Coriander, Potato-Brinjal-Cauliflower, Potato-Okra-Cabbage, Brinjal-French bean-Spinach and Pumpkin-Okra-Cabbage were taken for the evaluation.

The GHG Emission (kg CO_2 eq) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under Conventional Farmers' Practice (CFP) is given in table 1. Total GHG Emission from Nutrient Sources (Chemical NPK) was highest (6789 kg CO_2 eq /ha./year) in the case of Potato-Okra-Cabbage where as it was lowest (3593 kg CO_2 eq /ha./year) in case of Brinjal-French bean-Spinach. In terms of the chemical pesticides the total GHG emission was highest in case of Potato-Brinjal-Cauliflower (488 kg CO_2 eq /ha./year) closely followed by Brinjal-French bean-Spinach (460 kg CO_2 eq /ha./year)

When considered together, the total GHG emission from Chemical Fertilizers and Pesticides under Conventional Farmers' Practice (CFP), per kg crop (kg CO_2 equivalent/ per kg. crop) varied from 0.09 – 0.12 kg with highest carbon footprint (0.12 kg CO_2 eq per kg crop) under Pumpkin-Okra-Cabbage crop sequence.

Fig. 4, 5 and 6 show the comparative GHG Emission (kg CO_2 eq) from two major unsustainable sources (Chemical Fertilizers & Pesticides) in five major Crop Sequences under Conventional Farmers' Practice (CFP) and indicates that Chemical Fertilizers specially N Fertilizers are major contributor towards GHG emission. Fig. 5 shows the average GHG Emission and indicates that among the two most un-sustainable inputs, **Chemical Fertilizers contribute about 78 % of the total emission.**

Comparative GHG Emission (kg CO_2 eq/ha./year) from the two major unsustainable sources (Chemical Fertilizers & Pesticides) under the different farming practices (table 2 and 3, fig. 7, 8 9 and 10) indicated the **HIGHEST GHG MITIGATION – 570% Lower GHG Footprint** with a Net GHG Footprint of **(-) 37553** kg. CO_2 eq/ha/year, or **(-) 0.57** kg. CO_2 eq per kg Crop; **over CFP** (*on an average*) **under 'Clean Food' Model where 100 % Reduction of both N-fertilizer and Chemical Pesticide was done**. Among the different crop sequences, **the mitigation was highest under Potato-Okra-Cabbage (41160 kg. CO_2 /ha/year)** followed by Potato-Brinjal-Cauliflower (40943 kg. CO_2 /ha/year) and Pumpkin-Okra-Cabbage (39954 kg. CO_2 /ha/year). Table 4 indicates that adoption of 'Clean Food' Model with the **omission of one major unsustainable input i.e. chemical pesticides can enable a 25 % Reduction in GHG emission** (on an average) .

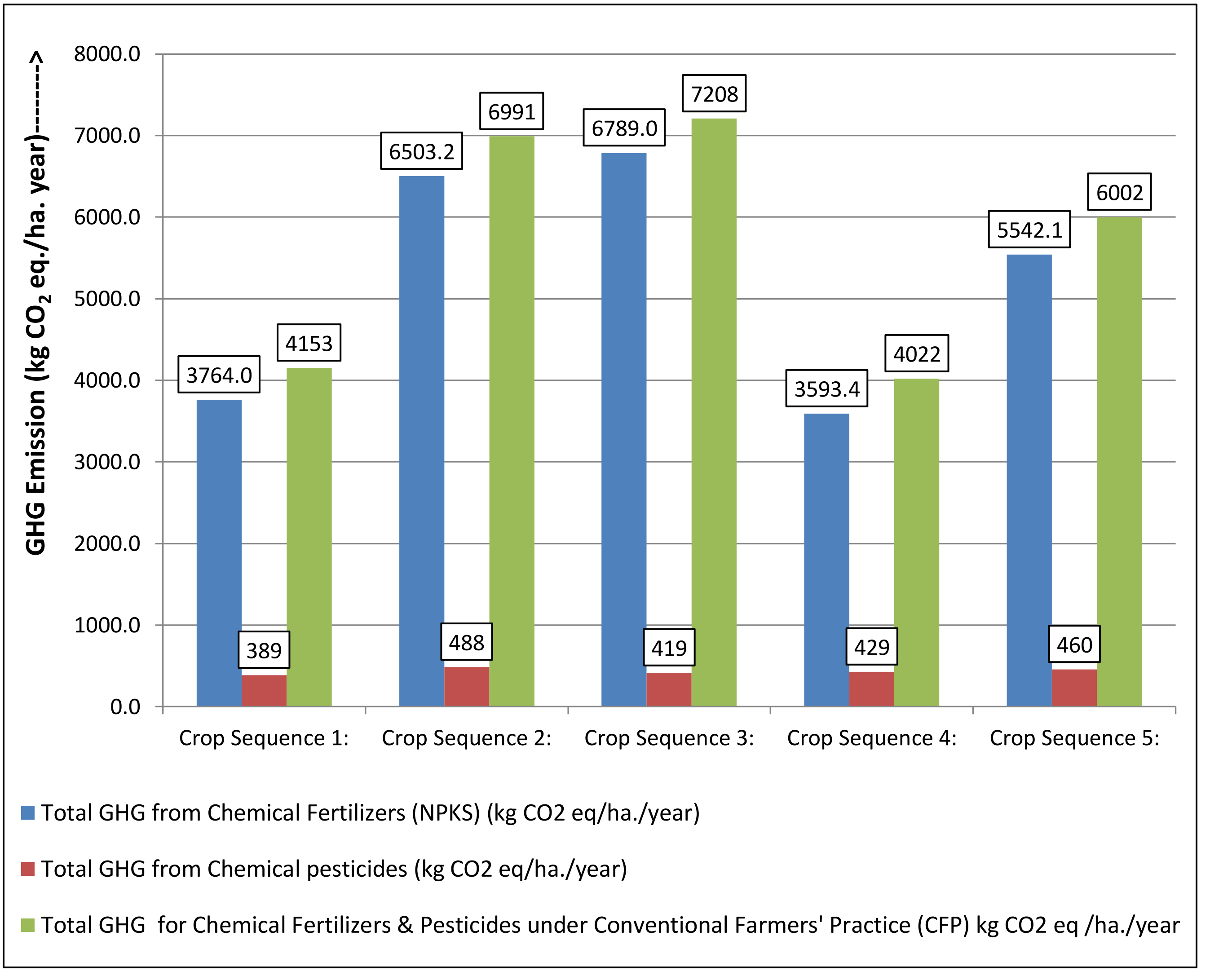


Fig. 4 : GHG Emission (kg CO_2 eq) from two major unsustainable sources (Chemical Fertilizers & Pesticides) in five Major Crop Sequences under Conventional Farmers' Practice (CFP).

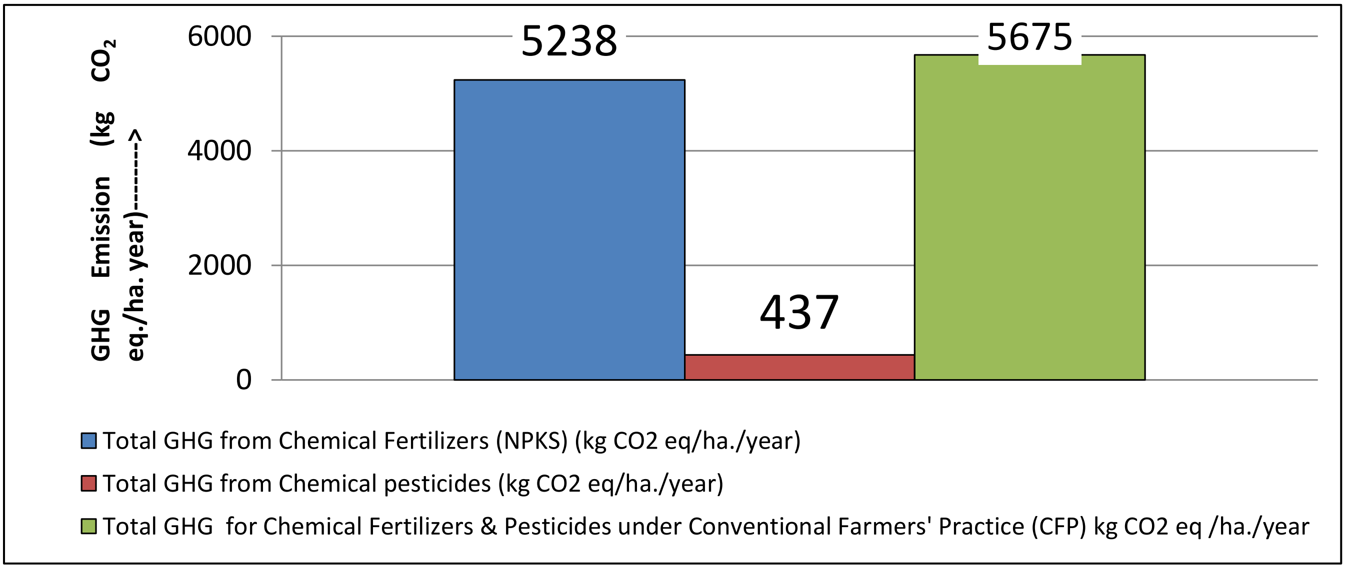


Fig 5 Avg. GHG Emission in five Major Crop Sequences From two major unsustainable sources (Chemical Fertilizers & Pesticides) under Conventional Farmers' Practice (CFP).

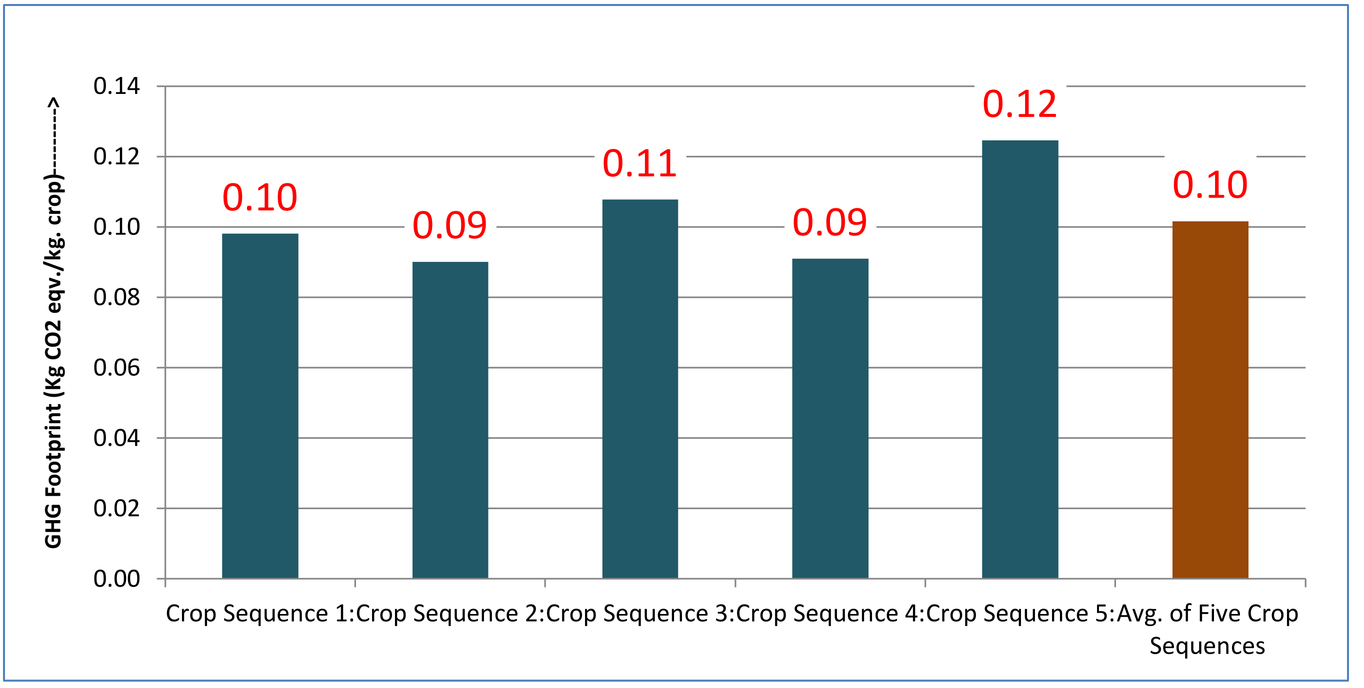


Fig 6: Total GHG Footprint in 5 Major Crop Sequences under Conventional Farmers' Practice per kg crop (CFP) kg CO_2 eq. /kg. crop.

TABLE 2: Comparative GHG Emission (kg CO_2 eq/ha./year) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under different farming practice

Different Management Practices	Crop Seq 1	Crop Seq 2	Crop Seq 3	Crop Seq 4	Crop Seq 5	**Avg. of 5 Crop Sequences**
Conventional Farmers' Practice: Total GHG for Chemical Fertilizers & Pesticides under Conventional Farmers' Practice (CFP) kg CO_2 eq /ha./year	**4153**	**6991**	**7208**	**4022**	**6002**	**5675**
Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide): Net Negative GHG Emission over CFP kg. CO_2 /ha./year	18188	21423	21331	18256	21280	20095
Clean Food Program (100 % N Reduction+100 % Reduction of Chemical Pesticide): Net Negative GHG Emission over CFP kg. CO_2 /ha./year	32920	40943	41160	32789	39954	37553

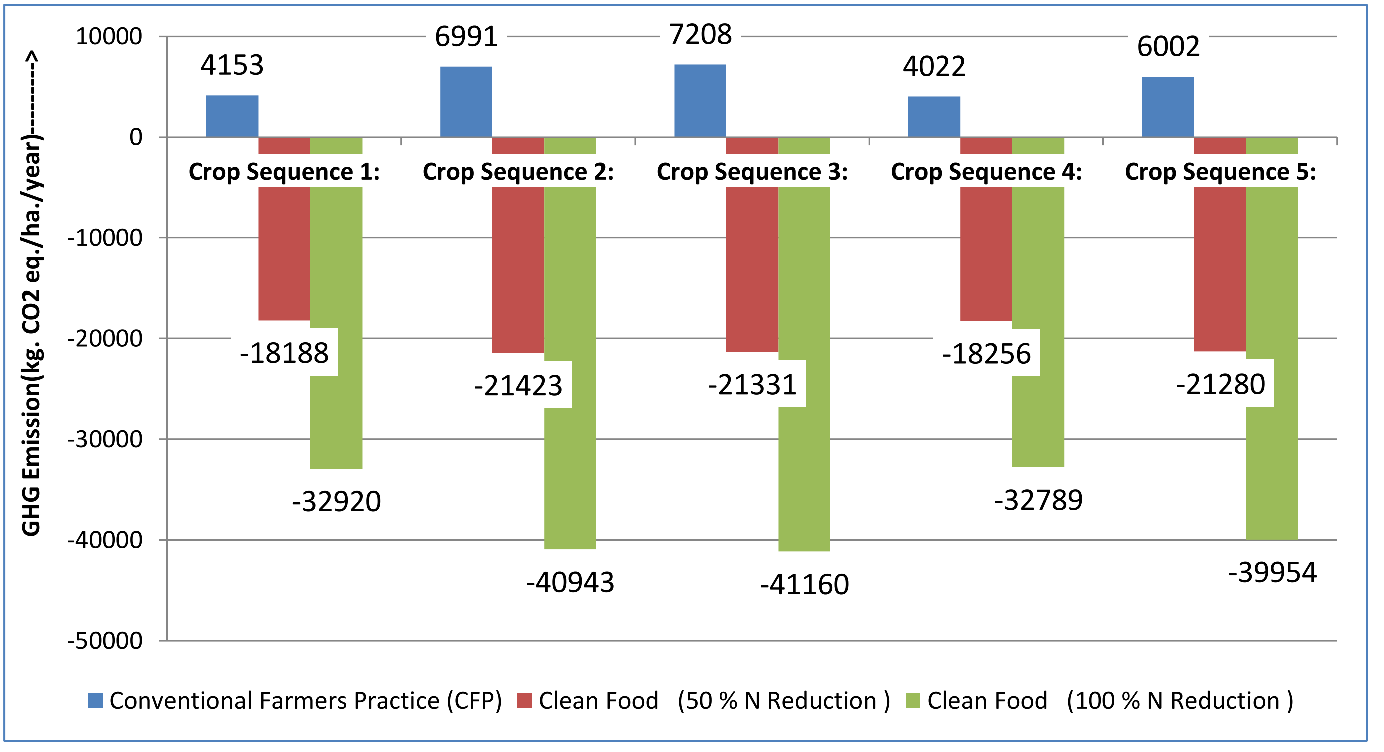


Fig. 7: GHG Emission (kg CO_2 eq/ha./year) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under different Management Practice.

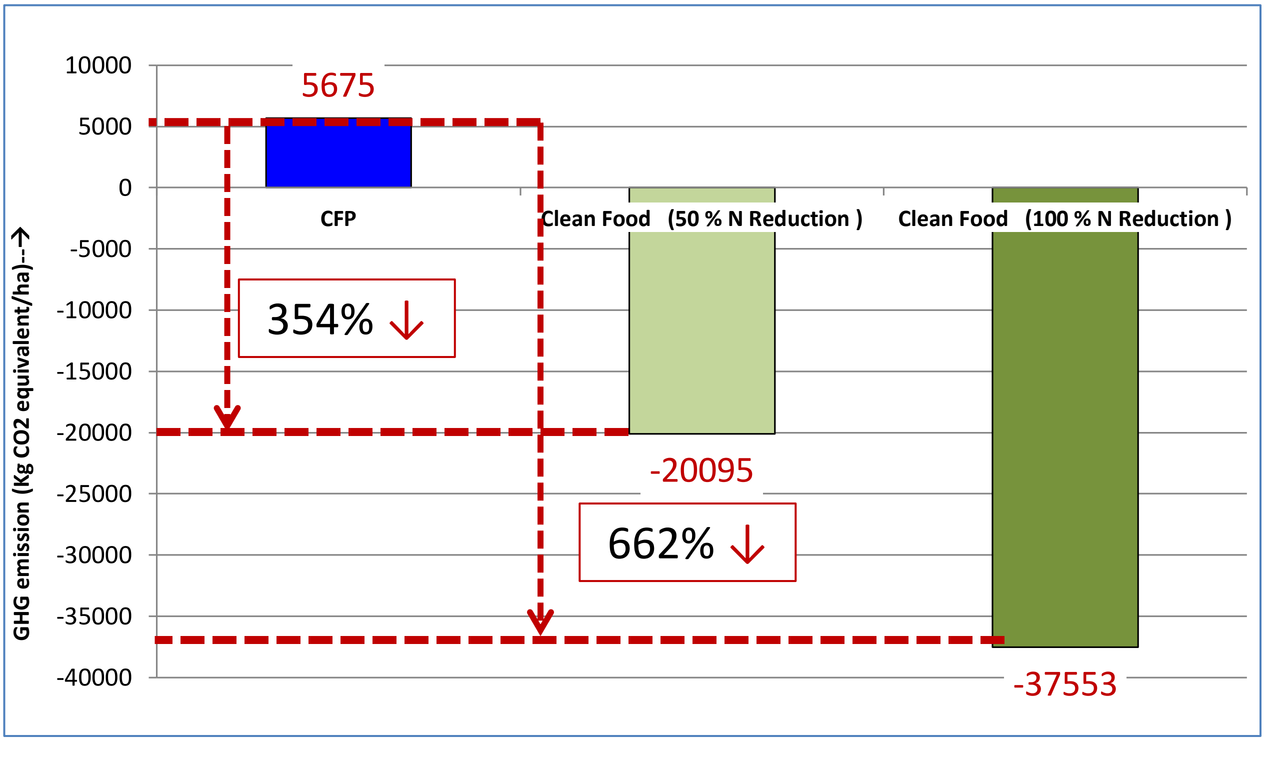


Fig. 8: Comparative GHG Emission (kg CO_2 eq/ha./year) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under different Management Practice.

TABLE 3: GHG Footprint (kg CO_2 eq/ kg Crop) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under different Management Practice

Different Management Practices	Crop Seq 1	Crop Seq 2	Crop Seq 3	Crop Seq 4	Crop Seq 5	Avg. of 5 Crop Sequences
Conventional Farmers' Practice: Total GHG Footprint under Conventional Farmers' Practice (CFP) kg CO_2 eq /kg. crop	**0.10**	**0.09**	**0.11**	**0.09**	**0.12**	**0.10**
Clean Food Program (50 % N Reduction+100 % Reduction of Chemical Pesticide): Net Negative GHG Footprint over CFP kg. CO_2 /kg. crop	**- 0.39**	**- 0.25**	**- 0.29**	**- 0.38**	**- 0.40**	**- 0.33**
Clean Food Program (100 % N Reduction + 100 % Reduction of Chemical Pesticide): Net Negative GHG Footprint over CFP kg. CO_2 /kg. crop	**- 0.64**	**- 0.46**	**- 0.52**	**- 0.62**	**- 0.71**	**- 0.57**

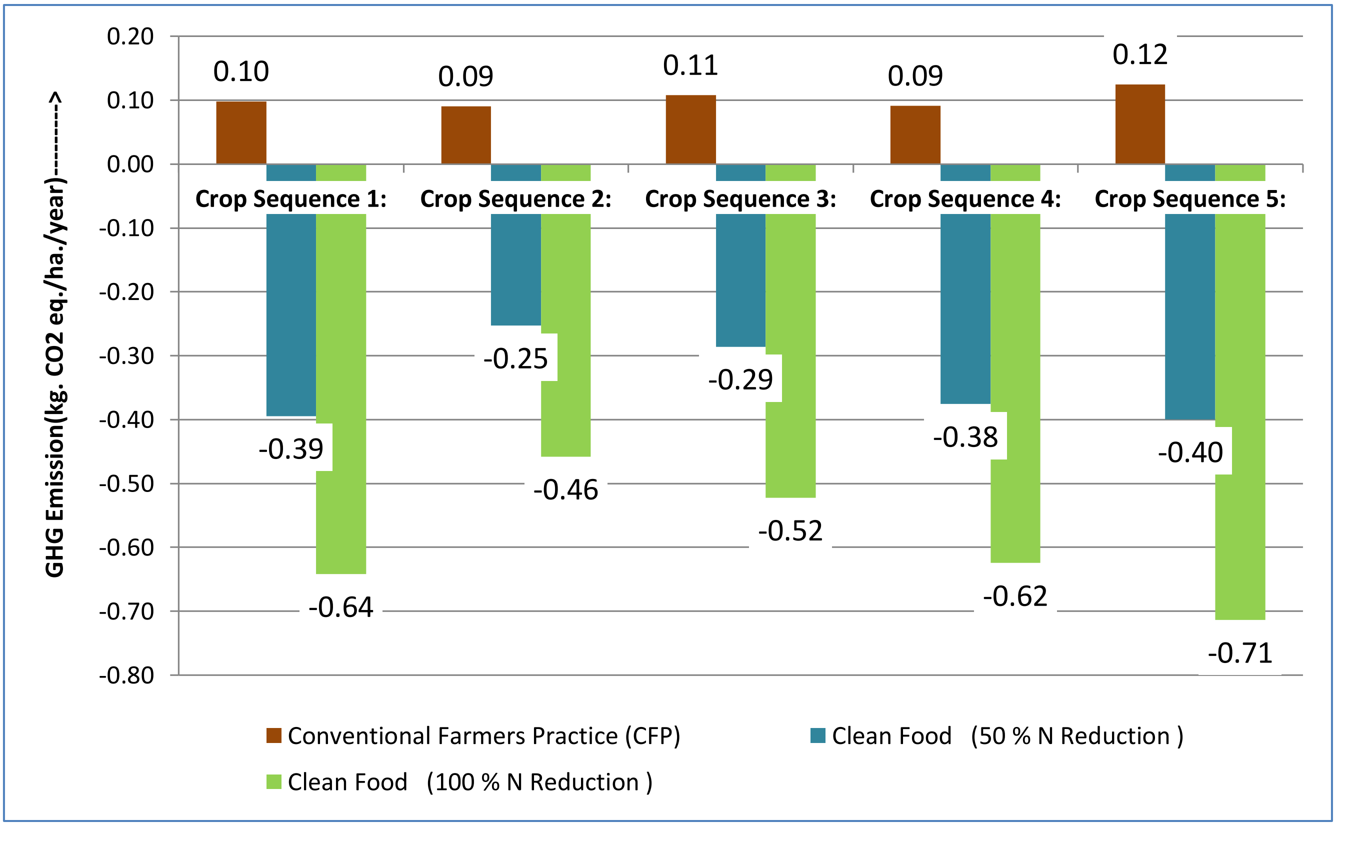


Fig. 9 : Comparative study of GHG Footprint (kg CO_2 eq/ kg crop) from two major unsustainable sources (Chemical Fertilizers & Pesticides) under different Management Practice.

Fig. 10 : Comparative GHG Footprint (kg CO_2 eq/ kg crop) from two major unsustainable sources (Chemical Fertilizers & Pesticides) in the Crop Sequences under different Management Practice.

TABLE 4: Total GHG Emission (kg. CO_2 eq./ha./year) under Clean Food Program (100 % Reduction of Chemical Pesticide).

Clean Food Program (100 % Reduction of Chemical Pesticide)	Crop Seq 1	Crop Seq 2	Crop Seq 3	Crop Seq 4	Crop Seq 5	Avg. of five Crop Sequences
Total GHG Emission from Nutrient Sources (Chemical NPK) kg CO_2 eq /ha./year	3764	6503	6789	3593	5542	**5238**
Total GHG from Alternative Pest Management (Neem Oils & Sulphur) under CF Program (kg CO_2 eq/ha./year)	**185**	**165**	**186**	**185**	**206**	**185**
Total GHG for Chemical Fertilizers & Pesticides and Alternative Pest Mgt. under CF Program (kg CO_2 eq/ha./year)	**3949**	**6668**	**6975**	**3778**	**5748**	**5424**
Total Crop under Clean Food Program (100 % Reduction of Chemical Pesticide)	**45030**	**83084**	**73898**	**45218**	**52272**	**59900**
GHG (Chemical Fertilizers & Pesticides) emission per kg crop under Clean Food Program (100 % Reduction of Chemical Pesticide)	**0.09**	**0.08**	**0.10**	**0.08**	**0.11**	**0.09**

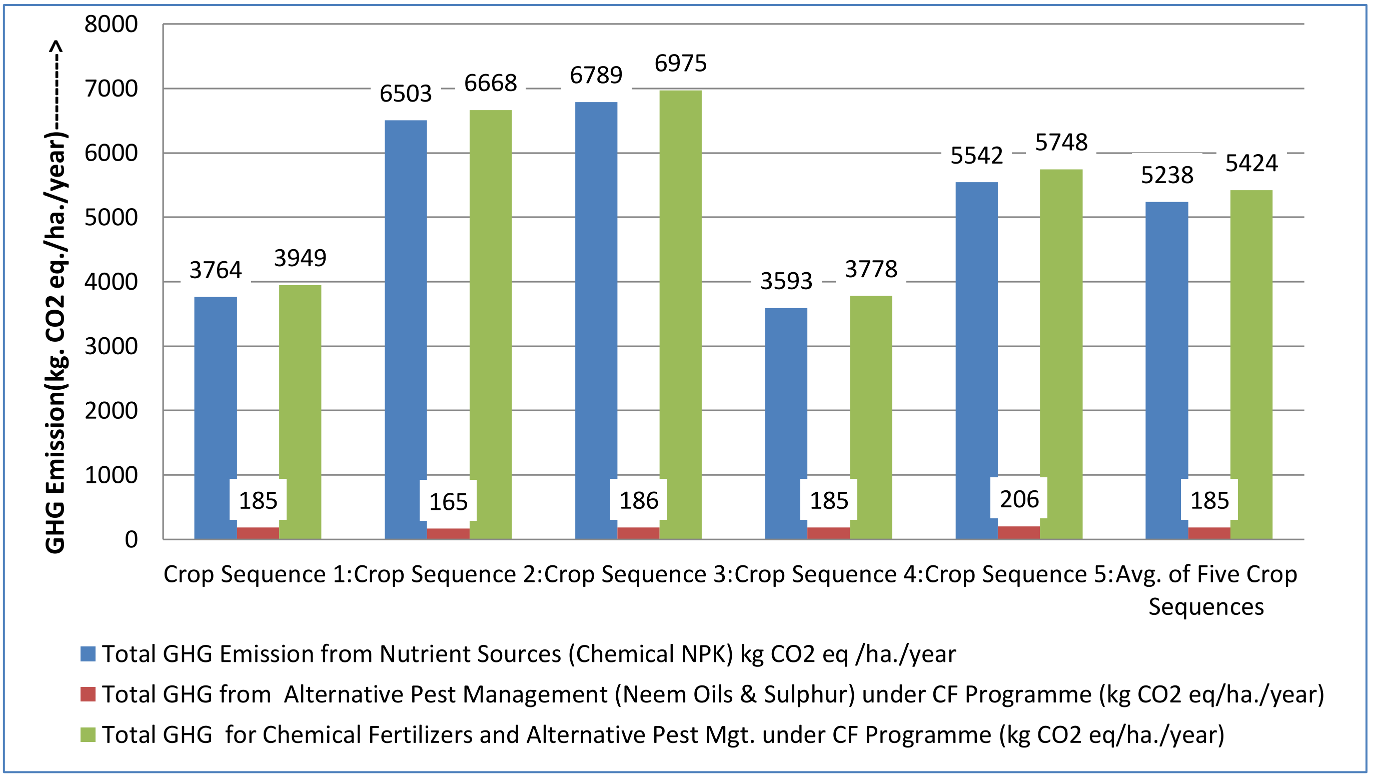


Fig. 11: : GHG Emission (kg CO_2 eq) under Clean Food Program (100 % Reduction of Chemical Pesticide).

The GHG Emission from input use for crop production as well as the total GHG Emission/ Mitigation under the 'Clean Food' Models are presented in table 4, 5 and 6 and fig. 11. The tables and figure indicated that Clean Food Program enabled GHG mitigation where as GHG emission was observed in the case of conventional farmers' practice,.

Average GHG emission was **(+) 0.12** kg CO_2 eq/kg produce under conventionally managed crop sequence. Whereas (+) 0.09 kg CO_2 eq/kg produce, (-) 0.33 kg CO_2-eq/kg produce and **(-) 0.57 CO_2-eq/kg Crop**, were recorded under Clean Food Program with 100 % reduction of Chemical Pesticides, 50 % N-Fertilizer Reduction+100 % Reduction of Chemical Pesticides and 100 % N-Fertilizer Reduction + 100 % Reduction of Chemical Pesticides; respectively**.**

The Positive GHG value under Conventional Farmers' Practice was primarily due to the use of Chemical N Fertilizers and pesticides. While the **Clean Food Model with 100% Reduction of both N-Fertilizer and Chemical Pesticides** recorded **570% LOWER GHG FOOTPRINT** as compared to Conventional Farmers' Practice. The Comparative GHG Emission/ Mitigation Potential (kg CO_2 eq/ kg produce) under different 'Clean Food' Models showed that a **SWITCH OVER from Conventional Farmers' Practice to Clean Food Model with 100 % N Reduction-driven by IRF Technology; can totally transform agriculture from being GHG emitting source to a GHG Sink.**

This Model Farm initiative led to Development of Clean Food 'NET ZERO' - A Stupendous- First of a Kind Climate Action Model in Agriculture

Table 5: Total GHG Emission kg. CO_2 eq./ha./year & GHG Footprint Kg. CO_2 eq./kg. Crop) under Clean Food Program with 50 % N Reduction + 100 % Reduction of Chemical Pesticide).

Clean Food (50 % N Reduction)	Crop Seq 1	Crop Seq 2	Crop Seq 3	Crop Seq 4	Crop Seq 5	Avg. of five Crop Sequences
Total NOVCOM Compost Applied (kg/ha./year)	38	45	45	38	45	**42**
NOVCOM PROCESS EFFICIENCY : kg CO2 per ha. Saving - for Compost application (15 tons or 30 tons/ha/crop)	**7050**	**8460**	**8460**	**7050**	**8460**	**7896**
Net CO2 Sequestration (kg CO2 per ha.) for Compost application **(15 tons or 30 tons/ha/crop)**	4146	3133	2824	4344	3979	3685
GHG Abetment through adoption of CF 100% N reduction Model ((Kg CO2 equivalent/ha)	**4153**	**6991**	**7208**	**4022**	**6002**	**5675**
Carbon saving in terms of CO2 equivalent due to Change of Management Pracice (kg/ha.)	**2839**	**2839**	**2839**	**2839**	**2839**	**2839**
Actual GHG negative emission (Kg CO2 equivalent/ha)	18188	21423	21331	18256	21280	20095
Total Crop under Clean Food Program (100 % N Reduction)	46125	84750	74625	48600	53250	**61470**
NET GHG Footprint (- ve) under CF 50% N-fertilizer Reduction (Kg CO2 equivalent/ per kg. crop)	**0.39**	**0.25**	**0.29**	**0.38**	**0.40**	**0.33**

Table 6: GHG AUDIT (Total GHG Emission kg. CO_2 eq./ha./year & GHG Footprint Kg. CO_2 eq/ kg Crop) under Clean Food Program with 100 % N Reduction + 100 % Reduction of Chemical Pesticides

Clean Food (100 % N Reduction)	Crop Seq 1	Crop Seq 2	Crop Seq 3	Crop Seq 4	Crop Seq 5	Avg. of five Crop Sequences
Total NOVCOM Compost Applied (kg/ha./year)	**75**	**90**	**90**	**75**	**90**	**84**
NOVCOM PROCESS EFFICIENCY : kg CO_2 per ha. Saving - for Compost application (15 tons or 30 tons/ha/crop)	**14100**	**16920**	**16920**	**14100**	**16920**	**15792**
Net CO_2 Sequestration (kg CO_2 per ha.) for Compost application **(15 tons or 30 tons/ha/crop)**	11828	14193	14193	11828	14193	13247
GHG Abatement through adoption of CF 100% N Reduction Model ((Kg CO_2 equivalent/ha)	**4153**	**6991**	**7208**	**4022**	**6002**	**5675**
Carbon saving in terms of CO_2 equivalent due to Change of Management Pracice (kg/ha.)	**2839**	**2839**	**2839**	**2839**	**2839**	**2839**
Actual GHG negative emission (Kg CO_2 equivalent/ha)	32920	40943	41160	32789	39954	37553
Total Crop under Clean Food Program (100 % N Reduction)	**51300**	**89400**	**78825**	**52500**	**55995**	**65604**
NET GHG Footprint (- ve) under CF 100% N-fertilizer Reduction (Kg CO_2 equivalent/ per kg. crop)	**0.64**	**0.46**	**0.52**	**0.62**	**0.71**	**0.57**

Carbon Sustainability Index (CSI), Carbon Efficiency Ratio (CER) and Carbon Productivity Ratio (CPR)

Sustainability of any agricultural system can be measured through carbon input and carbon output from the crop production system. Carbon input is basically due to use of fossil fuel, electricity and farm machinery for agricultural operations as well as use of synthetic chemical inputs in terms of chemical fertilizers, micro nutrients, chemical pesticides, fungicides, herbicides, etc. GHG emission from manure management as well as livestock rearing related to agriculture is also included in carbon input. On the other hand as Carbon output; the total biomass generated due to agricultural activity including harvested crop, roots and remaining plant excess are included. **Now under SUSTAINABLE FARMING APPROACH, we propose to include the carbon incorporated directly in soil under soil management program (through compost/ organic manure application) in the CARBON OUTPUT CALCULATION**.

Total C output in terms of total biomass generation is the sum of the carbon equivalent of harvested crop, remaining plant excess and root biomass produced by the crop. **Remaining portion of the crop other than the harvested part is considered to be 25 % of total biomass assuming 0.75 as harvested Index of vegetables**. Total C present in vegetable biomass was estimated by multiplying the yield with a factor of 0.0424, as it was assumed that **biomass contains 90 % moisture and 42% C in the harvested part**.

Accordingly the following indices were developed :

Carbon Sustainability Index (CSI) =

$$= \frac{\underset{\text{(Total C sequestration in terms of biomass generation and compost/ organic manure application)}}{\text{Carbon Output}} - \underset{\text{(Total GHG emission in C – equivalent)}}{\text{Carbon Input}}}{\underset{\text{(Total GHG emission in C – equivalent)}}{\text{Carbon Input}}} \quad \text{--- (i)}$$

$$\text{Carbon Efficiency Ratio (CER)} = \frac{\underset{\text{(Total C sequestration in terms of biomass generation and compost/ organic manure application)}}{\text{Carbon Output}}}{\underset{\text{(Total GHG emission in C – equivalent)}}{\text{Carbon Input}}} \quad \text{--- (ii)}$$

$$\underset{\text{(GHG emission/ mitigation per unit Crop Production)}}{\text{Carbon Productivity Ratio (CPR)}} = \frac{\text{Total Harvested Output (kg)}}{\underset{\text{(Net GHG in C – equivalent from all input sources)}}{\text{Net Carbon Input}}} \quad \text{--- (iii)}$$

Carbon Sustainability Index (CSI)

Industrial agriculture has become a major source of GHG emission and thus contributes to climate change which can have negative impact on future food security and sustenance of life on earth. Different sustainable initiatives have been taken up worldwide towards GHG mitigation and adaptation, **but to assess as a whole whether an agricultural system is sustainable or not ; IORF developed the First of a Kind, CARBON SUSTAINABILITY INDEX (CSI).**

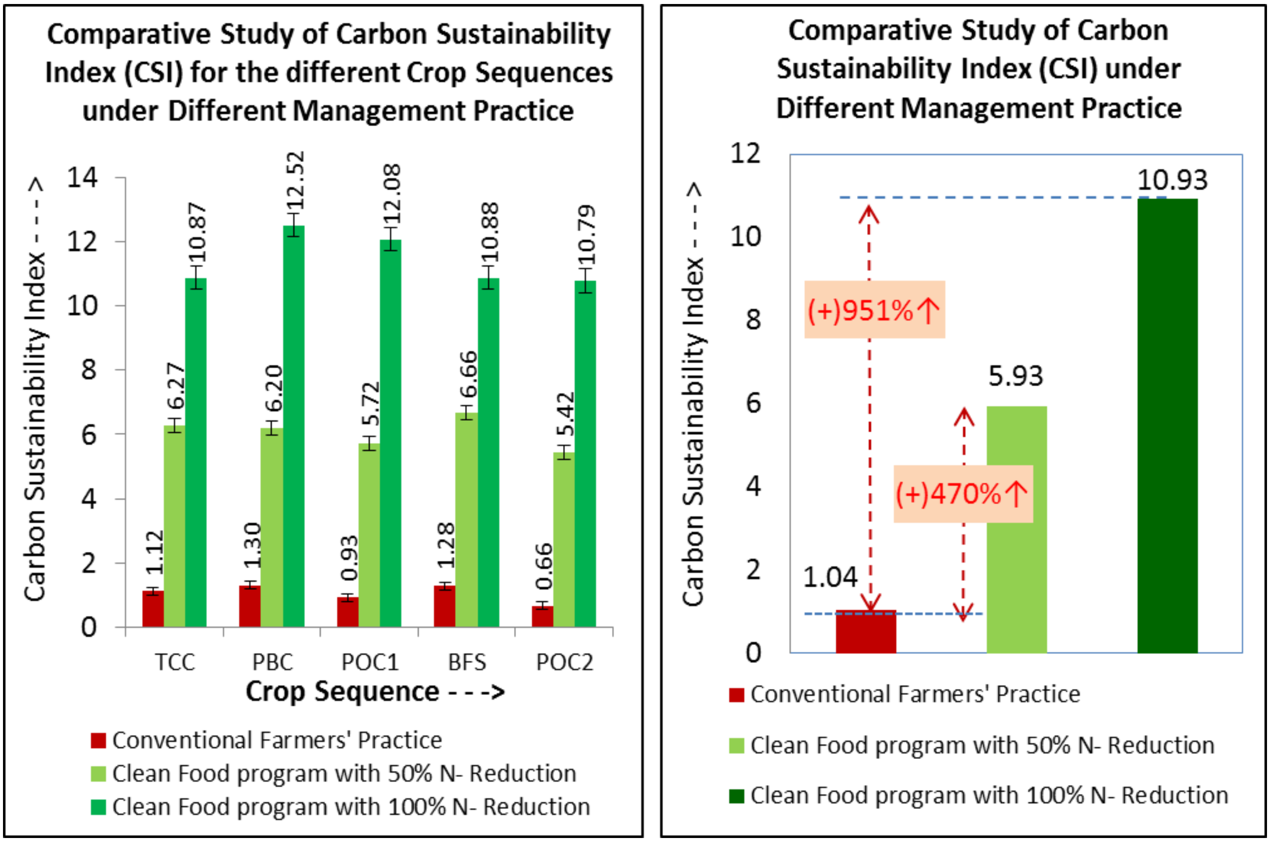


Fig. 12A & 12B : Comparative Study of Carbon Sustainability Index (CSI) under Different Management Practice.

**Based on Two Major unsustainable Inputs i.e. N- Fertilizer & Chemical Pesticide*

Carbon Sustainability Index (CSI) value made a **QUANTUM JUMP (951%)** with change over from conventional farmers' practice and indicated HIGH SUSTAINABILITY POTENTIAL of the **'Clean Food' Models due to the dual approach of GHG MITIGATION and ADAPTATION**. In the scale of Carbon Sustainability Index, **if any score is more than 1.0,** it will indicate that the adopted management practice **POSITIVELY IMPACTS SUSTAINABILITY AND CARBON SAVING AND VICE VERSA. CSI was more than 5.0 and went close to 11.0 under the different 'Clean food' Models**

Comparative Study of Carbon Efficiency Ratio (CER) and Carbon Productivity Ratio (CPR) under Different Management Practice

Carbon Efficiency Ratio (CER) indicates the efficiency in carbon usage in terms of carbon input and output in any agricultural system. **Higher CER value indicates more stable and sustainable system and the positive impact of the agricultural system in terms of carbon saving as well as crop sustainability. So a CER value of 11.93 under Clean Food Model with 100% reduction of both N- Fertilizer and Chemical Pesticide indicates a Very High C-Sequestration Potential.**

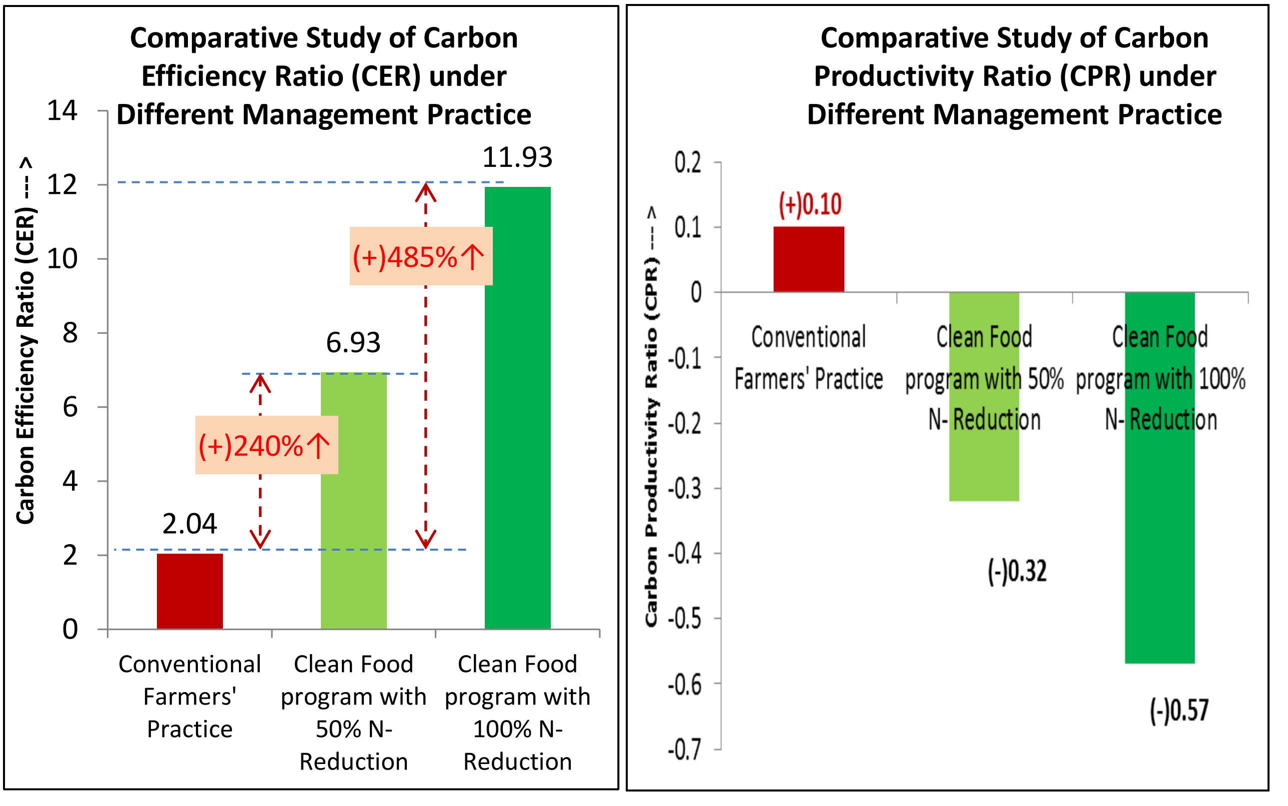


Fig 13A & 13B : Comparative Study of Carbon Efficiency Ratio (CER) and Carbon Productivity Ratio (CPR) under Different Management Practice.

Carbon Productivity Ratio (CPR) indicates the GHG emission/ offset (in terms of kg CO_2 eq)for every unit of Crop Production. Positive value indicates Net GHG emission for crop production under an agricultural system, while **negative value indicates GHG mitigation**. **Sustainable agriculture should result in a negative CPR value. Higher the NEGATIVE VALUE, higher the impact both in terms of HIGHER CROP YIELDS as well as A HIGH GHG MITIGATION POTENTIAL.**

670% HIGHER CARBON PRODUCTIVITY meaning a High C- Sequestration under 'Clean Food' Model with 100% reduction of both N- Fertilizer and Chemical Pesticide**, practically demonstrates the Carbon Saving Aspect of Sustainable Agriculture - driven by IRF Technology.**

CHAPTER 19 : DEVELOPMENT OF PATHWAY FOR TRANSPARENT SUPPLY OF 'CLEAN FOOD' FROM THE PRODUCERS TO THE CONSUMERS

One of the Primary Objectives of the IBM-IORF Sustainability Accelerator Project was to Deliver Sustainability at Two Levels- The Farmers and The Consumers.

The 1st Phase of the Project has ensured the adoption of a Safe and Sustainable Crop Technology (IRF Technology) towards 'Clean Food' Production to ensure Sustainability attainment at the farm level. And IORF has established a Farmers' Producers' Company (FPC) for effective execution of Safe and Sustainable Agriculture Project and for Farm Level Sustainability Delivery.

But the ultimate objective of this Project is to deliver and ensure continuity of this Sustainability upto the end of the Food Supply Chain i.e., the consumers – IORF has established a Dissemination Wing solely to ensure that the 'Clean Food' produced through Safe and Sustainable Agriculture reach the Consumers at a Sustainable Price- The 1st Such Initiative Pan India

MAPCL – the Sustainability Executor

To ensure that the true benefits of this holistic sustainable agricultural pathway reach the actual farmers who follow it, IORF organized the farmers participating in the IBM Clean Food Program at Haringhata Block, Nadia, West Bengal and facilitated the creation of a unique Farmer Producers Company (FPC) involving their representatives.

This niche FPC – named Manobjomin Agro Producers Company Limited (MAPCL) – is the one and only of its kind in the entire country, being dedicated solely towards Safe and Sustainable Agriculture.

In order to steer this unique FPC in its initial days, IORF allowed its Chief Scientist to act as the CEO of MAPCL – this, again, makes MAPCL unique as being the only FPC of the country whose executive powers are bestowed on a highly qualified agricultural scientist.

Thousands of FPCs have been formed across the country, in accordance with the mandate from Govt. of India to empower the farmers, but none of them can match MAPCL in terms of their stated objectivities – A Total Dedication Towards Safe and Sustainable Agriculture.

MAPCL has been involved in the ground-level execution of the IBM Clean Food Program since its very inception – facilitating and organizing all farming and ancillary activities (*like training and motivation of participating farmers, logistical support for the organic inputs provided by IORF, local facilitation of large-scale Novcom composting and so on*) and ensuring that the Sustainability is maintained at the farm level.

SafeU – the Sustainability Disseminator

At the other end of the Clean Food value chain lies SafeU Agricultural Pathways Pvt. Ltd. – the dissemination wing of IORF. “SafeU” is the abbreviated form of ‘Sustainable Agriculture for Farmers, Ecology and yoU’ and the objectivity of this unique organization is enshrined within this name.

SafeU has been established to ensure that the Clean Food products produced through safe and sustainable agriculture reaches the end consumers in such a way that the latter need not pay any premium price (*unlike conventionally certified organic products*) for the same.

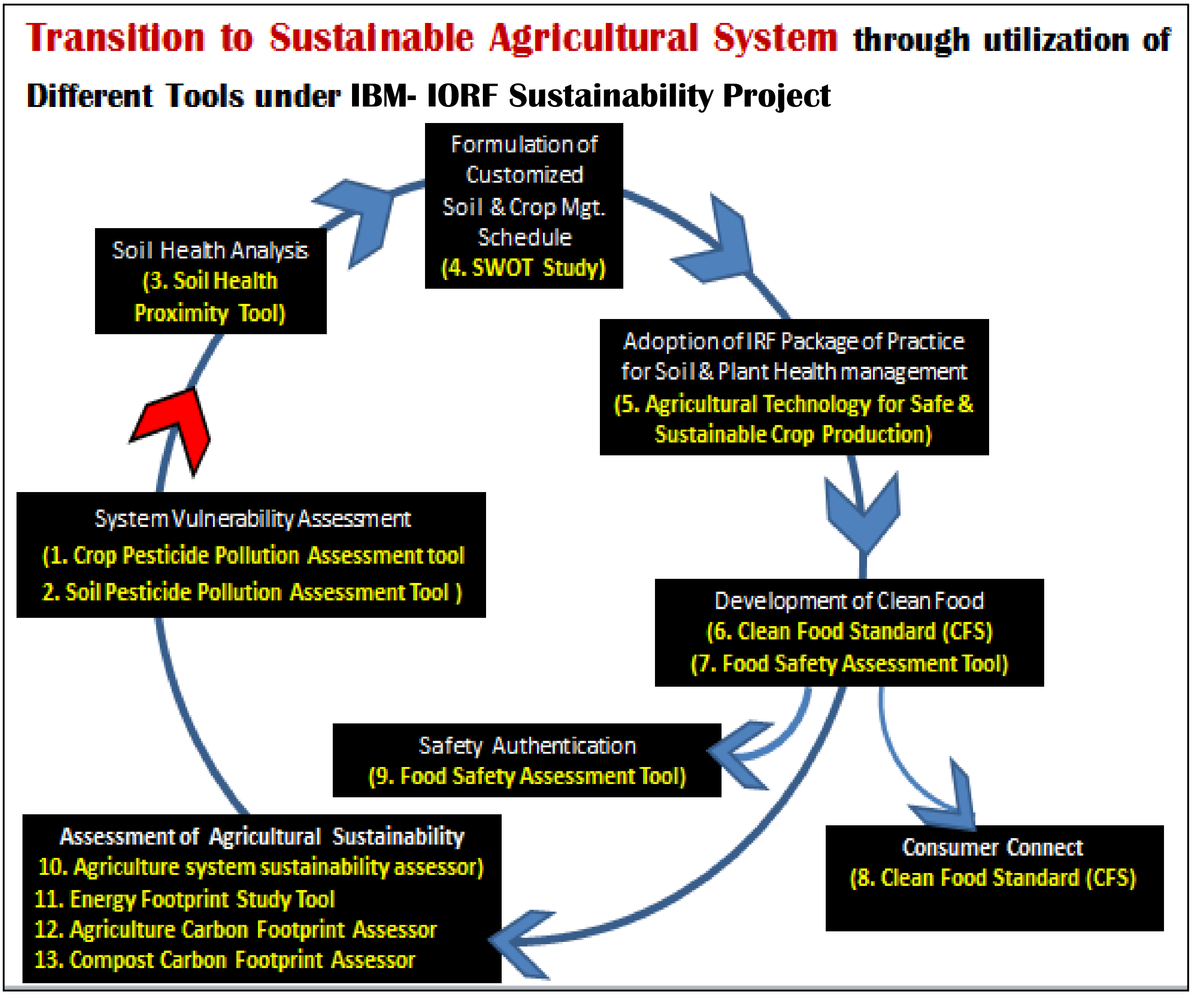
SafeU, thus, is designed to deliver economic sustainability to both the producers (*procuring Clean Food at competitive market prices, or even slightly higher at times*) and the consumers (*retailing Clean Food at competitive market prices of chemical-laden conventional produce, at no premium whatsoever, so as to establish the vision of IORF that “Access to Safe, Healthy & Nutritious Food is the Legitimate Right of All”*) at the two extremes of this unique value chain.

SafeU is entirely dedicated towards economic sustainability for the farmers, ecological sustainability of the farmland, physiological sustainability of the crops and nutritional sustainability of the consumers. SafeU, by its very charter, is not authorised to deal in any products that do not meet the above sustainability quartet.

Besides the above, SafeU is a unique StandUp venture (*woman entrepreneur led start up venture in Indian parlance, in conformity with the vision of our honourable Prime Minister*) in the domain of agriculture that has been conceived to deliver sustainability to the primary sector of our economy.

In the process of Clean Food development we utilized the different Tools and Indices previously developed by IORF towards quantification of the Soil and Plant Health under the Sustainable Agriculture Initiative. But the project also provided the opportunity to pursue the development of Specific Sustainability Tools that could enable Wide Scale Sustainability outreach especially to the Small and Marginal Farming Community.

Nine Sustainability Tools have come out as the Scientific Offshoots of the IBM-IORF Sustainability Project, some fully developed and some due for completion shortly.



1. SOIL HEALTH PROXIMITY MODEL - PROTOTYPE DEVELOPED

Soil Health Proximity Model is an **Innovative Scientific Solution for providing a Complete Soil Health Card to each Farmer as per their land fragmentation in the most economic and time bound manner**; that can help facilitate Soil Health based Sustainable Soil Health Managements.

The need for developing such model was first felt necessary when the IBM- IORF Sustainability Project provided insight into the **critical land fragmentation of the small and marginal farmers (land holding size <0.38 ha), the acute resource scarcity and the contrastingly high cropping intensity that meant extreme dependence on the land *vis-a-vis* extreme reliance on the unsustainable inputs (*chemical fertilizers & pesticides*); challenges that are further aggravated by the existential climate change impact.** Due to the extreme dependence on land, awareness regarding soil health of individual farm land is extremely crucial esepcially for these small and marginal land holders, but the analysis cost and the analysis time period primarily form the major bottleneck in this deirection. The exposure brought forth the need for **an effective, speedy and economic solution that can enable 'Soil health Card' for individual farm land – individual farmer**.

What spurred the need for such Model?

Soil analysis is the foundation for developing management strategies and land use plan for **Sustainable Crop Production and livelihood sustenance**. In India more than **86% of over 100 million farmers are small and marginal.** They contribute 51% of agricultural output with 46% of operated land, and produce a much higher share (70%) of high-value crops.

However, over exploitation of land, intensive use of agrochemicals, lack of exposure to modern techniques and limited/ no information regarding soil quality **increases** the risk of crop failure, in the pretext of the **existential climate change**. Vulnerability of these farm holders not only weakens the foundation of India's economy but also jeopardizes the social integrity. The solution lies in **adopting sustainable faming approach, and Soil Health Analysis of individual farm land is the 1st step in this direction.**

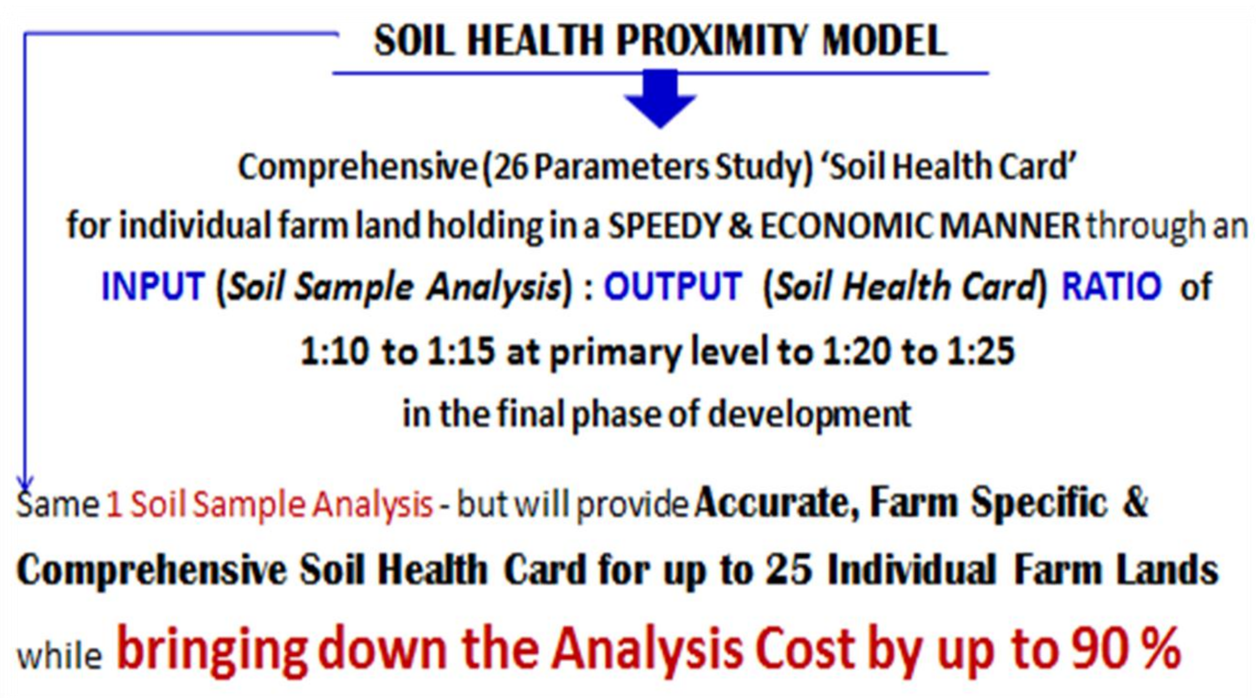
Soil Health Proximity Model can fulfill India's Commitment for Sustainable Agriculture Development

'Soil Health Card' is a great initiative by the Government of India that provides Soil Test based Recommendations for **Soil Nutrient Management**. The Soil Health Card is meant to provide each farmer with the soil nutrient status of his holding and advise on the dosage of fertilizers and micronutrients, and/ or soil amendments if required for long term maintenance of soil health. **But the fact remains that upto 10-12 farmers get the same Soil Health Report plus the absence of soil microbial analysis limits its relevance for the farmers especially considering the critical fragmentation of small and marginal farm lands.**

The **Soil Health Proximity Model can effectively mitigate the limitations of the presently provided Soil Health Card** by the Govt. and facilitate the reachness of the program to the small and marginal farming community in an economic and speediest manner; and can thus support India's commitment towards sustainable agriculture.

The Science of Proximity

The Soil Health Proximity Model is a harmonious amalgamation of GIS technique based information output with the soil analytical data base generated from multi-layer dynamic grid soil sampling along with incorporation of expert opinion as correction factor based on various logical Hypotheses. The inadequacy of the present soil fertility recommendations **spurred the development to enable a more comprehensive assessment of soil health**, based on the **TRIAD of Physical, Biological, and Chemical Properties**, which is more sensitive to land management practices and reportedly better correlated to ecosystem processes.



A Game Changer for Degraded Soil Management

Thus For the 1st Time, Pan India the **IORF- IBM Soil Health Card will provide Comprehensive Soil Health Card for each individual farm land, with 25 PARAMETERS Soil Quality Study and a complete set of SOIL MICROBIOLOGICAL ANALYSIS – The Most Relevant Component for Soil Health vis-à-vis Sustainable Crop Production**. Also the Development of **5 UNIQUE SOIL CHARACTER INDICES** along with Color Coding towards enabling easy understanding of the soil health status that can aid the farmers in adopting Sustainable Soil Health Management

According to a statement of United Nation, 'Only 60 Years of Farming Left If Soil Degradation Continues'. In India, out of its 179.9 million ha agricultural land, 67% area is already degraded which in turn, is affecting the country's productive resource base.

Apart from the climate change impact, this problem has been greatly aggravated in the recent decades because of bringing marginal areas under the plough to meet the growing food demand along with inappropriate agricultural practices and chemical abuse. Thus India will face a stiff challenge to achieve its target of becoming land degradation neutral by 2030, announced by the Prime Minister.

In this pretext, the **Soil Health Proximity Model can serve as the APT TOOL for aggregating the DEGRADED AGRICULTURAL LAND of India under DETAILED ANALYTICAL MAP – a crucial Step towards developing a SUSTAINABLE RECLAMATION PROGRAM**

> "We are also working towards restoring 26 million hectares of degraded land by 2030. This would contribute to India's commitment to achieving an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide equivalent,''
>
> **- Prime Minister Sri Narendra Modi**

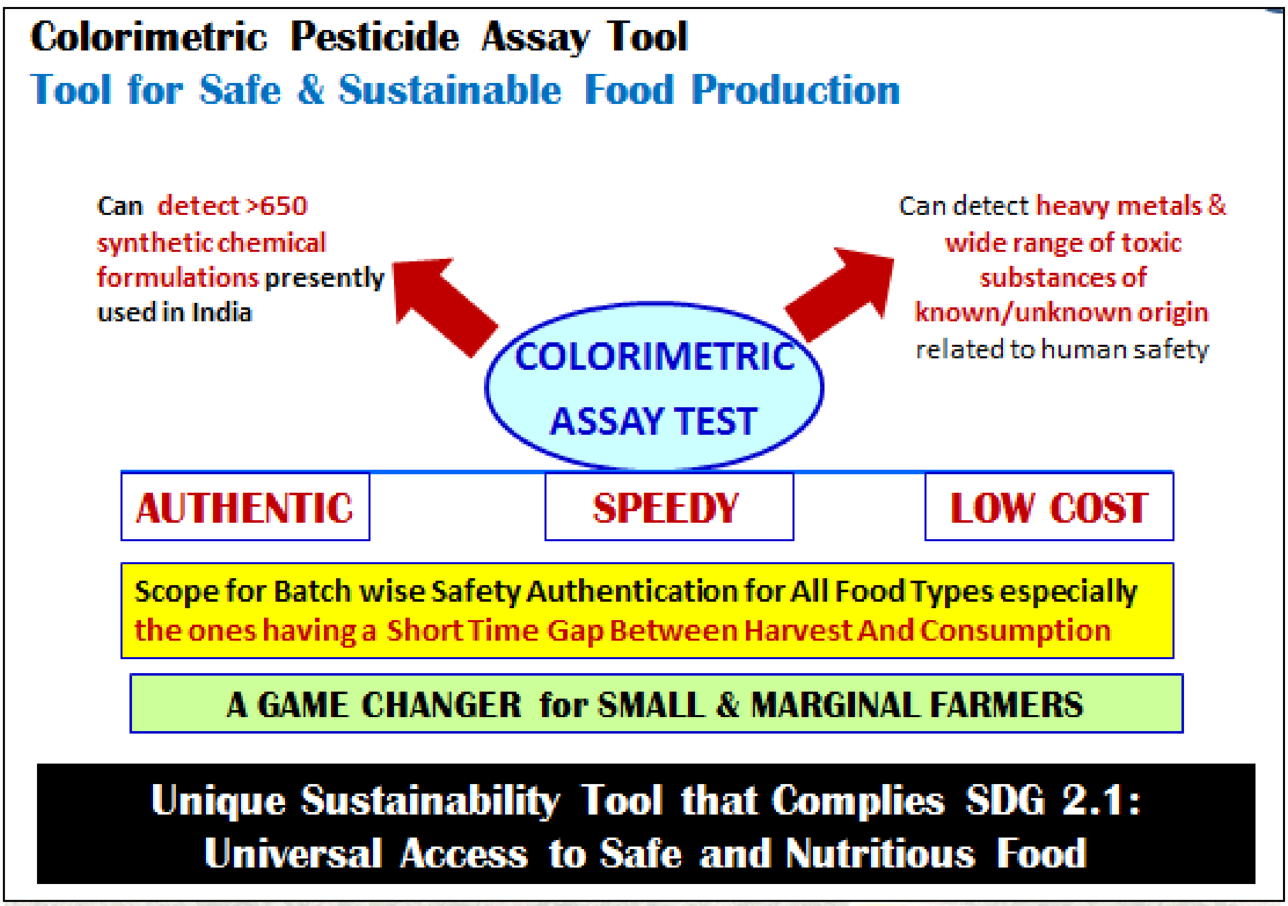
2. FOOD SAFETY ASSESSMENT TOOL - PROCESS STANDARDIZED

NECESSITY : Analysis of pesticide residues in food is the governing criteria for ensuring food safety. But the Chromatographic Techniques are hugely expensive, complex and time-taking process. So batch wise testing of Vegetables for Consumer Safety Compliance is out of question for small and marginal farmers. The Colorimetric Pesticide Assay Test can be a Game Changer in this respect and was Standardized for Vegetables under this Project by IORF in collaboration with KVK (Nadia), ICAR.

UTILITY :

- This method will Provide Qualitative & Quantitative Estimation of the Major Pesticide Groups in Vegetables.
- This method will enable the detection of heavy metals as well as other toxic substance of known/unknown origin related to human health and safety.

But Most Importantly all of these will be provided at 1/10th to 1/15th of the Cost & at 1/10th of the required Time under Chromatographic Testing Methods.



3. ENERGY FOOTPRINT STUDY TOOL - *Background Model Ready for Tool Development*

NECESSITY : The FAO has reiterated that to achieve SDG-2, Sustainable Agriculture with intervention of Modern Technologies is the ONLY PATHWAY. Sustainable Agriculture is critical for another Goal SDG-13 referring Climate Action. Higher energy usage in crop production indicates higher GHG emission. Hence, to define any process/ method as 'Sustainability Enabler', its Energy Usage has to be assessed first followed by steps to increase the Energy Productivity. An Energy Footprint Study Tool is highly relevant in both these contexts but so far there is none available simply because the Concrete Road map for Sustainable Agriculture, is absent.

UTILITY : It will be a 1st of a Kind Tool for Energy Audit of any Initiative w.r.t. Sustainable Agriculture, across agro ecosystems- which is Hugely Relevant in the Context of the SDG's.

4. AGRICULTURE CARBON FOOTPRINT ASSESSOR - *Background Model Ready for Tool Development*

NECESSITY : The highest indicator of Sustainable Agriculture is CO_2 Neutrality, for which Higher Crop Efficiency is Prerequisite. IRF Technology of IORF has enabled West Jalinga T.E. to become World's 1st & the Only Carbon Neutral T.E. Sustainable Agriculture means the Unsustainable Inputs will be Low/ No, along with Sustained/ Higher Crop. And for every kg of Extra Crop produced that much C- Sequestration or Tapping of Atmospheric- C occurs in the form of the Crop biomass that would be otherwise free in the atmosphere – indicates the Truest Form of C-Sequestration

UTILITY : This Tool will be a 1st of Kind Solution to assess the Sustainability Potential of any Agricultural Initiative – Hugely Relevant in the Context of Food Security Challenge under the existential Climate Change Impact considering that the Pathway for Sustainability Assessment is Practically Non- existent.

5. COMPOST CARBON FOOTPRINT ASSESSOR - *Background Model Ready for Tool Development*

NECESSITY : Compost is being recognized as a Tool for C- sequestration/ Sustainable Soil Management and an Expedient of Sustainable Agriculture. As per IPCC guidelines GHG emission from composting is usually derived by subtracting the emission from any biodegradable matter under an organized decomposition process, from the emission obtained from the same material left in an unorganized manner. But the estimation is not fully accurate because the emission during the entire biodegradation period is not considered; moreover there is no scientific judgment whether a Stable/ mature End Product is obtained at the end of the biodegradation period.

In the IBM- IORF Safe & Sustainable 'Clean Food' Project, IORF has taken a Step Ahead for evaluation of the C- sequestration potential under Novcom Composting Technology through Temporal Assessment of CO_2, N_2O (GHG gases) as well as NH_3, followed by Organic- C content assessment in Final Novcom Compost with Quality Analysis to authenticate its Maturity Aspects.

UTILITY : The Data Generated from this Experiment will be utilized to Develop the required Best Fit and a First of its Kind Sustainability Tool towards assessing the C- emission/ C- sequestration potential under any Biodegradation Process – Highly Relevant towards SDG 13- Climate Action

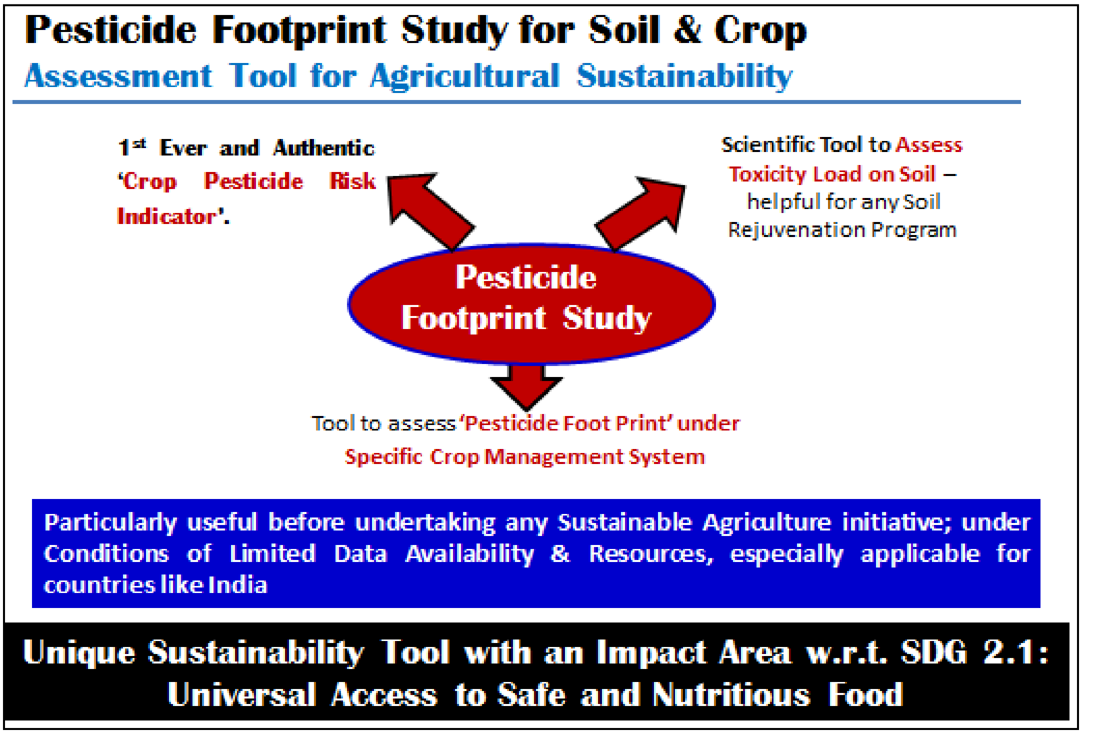
6. CROP PESTICIDE POLLUTION ASSESSMENT TOOL - ALREADY DEVELOPED

NECESSITY : The major contributions to the Food Basket of India comes from the Small & Marginal farmers. But these farmers lack the knowledge regarding Good Agricultural Practices, especially in respect of pesticides. Moreover due to very high dependence on land they resort to injudicious applications due to the continual threat of crop loss from pest/disease. This leads a higher risk of pesticide residue in crops especially in the case of short duration vegetable crops.

In this background '**Pesticide Risk Indicators**' can provide a crucial support in the assessment of the potential environmental and health risks from pesticide use- but reliable **pesticide risk indicators especially in the context of field crops are extremely scarce.**

The IBM Sustainability Stimulus provided the opportunity to IORF to Standardize its Crop Pesticide Footprint Assessment Tool (*originally developed and used in Plantation crops*) in respect of the Field Crops (Vegetables); as no such evaluation Pathway is presently available.

UTILITY : This Tool can be a 1st Ever and Authentic 'Crop Pesticide Risk Indicator' especially for use in the Widely Diversified Indian Field Crop Sector, especially to ascertain the Toxicity Load in those areas where actual residue analysis is not possible in the primary phase.



7. SOIL PESTICIDE POLLUTION ASSESSMENT TOOL - ALREADY DEVELOPED

NECESSITY : Pesticide residue in soil is one of the contributors towards food chain toxicity. For any Safe & Sustainable Agriculture Initiative; assessment of the Pesticide Load in soil is crucial to adjudge the risk of pesticide contamination of crop from soil and to undertake specific soil health management in order to mitigate residual toxicity as well as to foster the proliferation of beneficial soil micro and macroflora – towards restricting the Biotic Potential; which is immensely relevant in respect of Safe & Sustainable Crop production.

The IBM Sustainability Stimulus provided the opportunity to IORF to Develop and standardize the Soil Pesticide Footprint Assessment Tool as no such evaluation Pathway is presently available.

UTILITY : This Tool can be a 1st Ever and Authentic 'Soil Pesticide Risk Indicator' for use in Indian Agriculture, holds special relevance in respect of any Sustainable Agriculture Initiative.

8. CLEAN FOOD STANDARD (CFS) TOOL - UNDER PROCESS

NECESSITY : Standards exists for Organic Food but no such guidelines are available to authenticate Safe & Sustainable Agriculture (*Complete elimination of pesticides and No/ Low Nitrate Fertilizers*) leading to Clean Food Production.

The Clean Food Standard is being primarily designed to assure consumers about purity of 'Clean Food' in terms of pesticide residue, how food is produced on the farm by minimizing detrimental environmental impacts of farming operations, reducing dependence on chemical inputs and undertaking a responsible approach towards worker health and safety.

UTILITY : The CFS Tool will not only authenticate the safety and sustainability aspects of the cultivation practice and the end product but also guide the producer towards the objective through adoption of a Validated Sustainable Practice.

9. AGRICULTURE SYSTEM SUSTAINABILITY ASSESSOR - UNDER PROCESS

NECESSITY : Agriculture system sustainability assessor is required to evaluate overall sustainability quotient of any agricultural management system in terms of crop sustenance, environmental preservation, economic viability and adoptability potential by small and marginal farmers. So the tool will indicate usability of any agricultural practice towards safe and sustainable crop production in varied agro-ecologies as well as socio-economic settings.

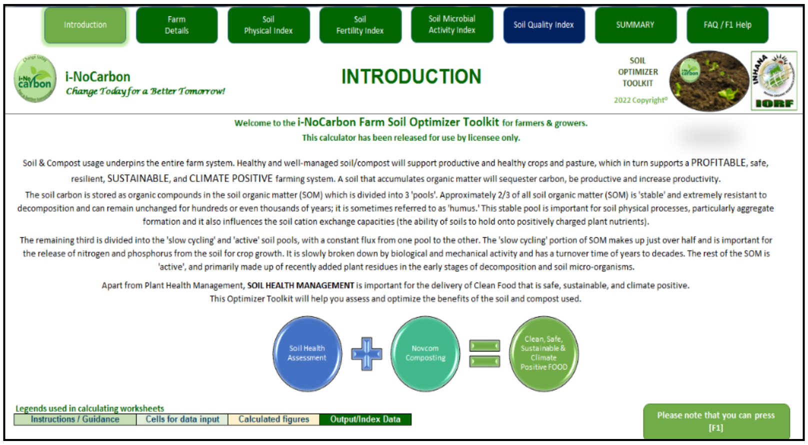
UTILITY : The AGRICULTURE SYSTEM SUSTAINABILITY ASSESSOR will not only measure the impact of any agriculture management system, but also assess its Strength and Weakness. This will help in making further developments or alterations necessary to ensure a systems' compliance towards Safe and Sustainable Agriculture.

Collaboration between IORF & i-NoCarbon

i-NoCarbon is a UK based Organization founded to help out companies to successfully transition to a low carbon and sustainable future. The services of i-NoCarbon are designed to make assessment of carbon footprint easier and provide necessary knowledge and highest certified information that can help companies to make right decisions to ensure Carbon Free presence and future sustainability.

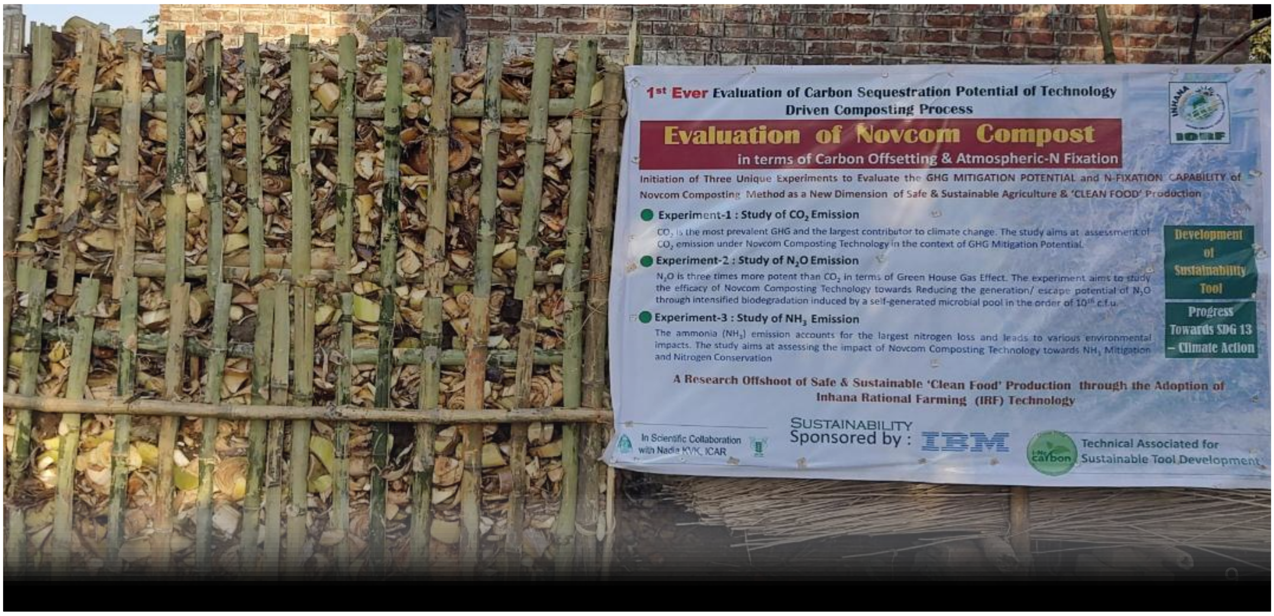
i-NoCarbon has collaborated with IORF for development of Sustainability Tools - a pioneering initiative for any safe and sustainable agricultural intervention. We are utilizing the huge data pool that has been generated under the 'Clean Food' Project, to develop scientifically validated technical tools to measure:

- **GHG emissions and Carbon Sequestration under Technology induced Compost Production.**
- **GHG emission under 'Clean Food' Production or any Safe & Sustainable Agri-Initiative.**
- **Energy Usage** under 'Clean Food' production or any Safe & Sustainable Agricultural Initiative .



Development of the **Soil Quality Index Calculator** has successfully reached the concluding phase. This Calculator will be **first of a kind** that will enable assessment of the **impact of any agricultural initiative on Soil Health vis-à-vis Agricultural Sustainability**; with the click of a mouse. **The development process for GHG Calculator & Energy Calculator are on-going.**

IORF collaboration with i-NoCarbon under the IBM-IORF 'Clean Food' Project was propelled by the desire to provide a wide spectrum of scientific intervention in agriculture (be it in terms of technology, analyses, study or even practical delivery), **which is nowhere to be found across the entire planet!**



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Annexure - 1

Farm Level Resource Map : Soil pH

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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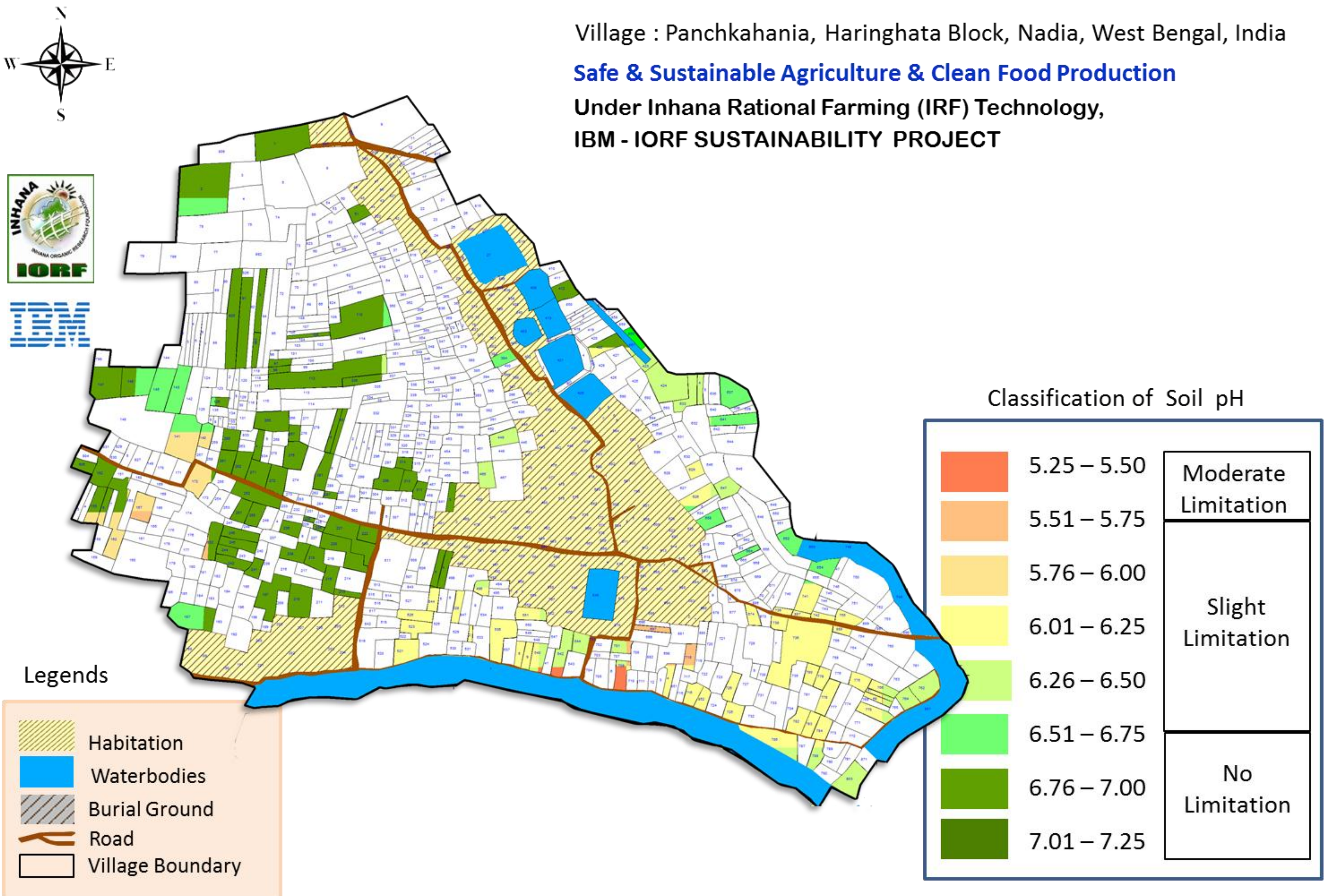

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Annexure - 2

Farm Level Resource Map : Soil Org. C (%)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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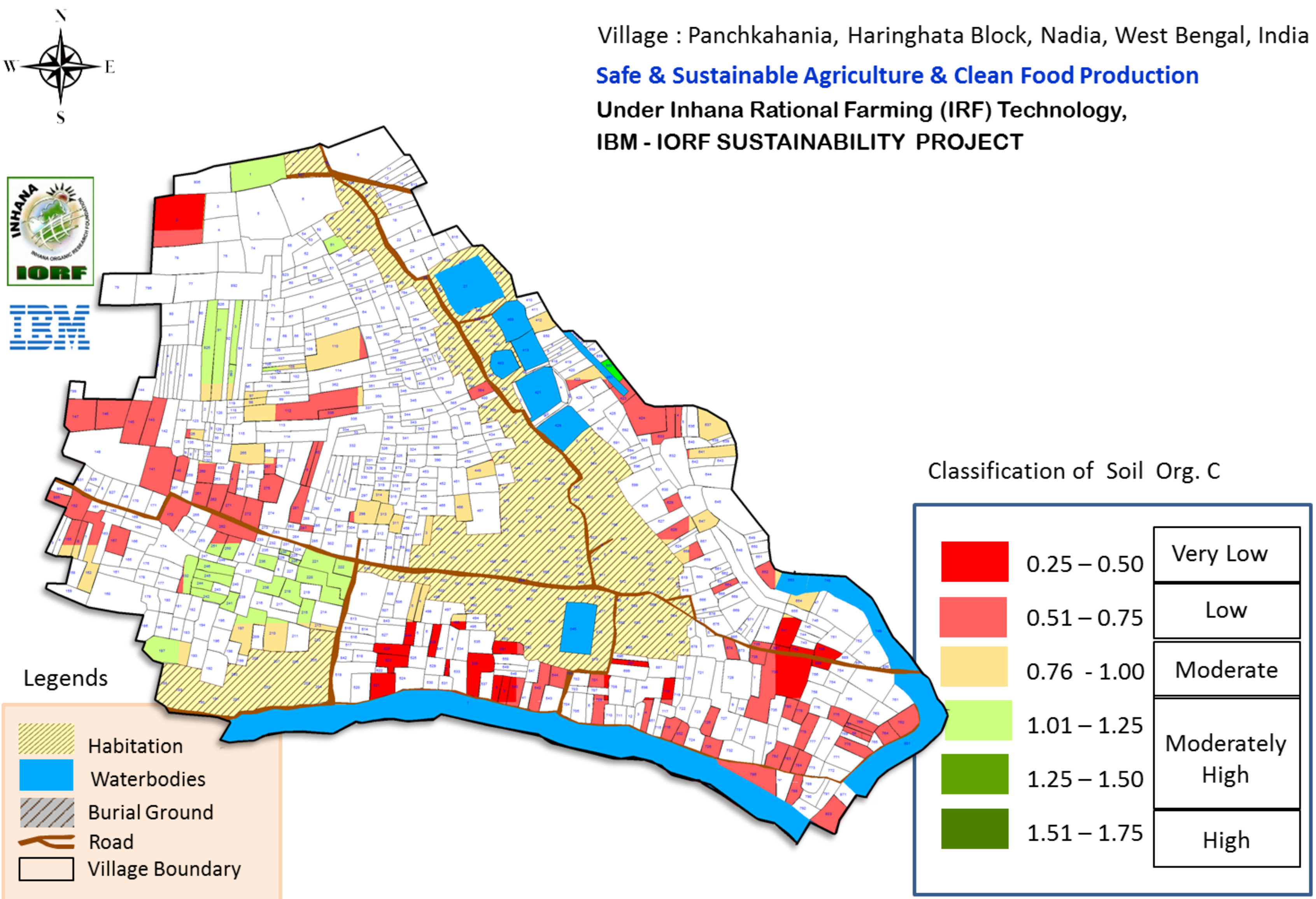

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Annexure - 3

Farm Level Resource Map : Soil Available Nitrogen (Kgha^{-1})

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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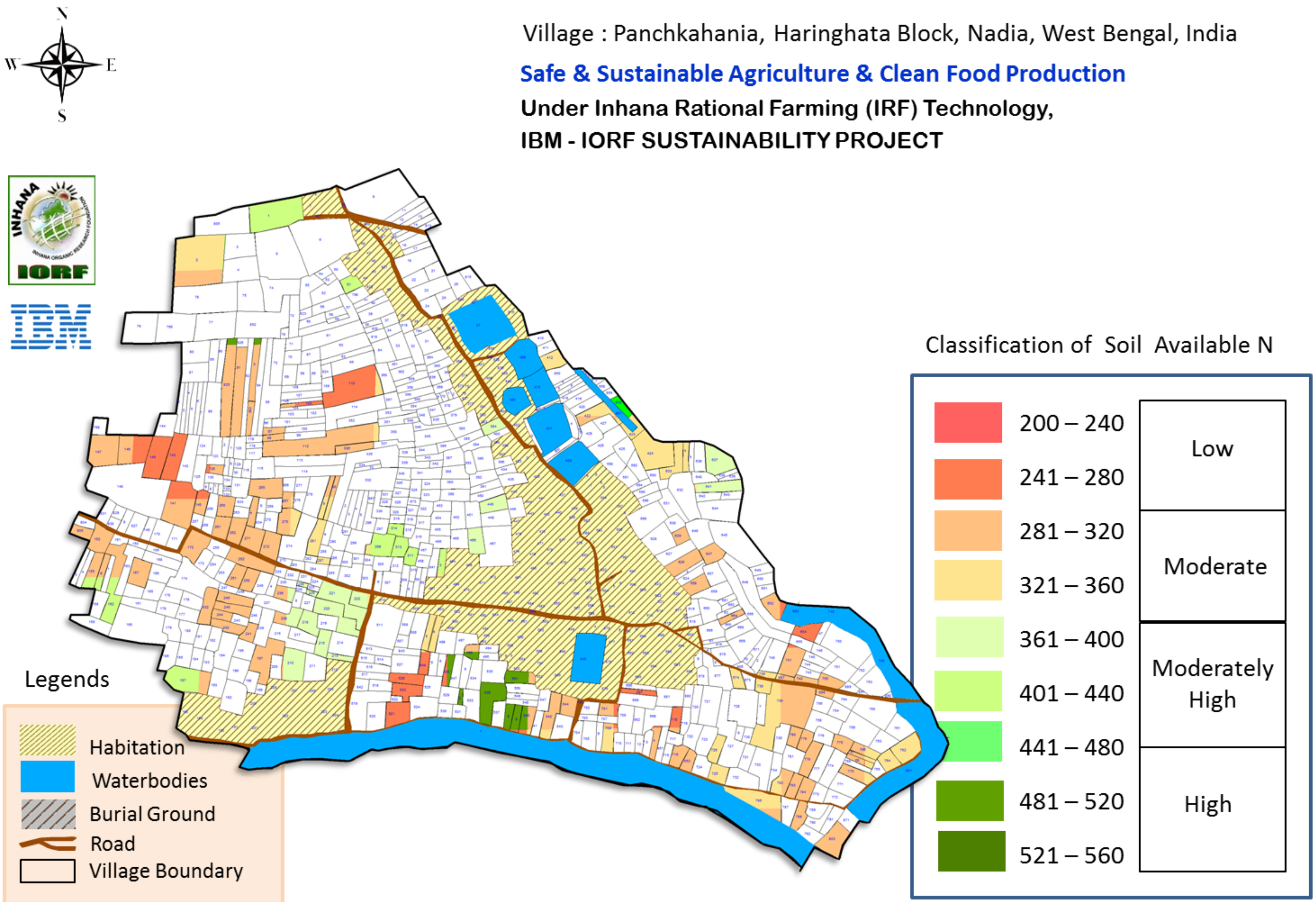

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Annexure - 4

Farm Level Resource Map : Soil Available Nitrate (mgKg^{-1})

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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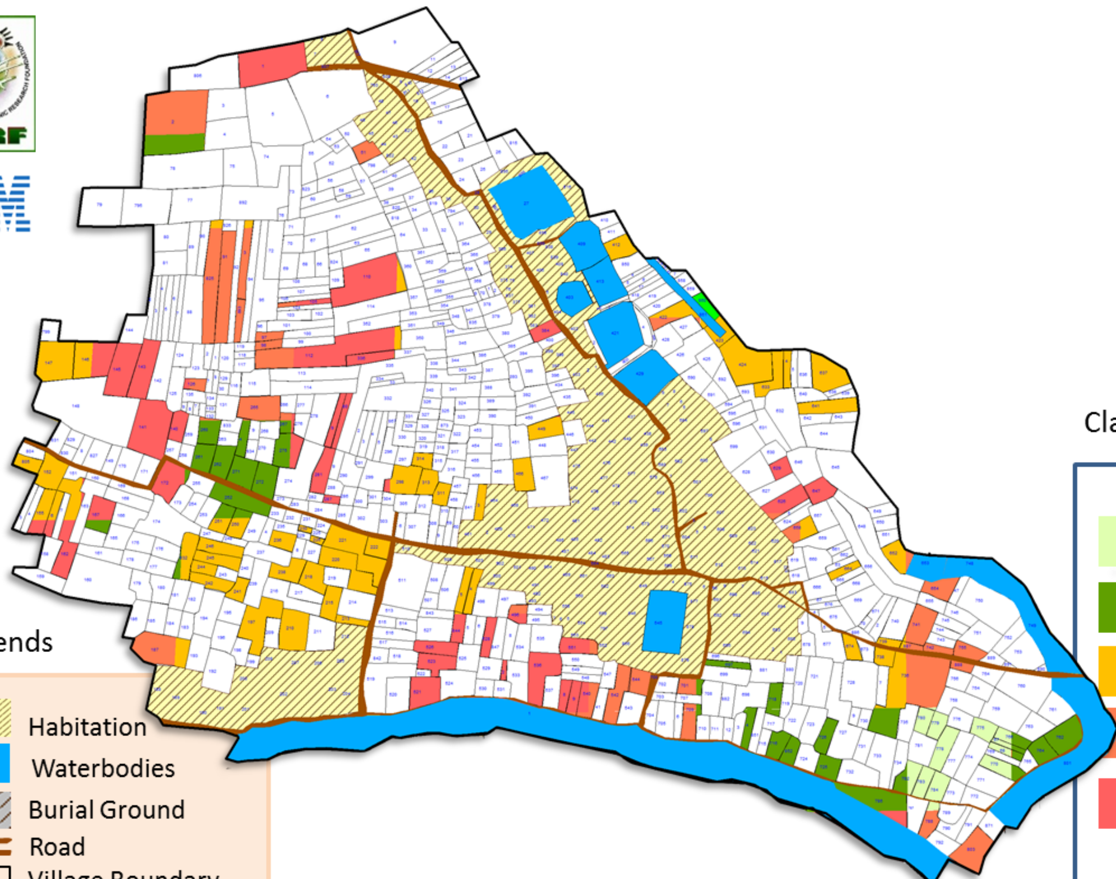

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Available NO_3

20 – 30	Moderately Good
31 – 40	Good
41 – 60	Cautious
61 -80	Very Cautious
>80	Extremely Cautious

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Annexure - 5

Farm Level Resource Map : Soil Available Phosphate ($Kgha^{-1}$)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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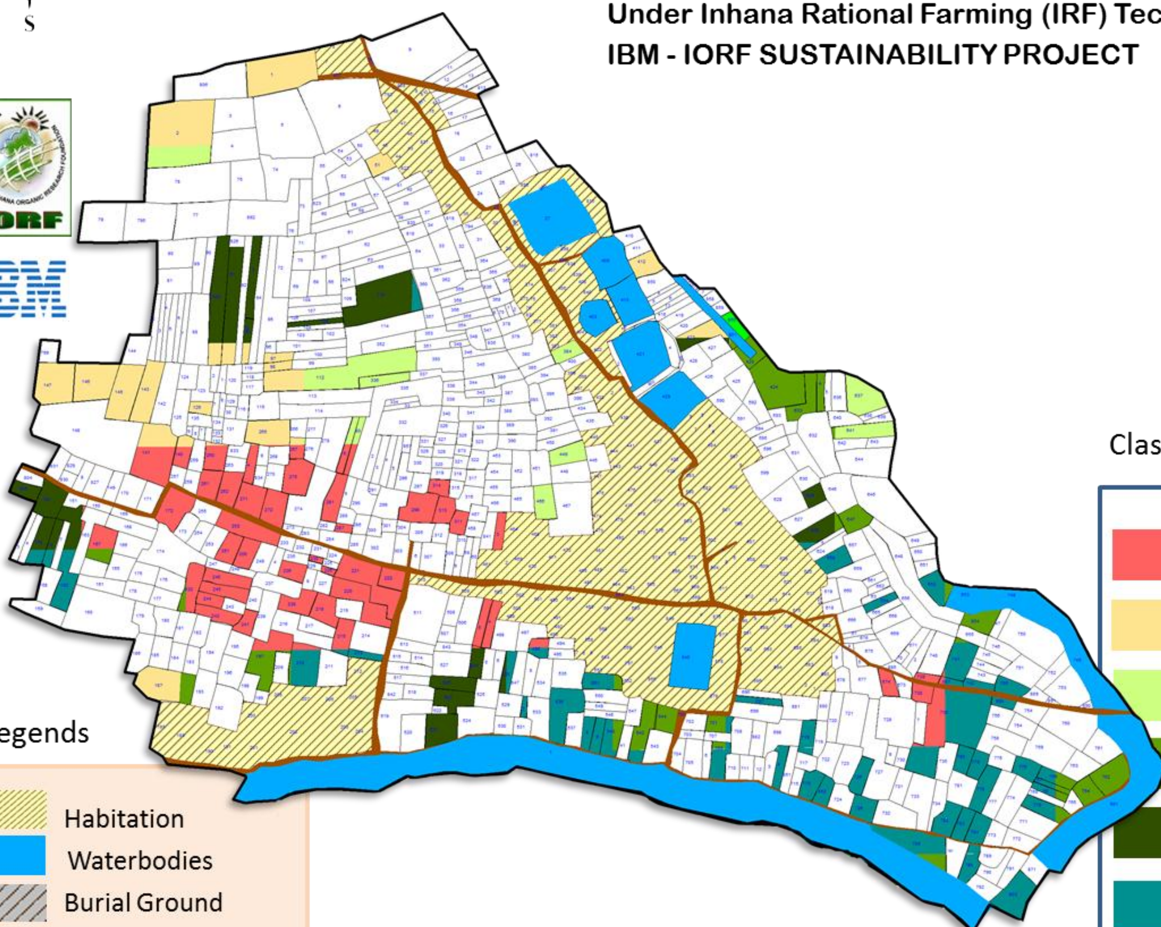

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Available P_2O_5

22.5 - 45	Low
46 - 70	Moderate
71 - 90	Moderately High
90 - 120	High
120 - 150	High
> 150	High

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Annexure - 6

Farm Level Resource Map : Soil Available Potash ($Kgha^{-1}$)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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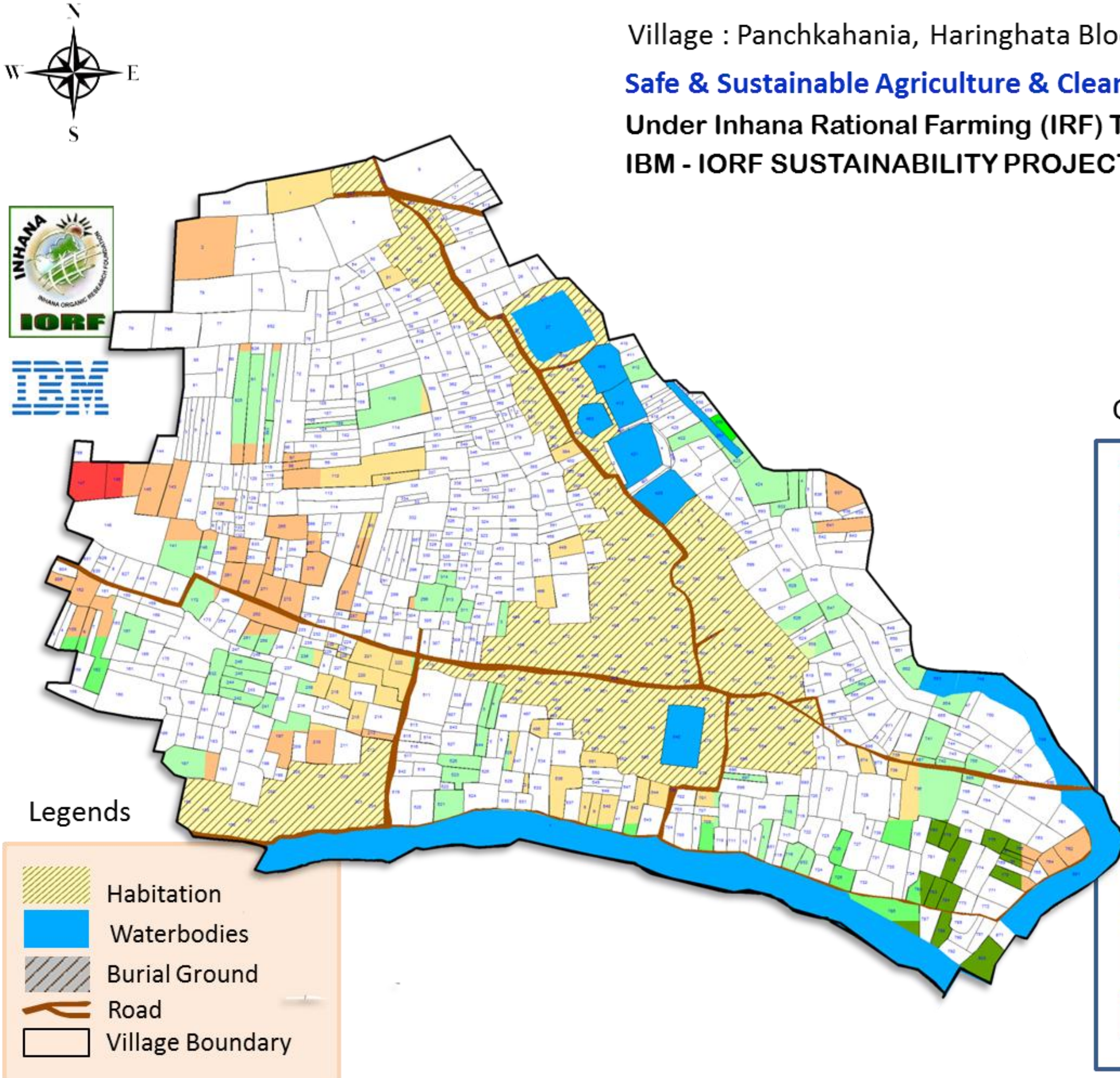

Classification of Soil Available K_2O

< 200	Low
200 - 250	Low
251 – 300	Moderate
301 – 350	Moderate
351 – 400	Moderately High
401 -450	Moderately High
451 – 500	High
501 – 550	High
> 550	High

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Annexure - 7

Farm Level Resource Map : Soil Available Sulphate (Kgha^{-1})

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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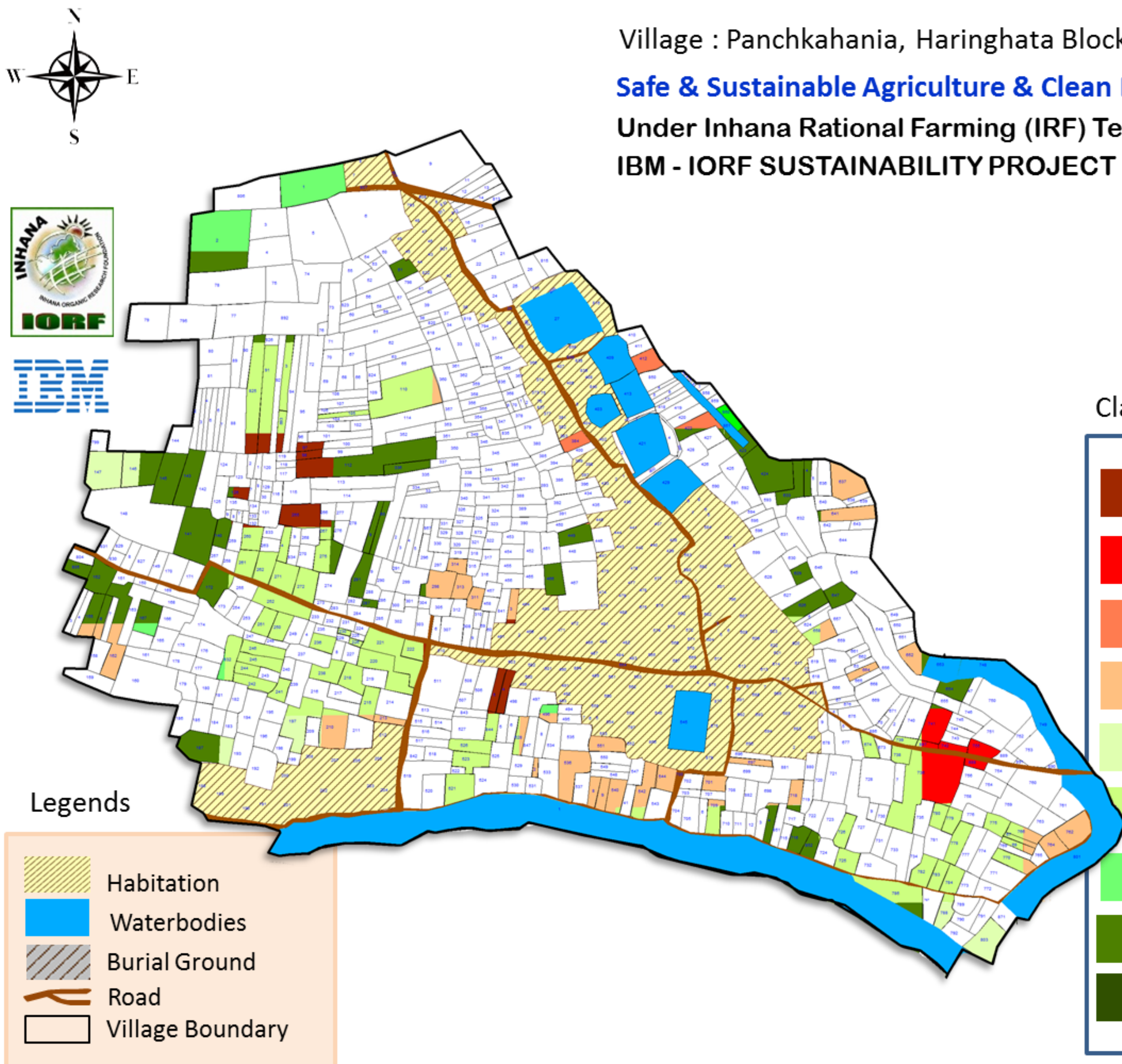

Classification of Soil Available SO_4

< 20	Very Low
20 – 40	Low
41 – 60	Low
61 – 80	Moderate
81 – 100	Moderate
101 – 120	Moderately High
121 – 140	Moderately High
141 – 160	High
> 160	High

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Annexure - 8

Farm Level Resource Map : Soil Microbial Biomass Carbon (MBC)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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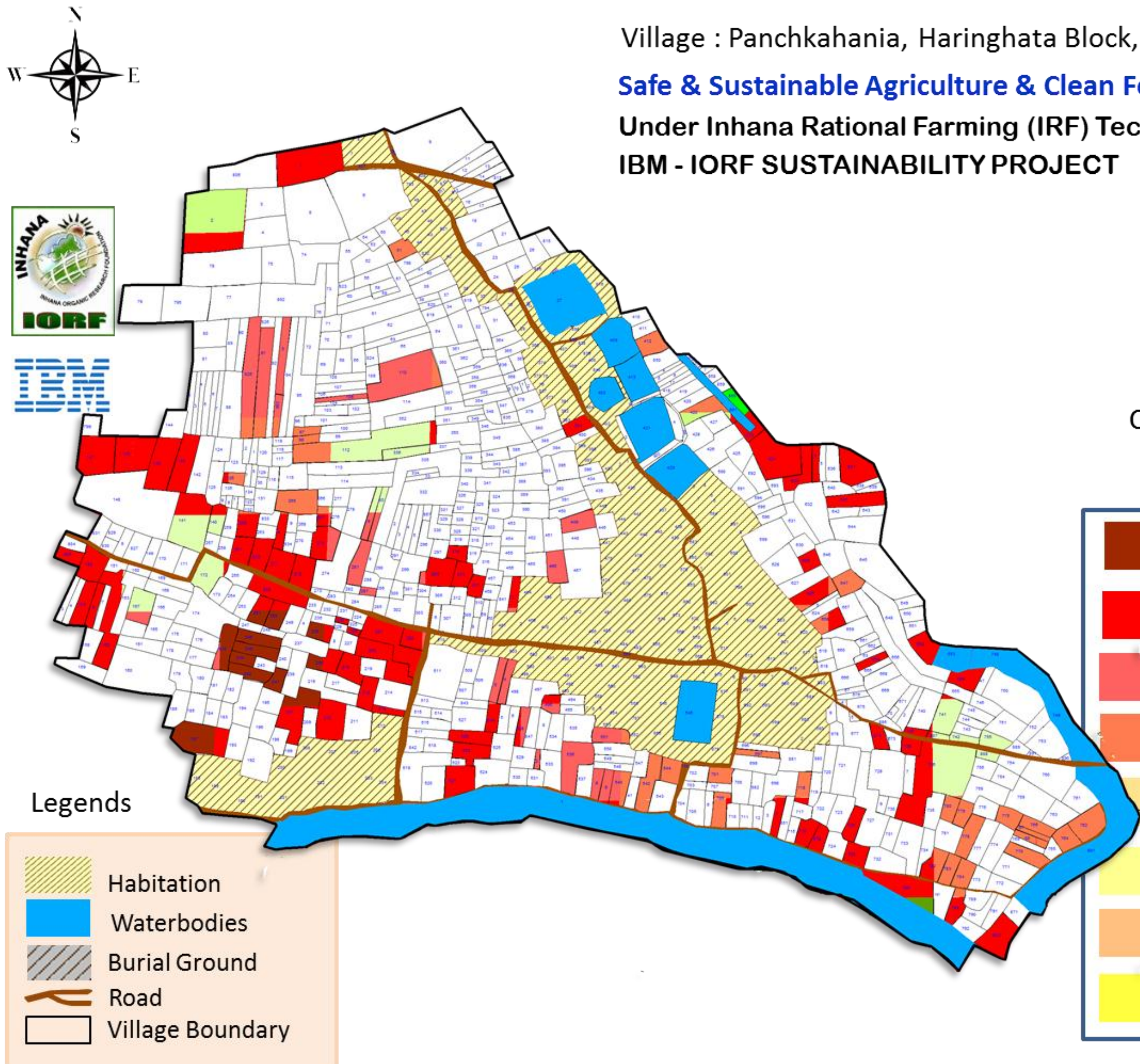

Classification of Soil Microbial Biomass Carbon (MBC)

MBC	Class
< 50	Extremely Low
50 – 100	Very Low
101 – 150	Very Low
151 – 200	Low
201 – 250	Low
251 – 300	Low
301 – 350	Moderate
351 - 400	Moderate

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Annexure - 9

Farm Level Resource Map : Fluorescein Diacetate Hydrolysis (FDAH)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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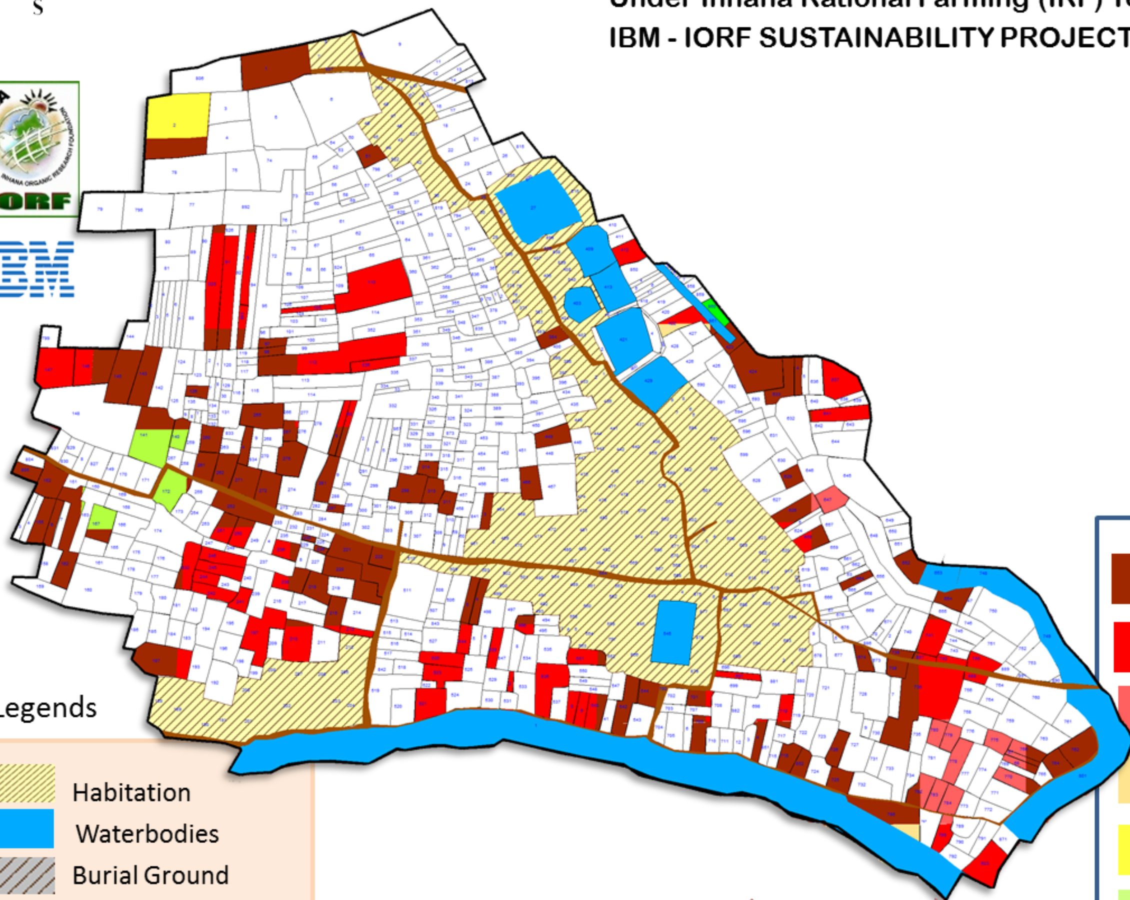

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Fluorescein Diacetate Hydrolysis (FDAH)

< 30	Extremely Low
30 – 60	Very Low
61 – 90	Low
91 – 120	Low
121 – 150	Moderate
151 - 180	Moderate

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Farm Level Resource Map : Soil Microbial Quotient(qMBC)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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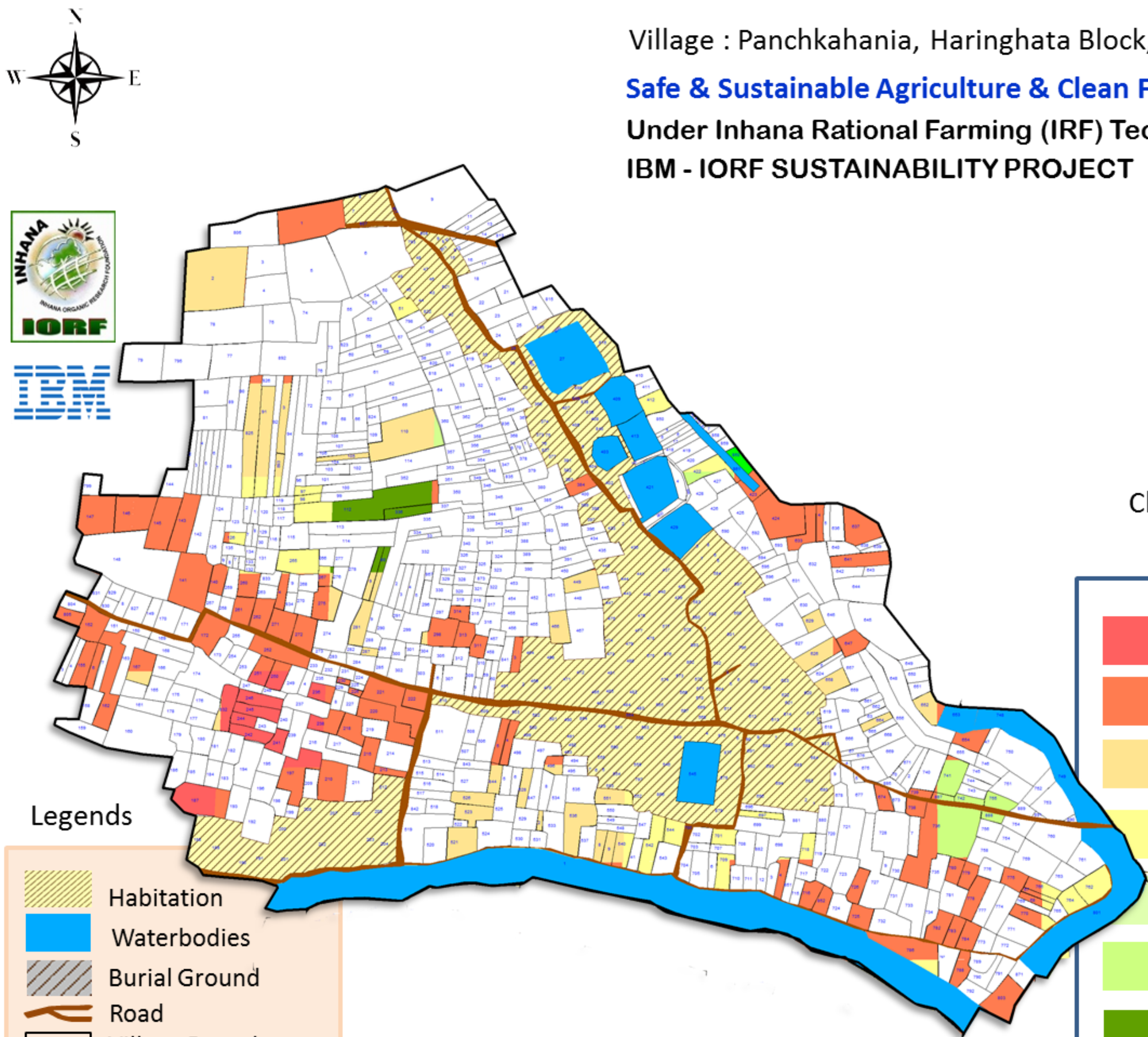

Classification of Soil Microbial Quotient (qMBC)

< 1.00	Very Low
1.01 – 2.00	Low
2.01 – 3.00	Moderate
3.01 – 4.00	Moderately High
4.01 – 5.00	High
5.01 – 6.00	High
> 6.00	High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Annexure - 11

Farm Level Resource Map : Soil Microbial Metabolic Quotient(qCO_2)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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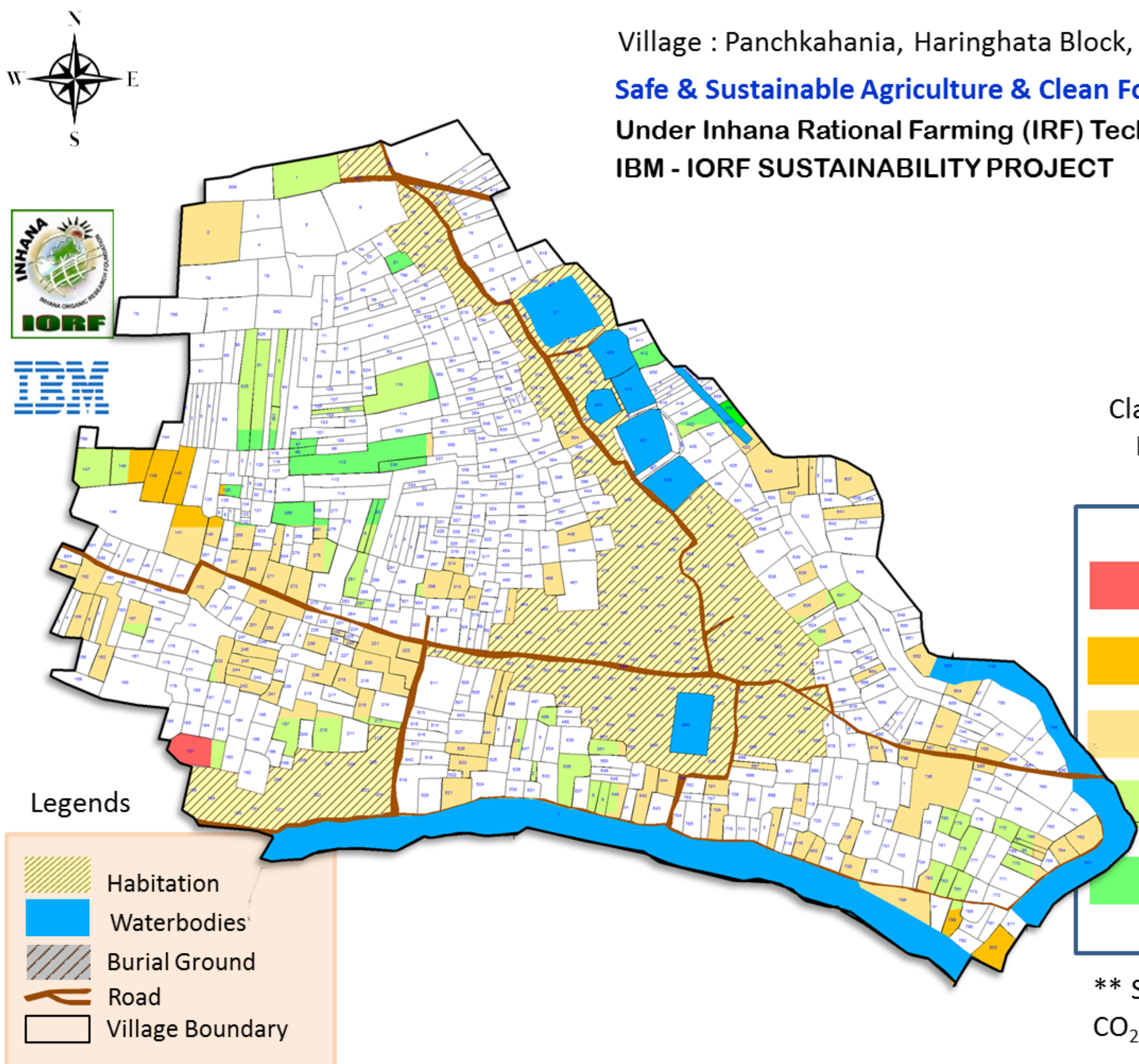

Classification of Soil Microbial Metabolic Quotient (qCO_2)

(red)	5.1 – 10.0	Stressed Condition
(orange)	2.6 – 5.0	Moderately Stressed
(light orange)	1.0 – 2.5	Slightly Stressed
(light green)	< 1.00	Very Low Population
(green)	< 1.00**	Stable Condition

** Soil Microbial Biomass >300 µg CO_2 –C / g dry soil)

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Annexure - 12

Farm Level Resource Map : Soil Fertility Index (FI)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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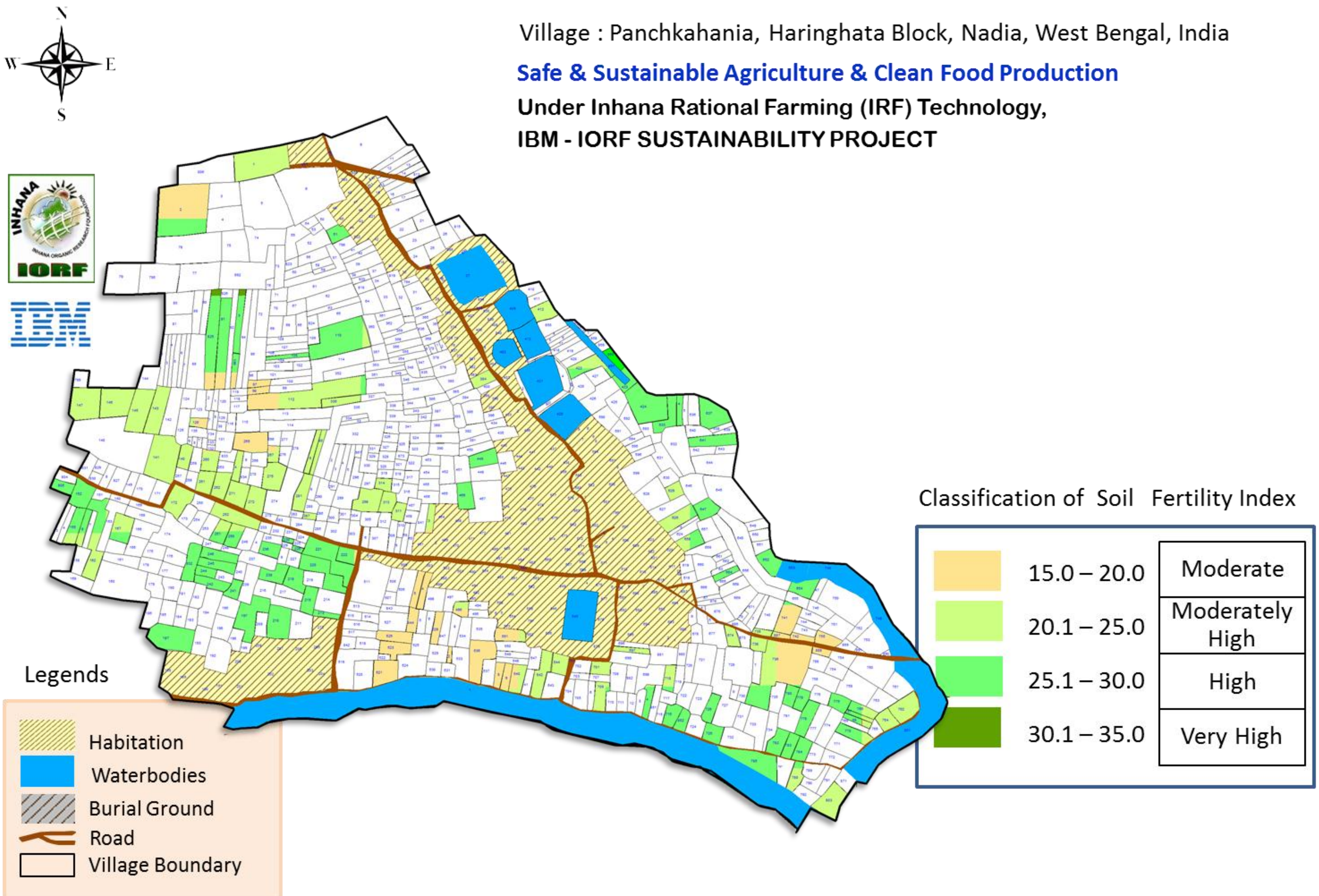

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Annexure - 13

Farm Level Resource Map : Soil Microbial Activity Potential (MAP)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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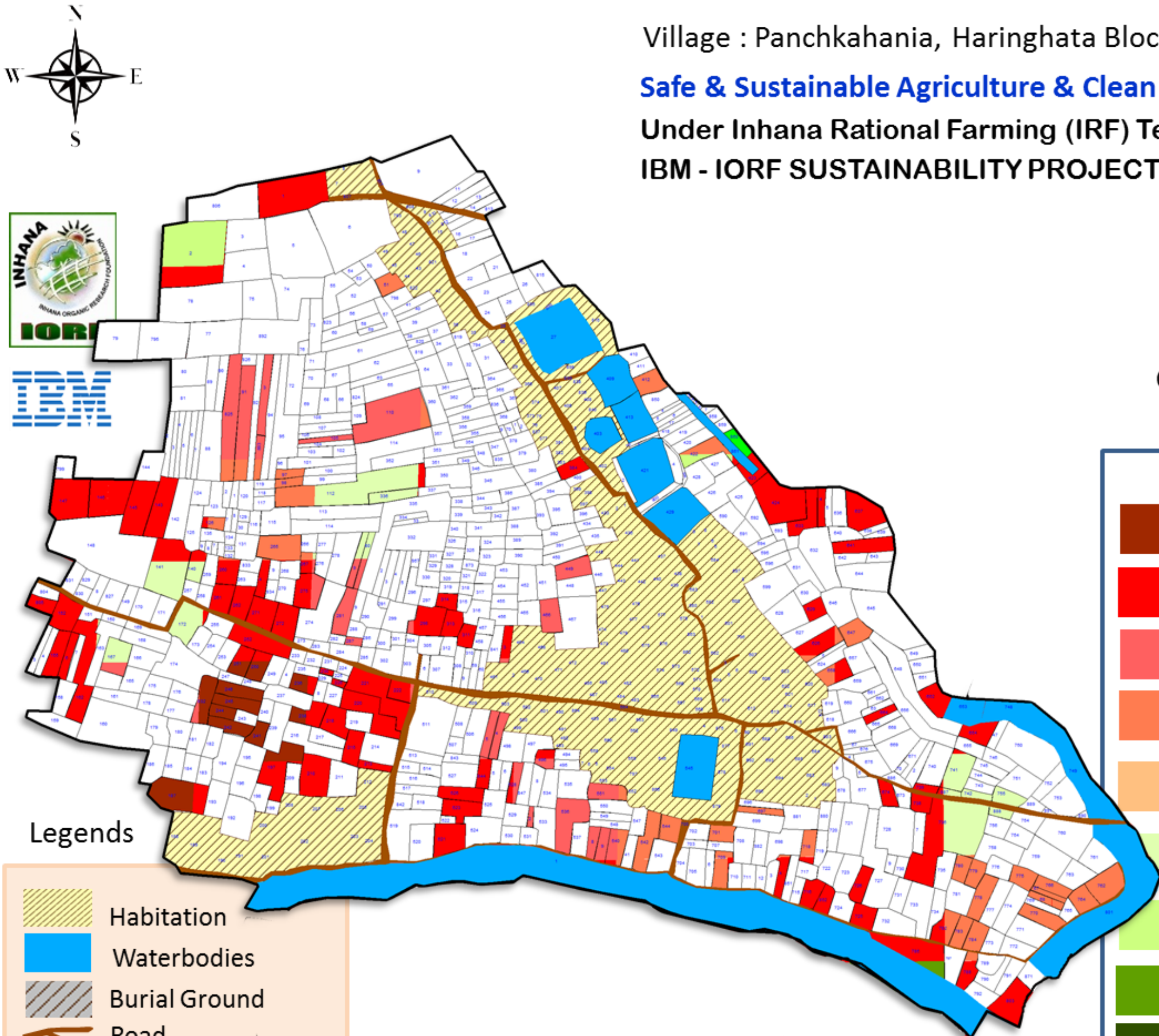

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Microbial Activity Potential (MAP)

MAP	Class
> 4.0	Extremely Low
4.0 – 6.0	Very Low
6.1 – 8.0	Very Low
8.1 – 10.0	Low
10.1 – 12.0	Moderate
12.1 – 14.0	Moderately High
14.1 – 16.0	Moderately High
16.1 – 18.0	High
18.1 – 20.0	High

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Annexure - 14

Farm Level Resource Map : Soil Physical Index (PI)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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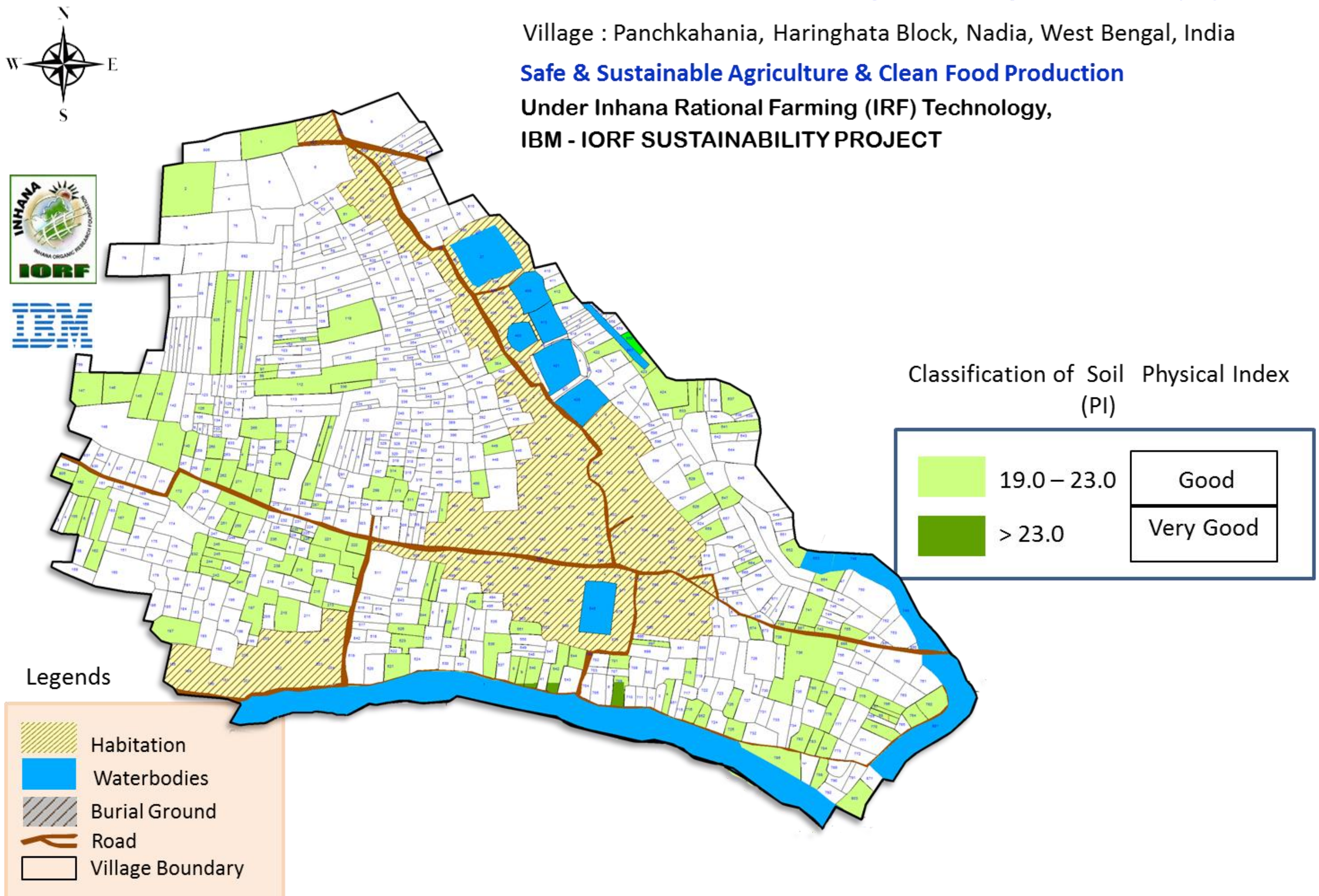

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Annexure - 15

Farm Level Resource Map : Soil Quality Index (SQI)

Village : Panchkahania, Haringhata Block, Nadia, West Bengal, India

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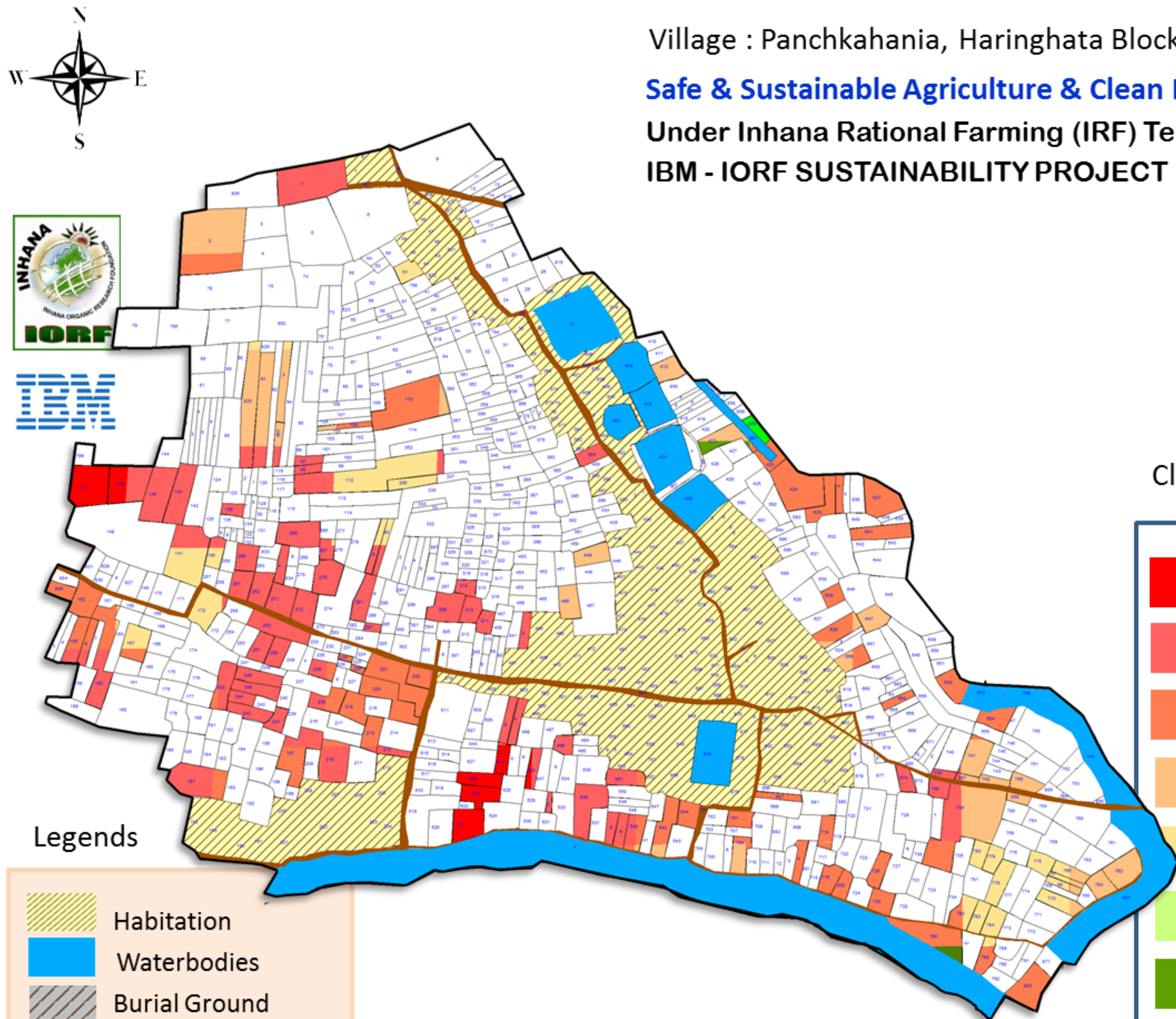


Classification of Soil Quality Index

SQI	Class
0.35 – 0.40	Poor
0.41 – 0.45	Poor
0.46 – 0.50	Moderate
0.51 – 0.55	Moderate
0.56 – 0.60	Moderate
0.61 – 0.65	Moderately High
0.66 – 0.70	Moderately High
0.71 – 0.75	Moderately High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

In Scientific Collaboration with Nadia KVK, ICAR

Annexure - 16

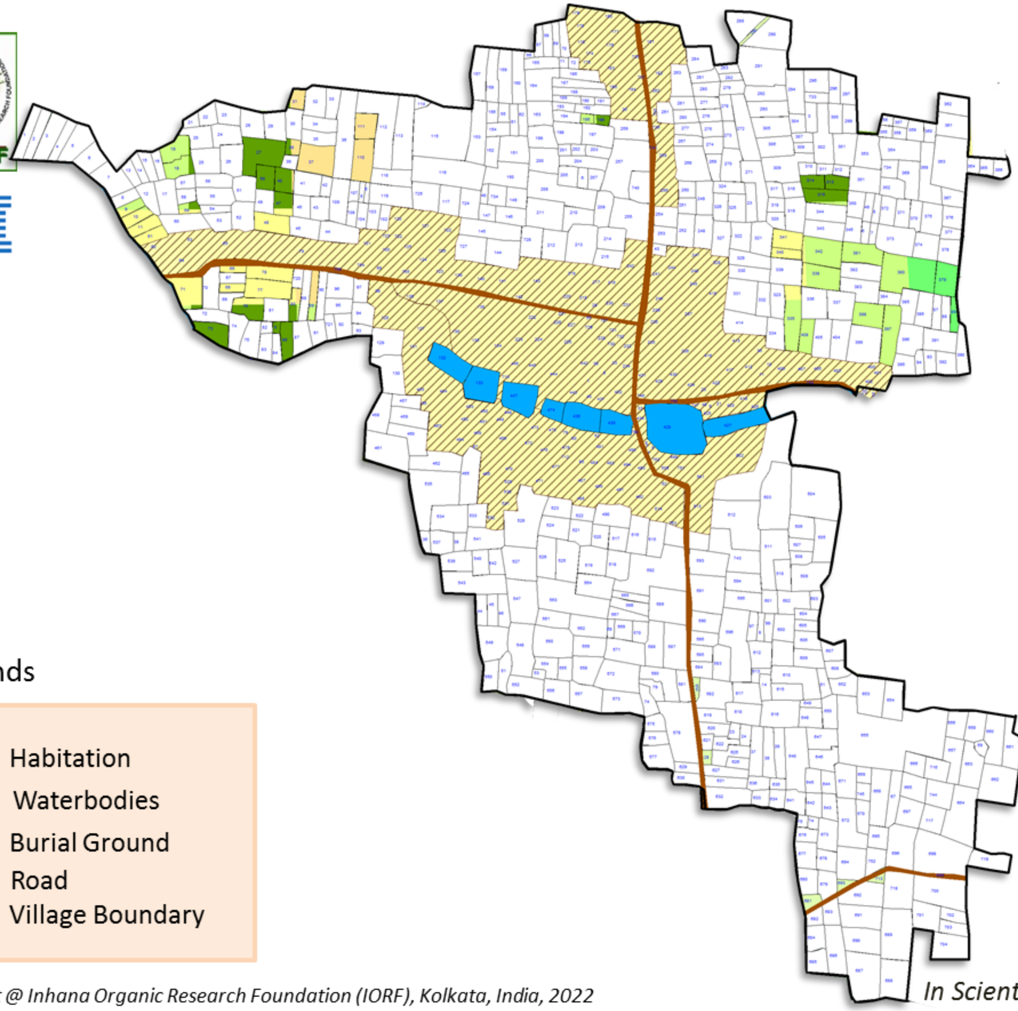
Farm Level Resource Map : Soil pH

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

Safe & Sustainable Agriculture & Clean Food Production

Under Inhana Rational Farming (IRF) Technology,

IBM - IORF SUSTAINABILITY PROJECT



Classification of Soil pH

5.25 – 5.50	Moderate Limitation
5.51 – 5.75	Moderate Limitation
5.76 – 6.00	Slight Limitation
6.01 – 6.25	Slight Limitation
6.26 – 6.50	Slight Limitation
6.51 – 6.75	Slight Limitation
6.76 – 7.00	No Limitation
7.01 – 7.25	No Limitation

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

In Scientific Collaboration with Nadia KVK, ICAR

Annexure -17

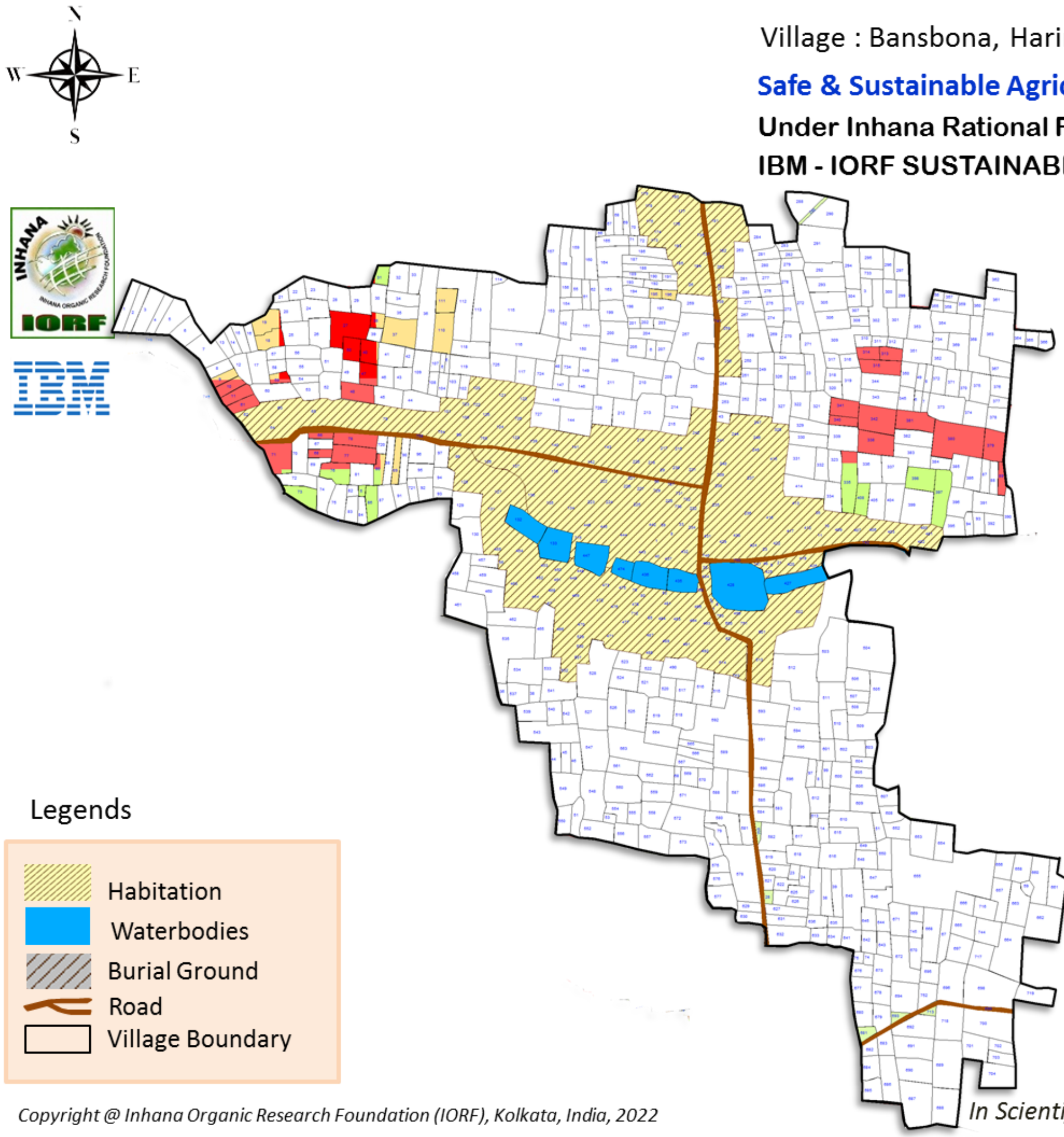
Farm Level Resource Map : Soil Org. C (%)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

Safe & Sustainable Agriculture & Clean Food Production

Under Inhana Rational Farming (IRF) Technology,

IBM - IORF SUSTAINABILITY PROJECT



Classification of Soil Org. C

0.25 – 0.50	Very Low
0.51 – 0.75	Low
0.76 - 1.00	Moderate
1.01 – 1.25	Moderately High
1.25 – 1.50	Moderately High
1.51 – 1.75	High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

In Scientific Collaboration with Nadia KVK, ICAR

Annexure - 18

Farm Level Resource Map : Soil Available Nitrogen ($Kgha^{-1}$)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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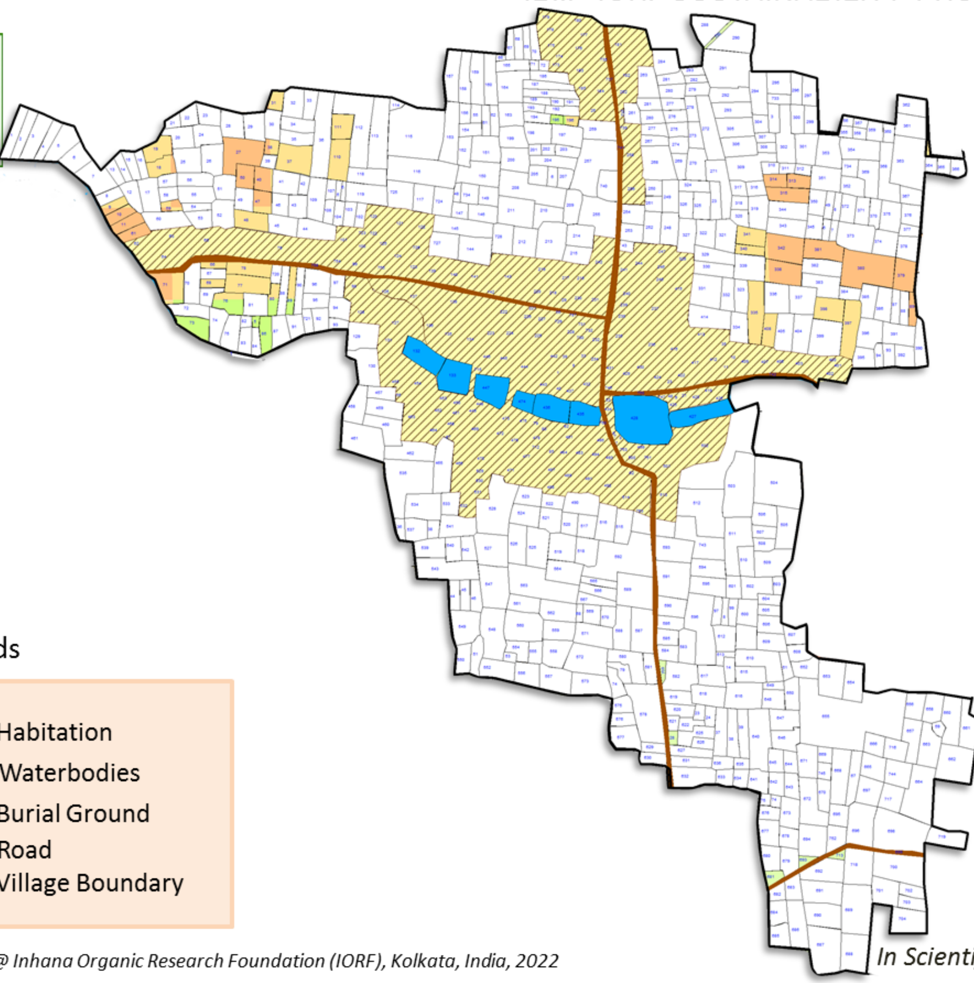

Classification of Soil Available N

200 – 240	Low
241 – 280	
281 – 320	Moderate
321 – 360	
361 – 400	Moderately High
401 – 440	
441 – 480	
481 – 520	High
521 – 560	

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Annexure - 19

Farm Level Resource Map : Soil Available Nitrate ($mgKg^{-1}$)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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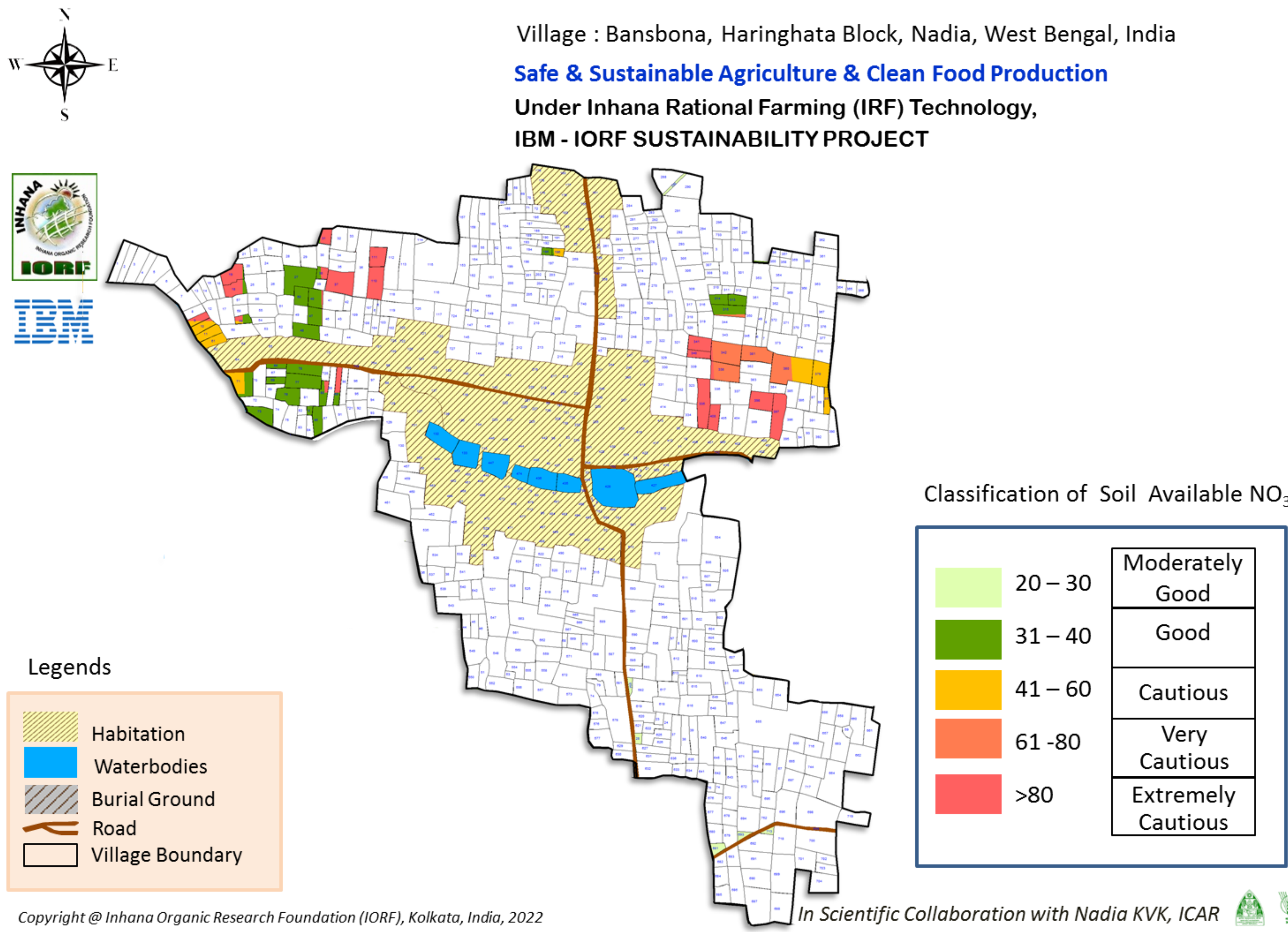

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Annexure - 20

Farm Level Resource Map : Soil Available Phosphate ($Kg ha^{-1}$)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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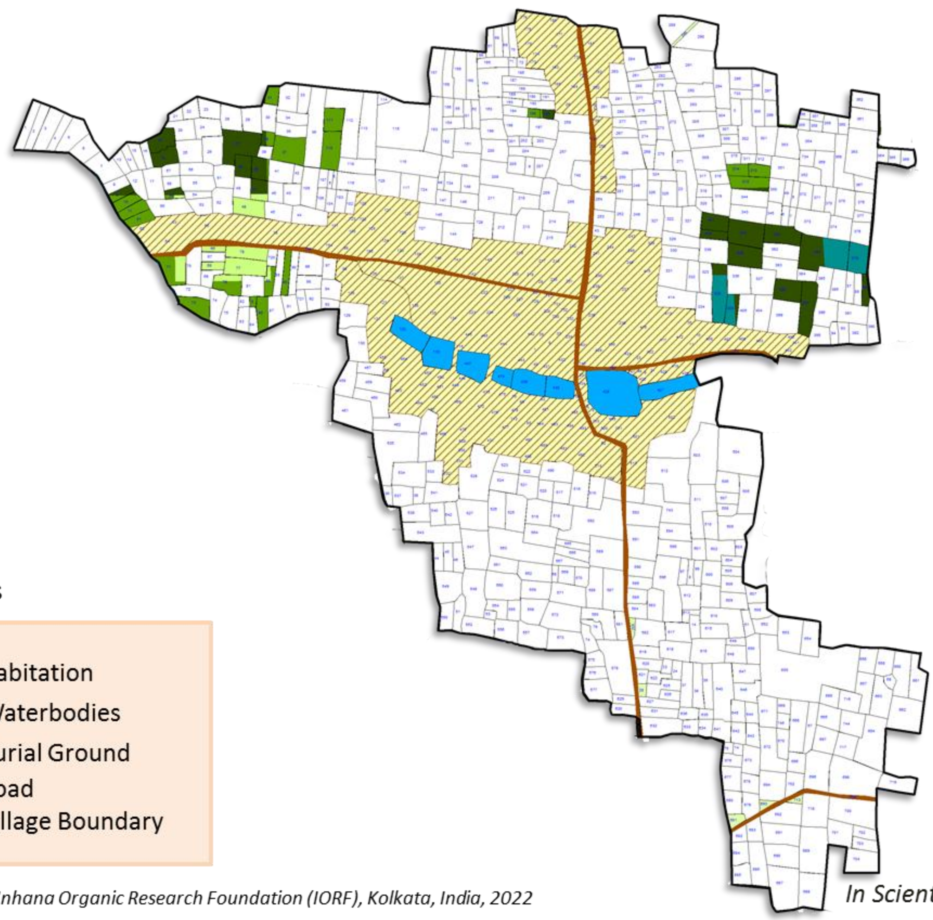

Legends

Classification of Soil Available P_2O_5

22.5 - 45	Low
46 - 70	Moderate
71 - 90	Moderately High
90 - 120	High
120 - 150	High
> 150	High

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Annexure : 21

Farm Level Resource Map : Soil Available Potash ($Kgha^{-1}$)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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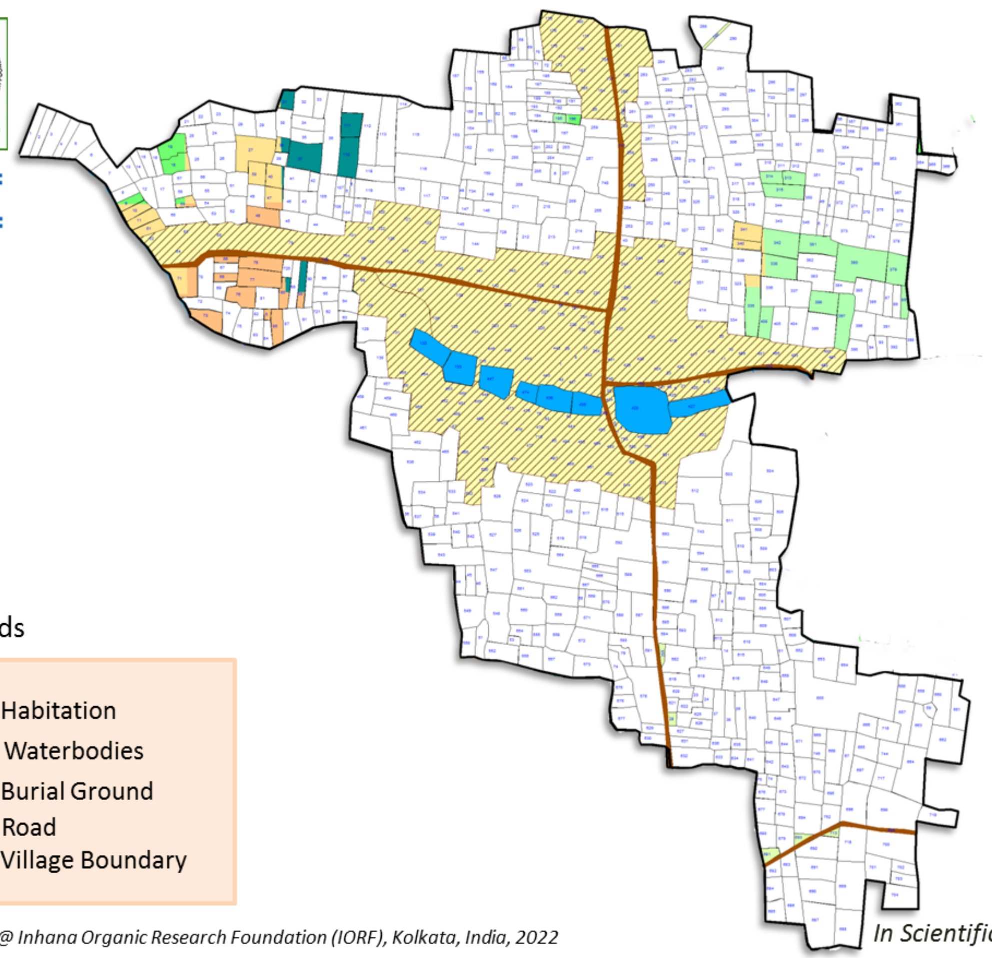

Classification of Soil Available K_2O

< 200	Low
200 - 250	Low
251 – 300	Moderate
301 – 350	Moderate
351 – 400	Moderately High
401 -450	Moderately High
451 – 500	High
501 – 550	High
> 550	High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Annexure - 22

Farm Level Resource Map : Soil Available Sulphate (Kgha^{-1})

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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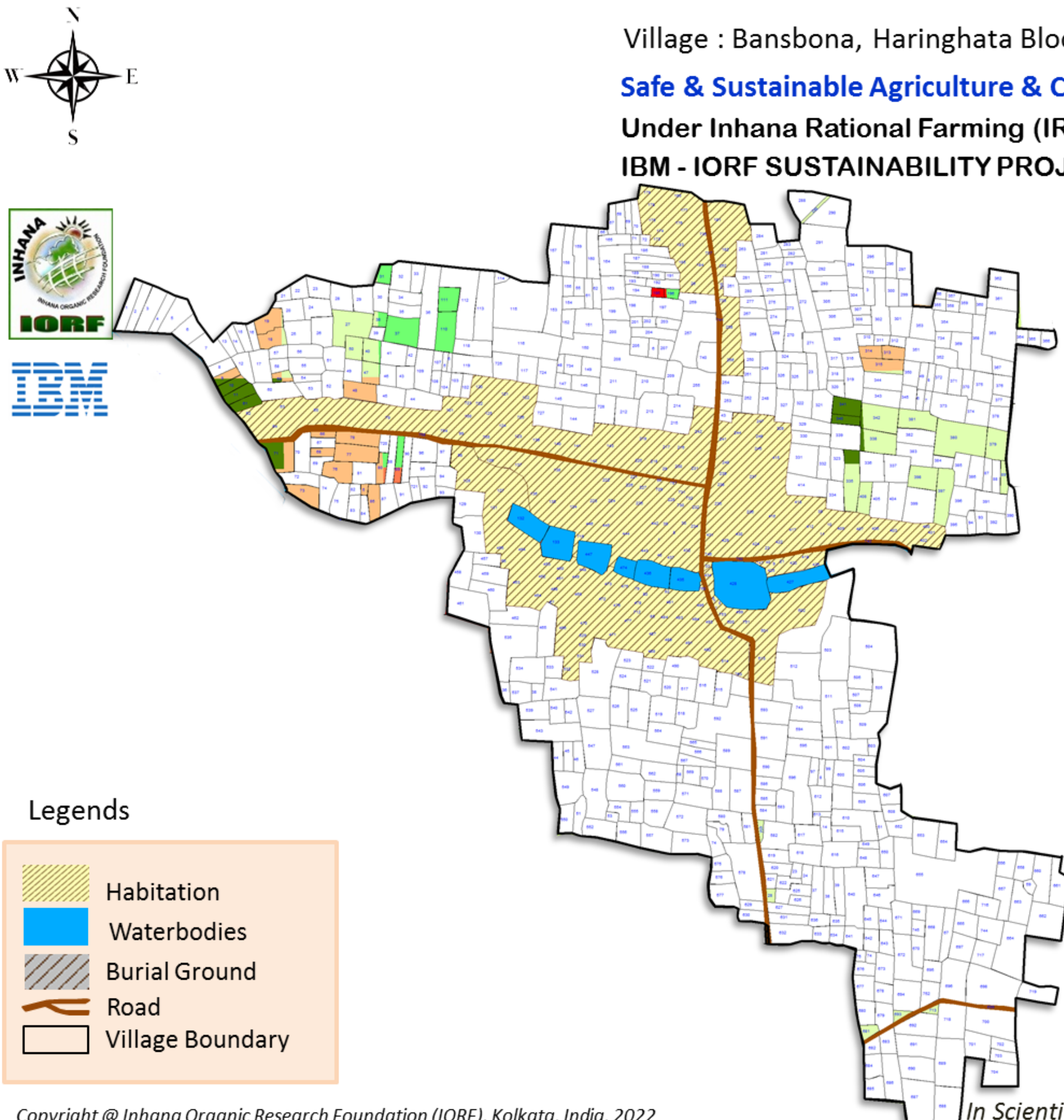

Classification of Soil Available SO_4

< 20	Very Low
20 – 40	Low
41 – 60	Low
61 – 80	Moderate
81 – 100	Moderate
101 – 120	Moderately High
121 – 140	Moderately High
141 – 160	High
> 160	High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Annexure - 23

Farm Level Resource Map : Soil Microbial Biomass Carbon (MBC)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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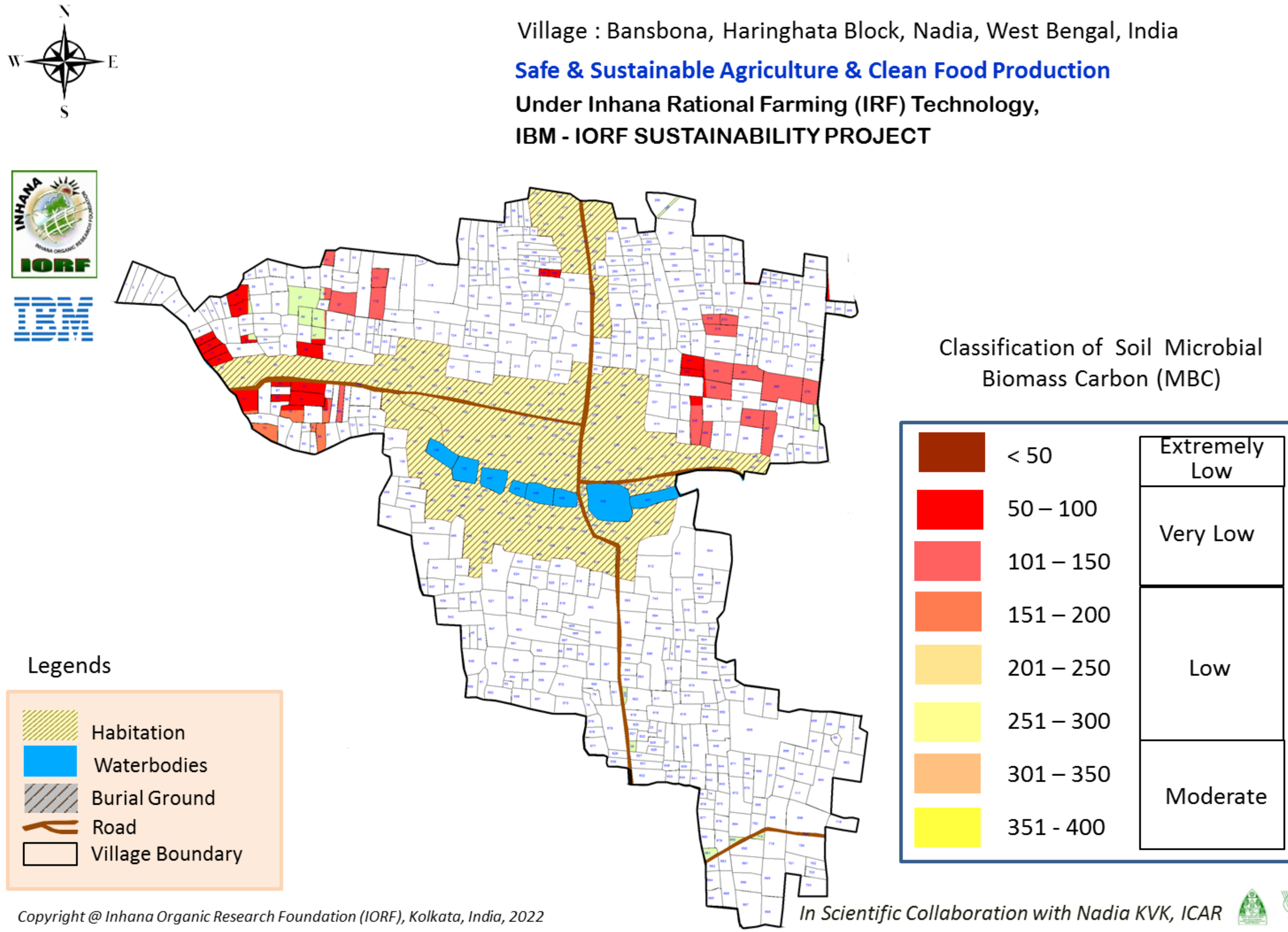

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Annexure - 24

Farm Level Resource Map : Fluorescein Diacetate Hydrolysis (FDAH)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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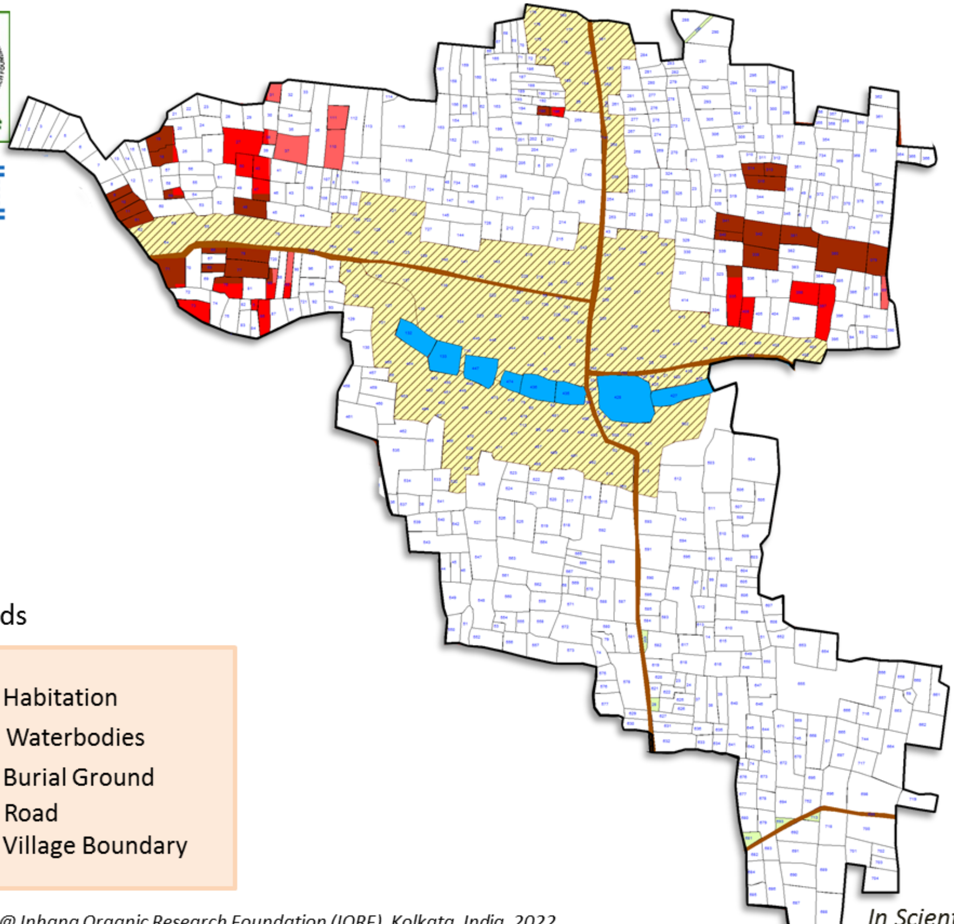

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Fluorescein Diacetate Hydrolysis (FDAH)

	< 30	Extremely Low
	30 – 60	Very Low
	61 – 90	Low
	91 – 120	
	121 – 150	Moderate
	151 - 180	

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Annexure - 25

Farm Level Resource Map : Soil Microbial Quotient(qMBC)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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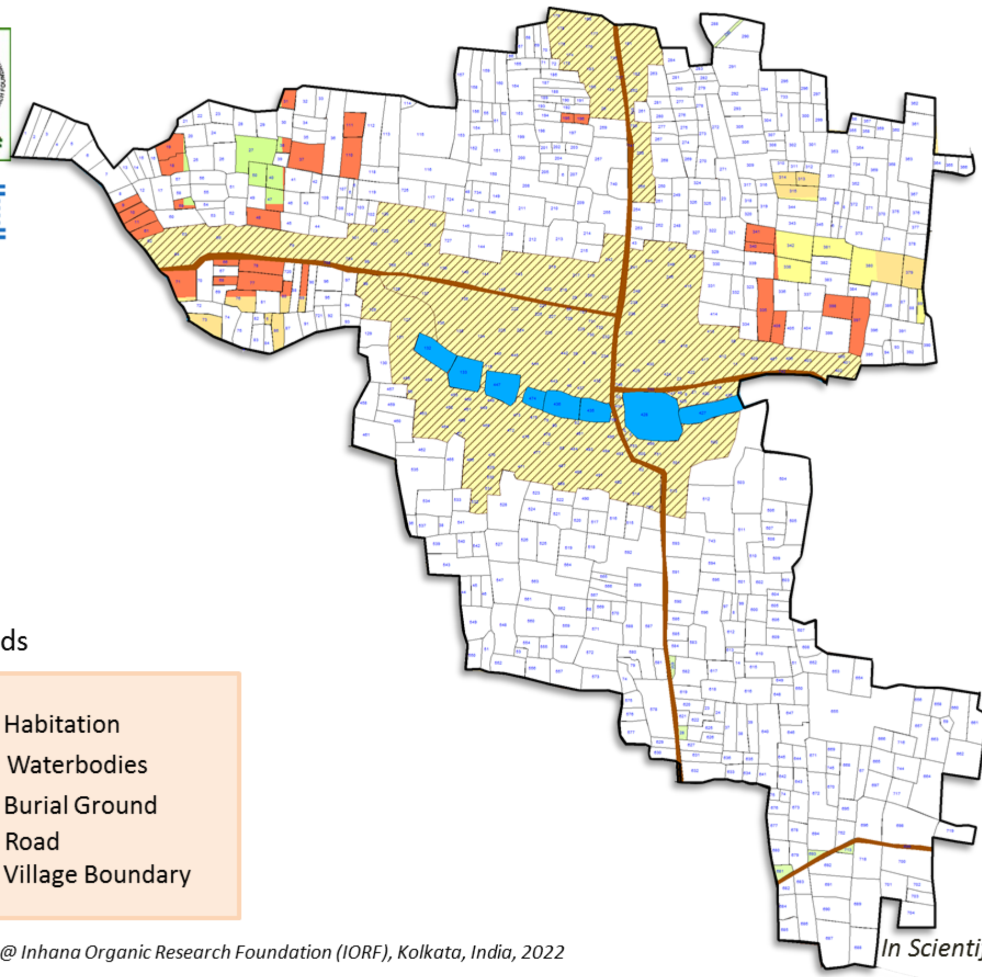

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Microbial Quotient (qMBC)

< 1.00	Very Low	
1.01 – 2.00	Low	
2.01 – 3.00	Moderate	
3.01 – 4.00	Moderately High	
4.01 – 5.00	High	
5.01 – 6.00		
> 6.00		

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Farm Level Resource Map : Soil Microbial Metabolic Quotient(qCO_2)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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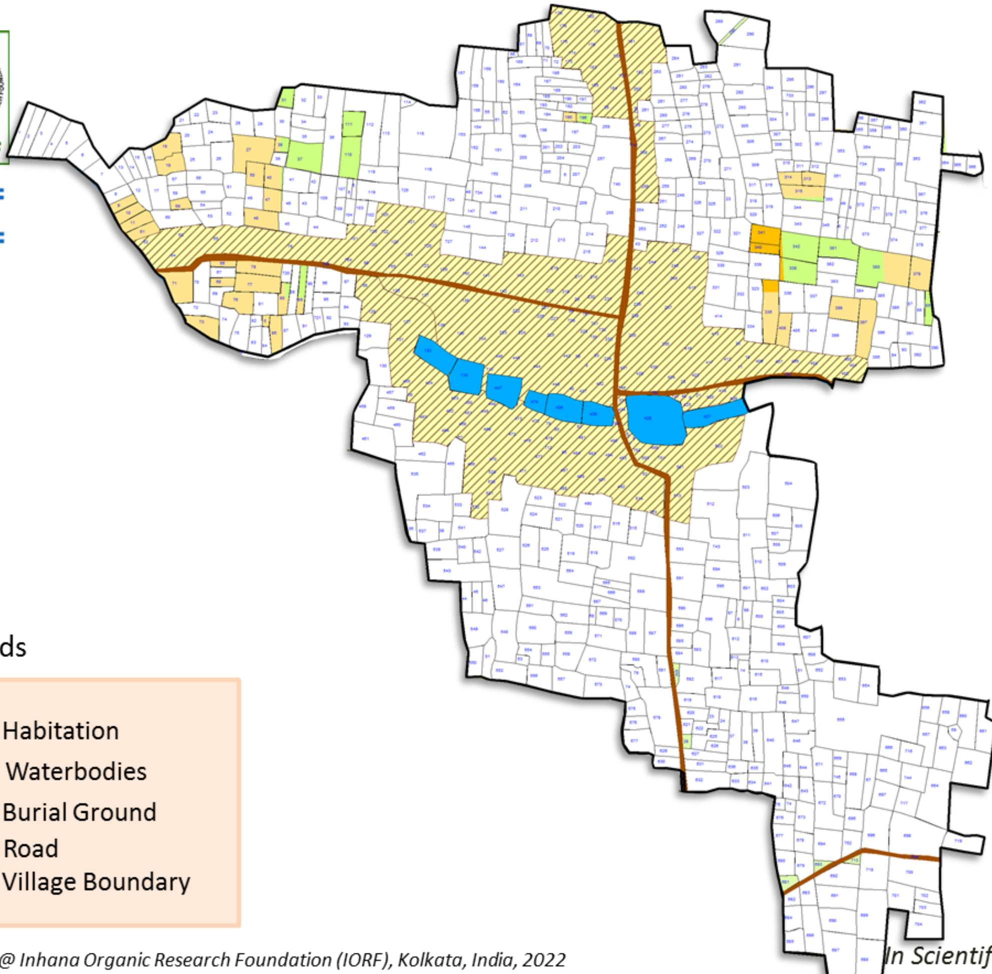

Classification of Soil Microbial Metabolic Quotient (qCO_2)

Range	Classification
5.1 – 10.0	Stressed Condition
2.6 – 5.0	Moderately Stressed
1.0 – 2.5	Slightly Stressed
< 1.00	Very Low Population
< 1.00**	Stable Condition

** Soil Microbial Biomass >300 µg CO_2 –C / g dry soil)

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Annexure - 27

Farm Level Resource Map : Soil Fertility Index (FI)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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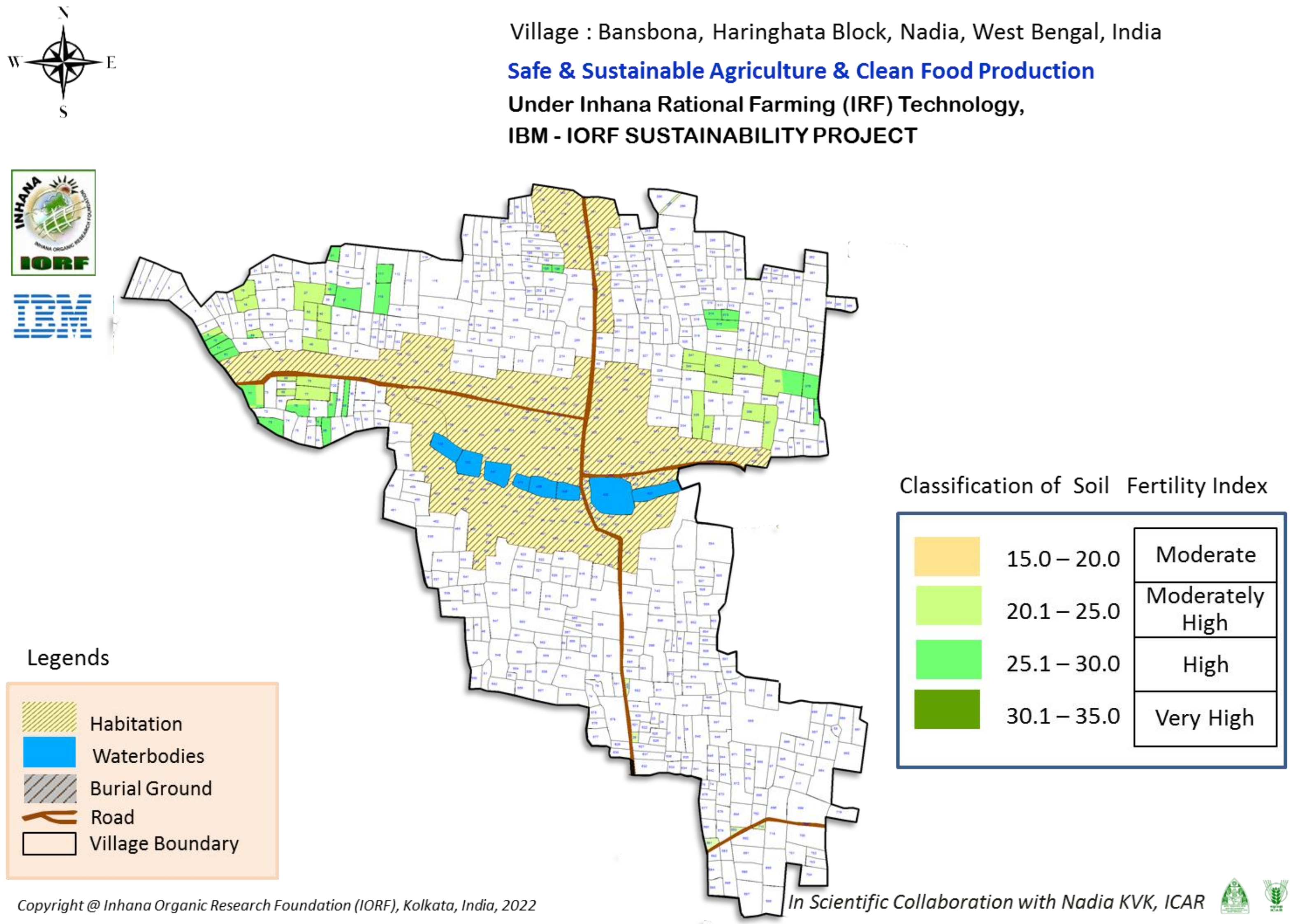

Farm Level Resource Map : Soil Microbial Activity Potential (MAP)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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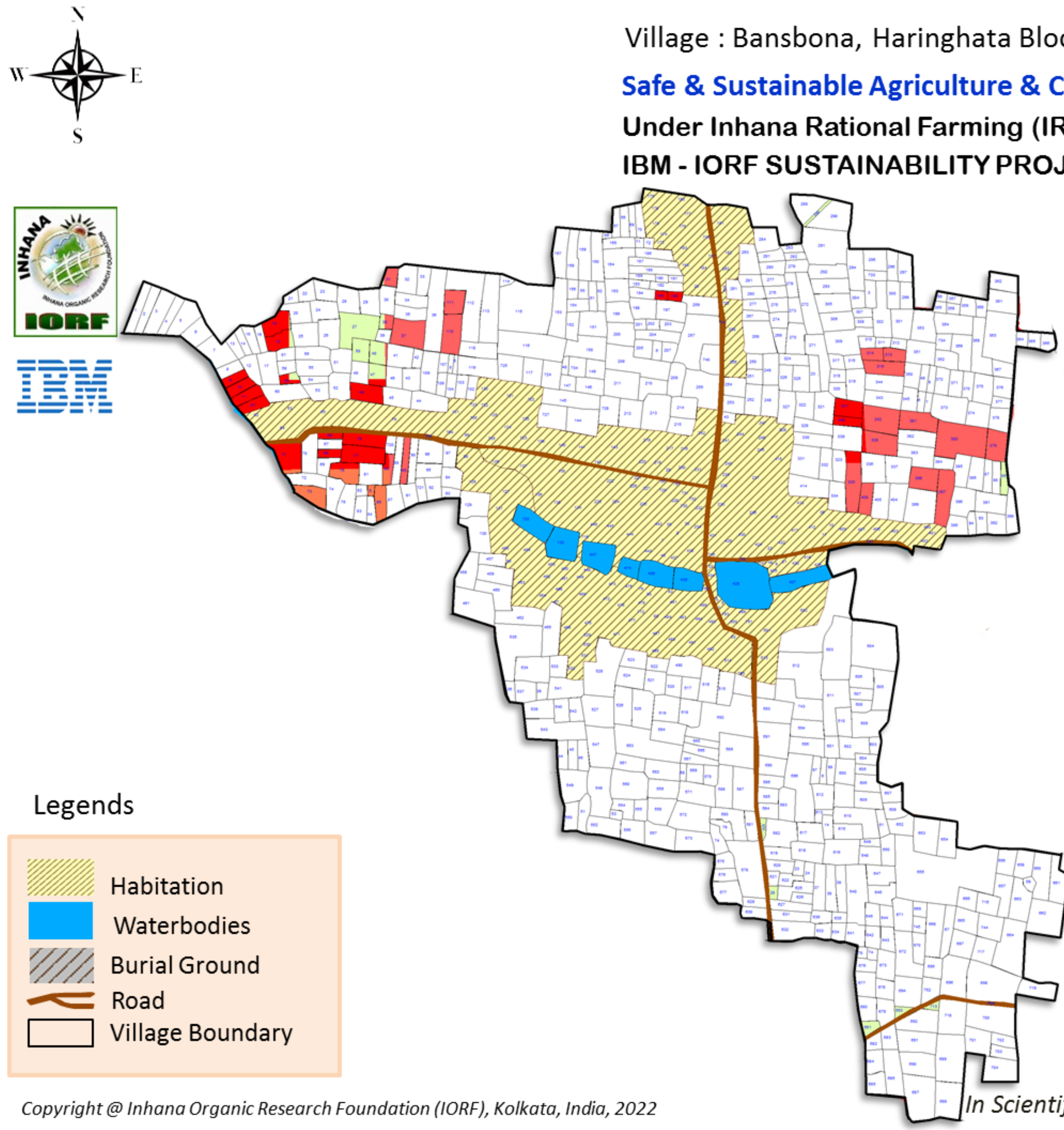

Classification of Soil Microbial Activity Potential (MAP)

> 4.0	Extremely Low
4.0 – 6.0	Very Low
6.1 – 8.0	Very Low
8.1 – 10.0	Low
10.1 – 12.0	Moderate
12.1 – 14.0	Moderately High
14.1 – 16.0	Moderately High
16.1 – 18.0	High
18.1 – 20.0	High

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Annexure - 29

Farm Level Resource Map : Soil Physical Index (PI)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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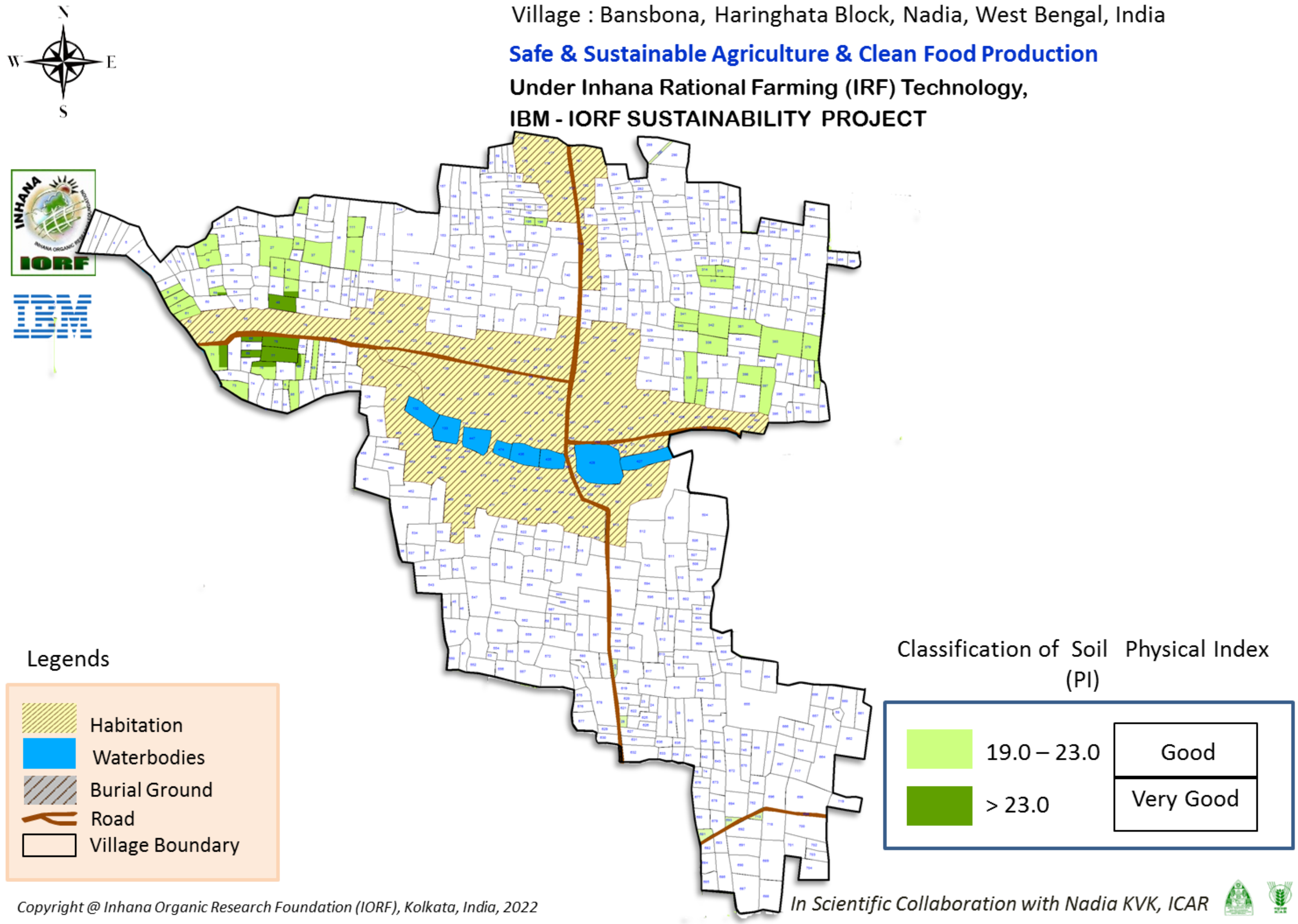

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Annexure - 30

Farm Level Resource Map : Soil Quality Index (SQI)

Village : Bansbona, Haringhata Block, Nadia, West Bengal, India

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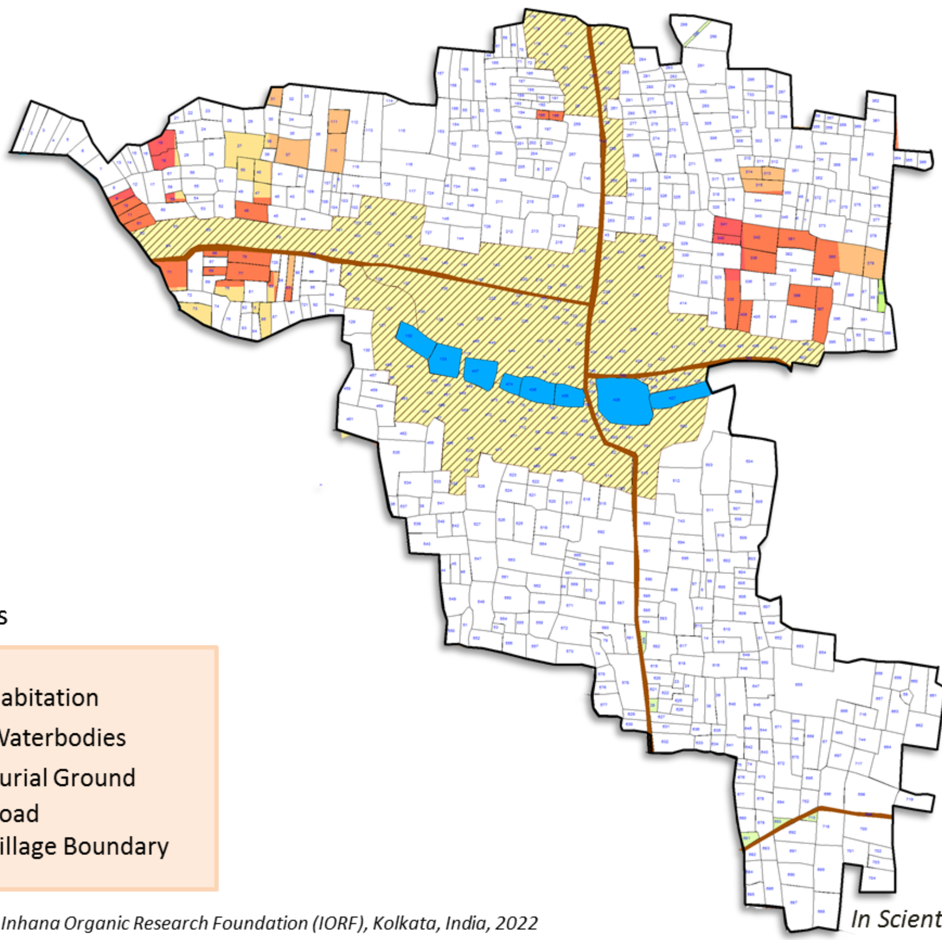

Classification of Soil Quality Index

SQI	Class
0.35 – 0.40	Poor
0.41 – 0.45	
0.46 – 0.50	Moderate
0.51 – 0.55	
0.56 – 0.60	
0.61 – 0.65	Moderately High
0.66 – 0.70	
0.71 – 0.75	

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Farm Level Resource Map : Soil pH

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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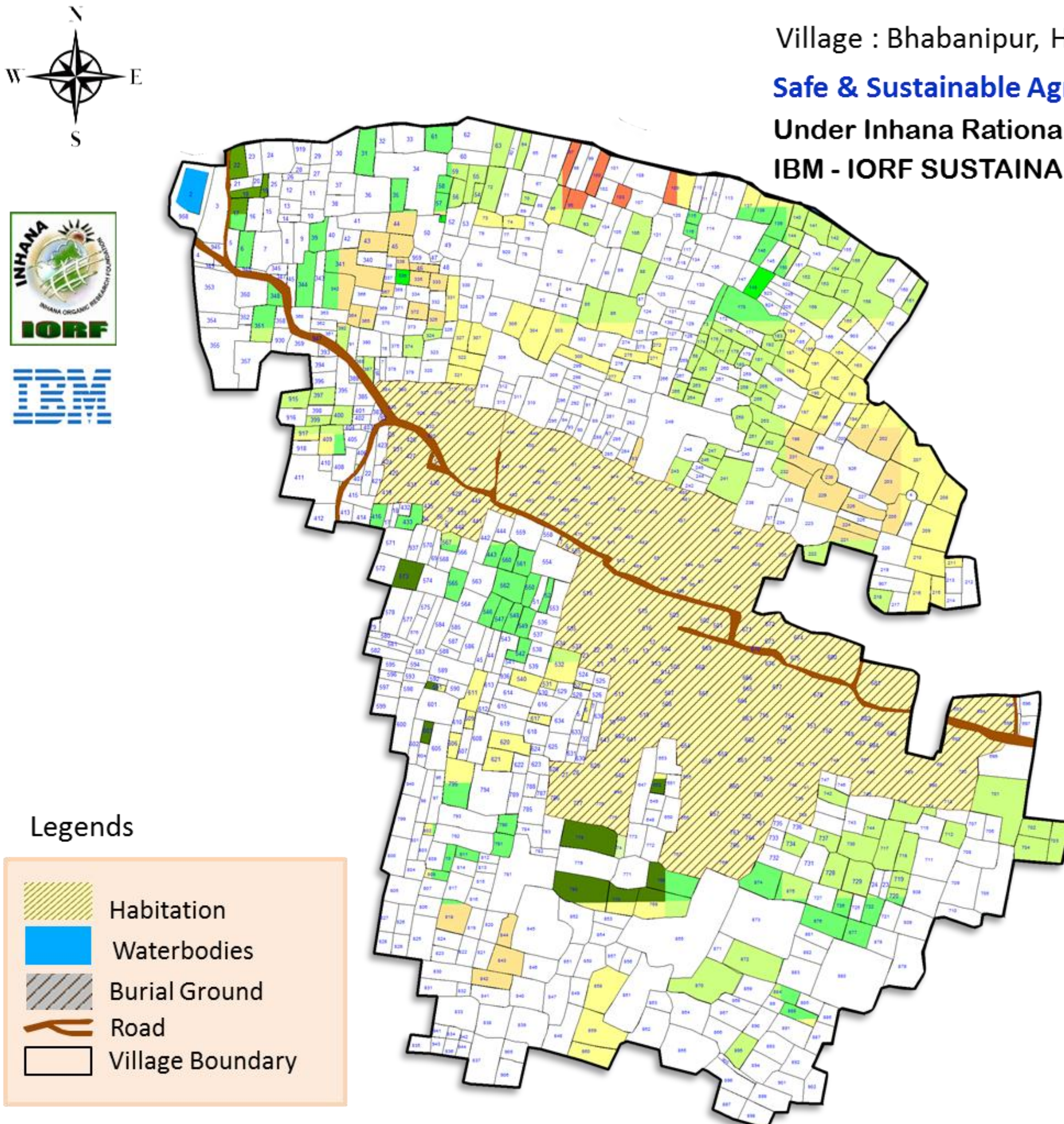

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil pH

5.25 – 5.50	Moderate Limitation
5.51 – 5.75	Moderate Limitation
5.76 – 6.00	Slight Limitation
6.01 – 6.25	Slight Limitation
6.26 – 6.50	Slight Limitation
6.51 – 6.75	No Limitation
6.76 – 7.00	No Limitation
7.01 – 7.25	No Limitation

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Annexure - 32

Farm Level Resource Map : Soil Org. C (%)

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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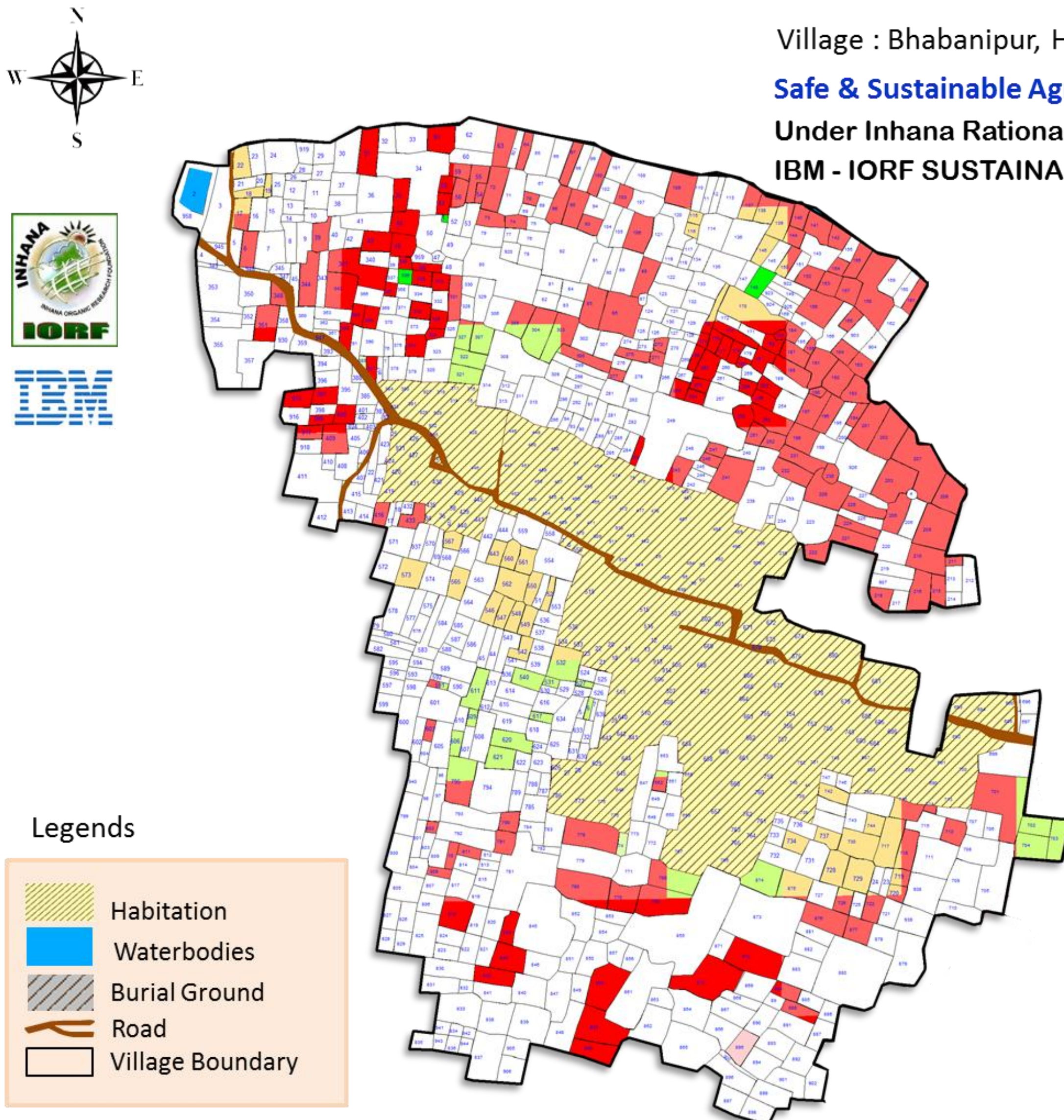

Classification of Soil Org. C

	0.25 – 0.50	Very Low
	0.51 – 0.75	Low
	0.76 - 1.00	Moderate
	1.01 – 1.25	Moderately High
	1.25 – 1.50	Moderately High
	1.51 – 1.75	High

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Annexure - 33

Farm Level Resource Map : Soil Available Nitrogen (Kgha^{-1})

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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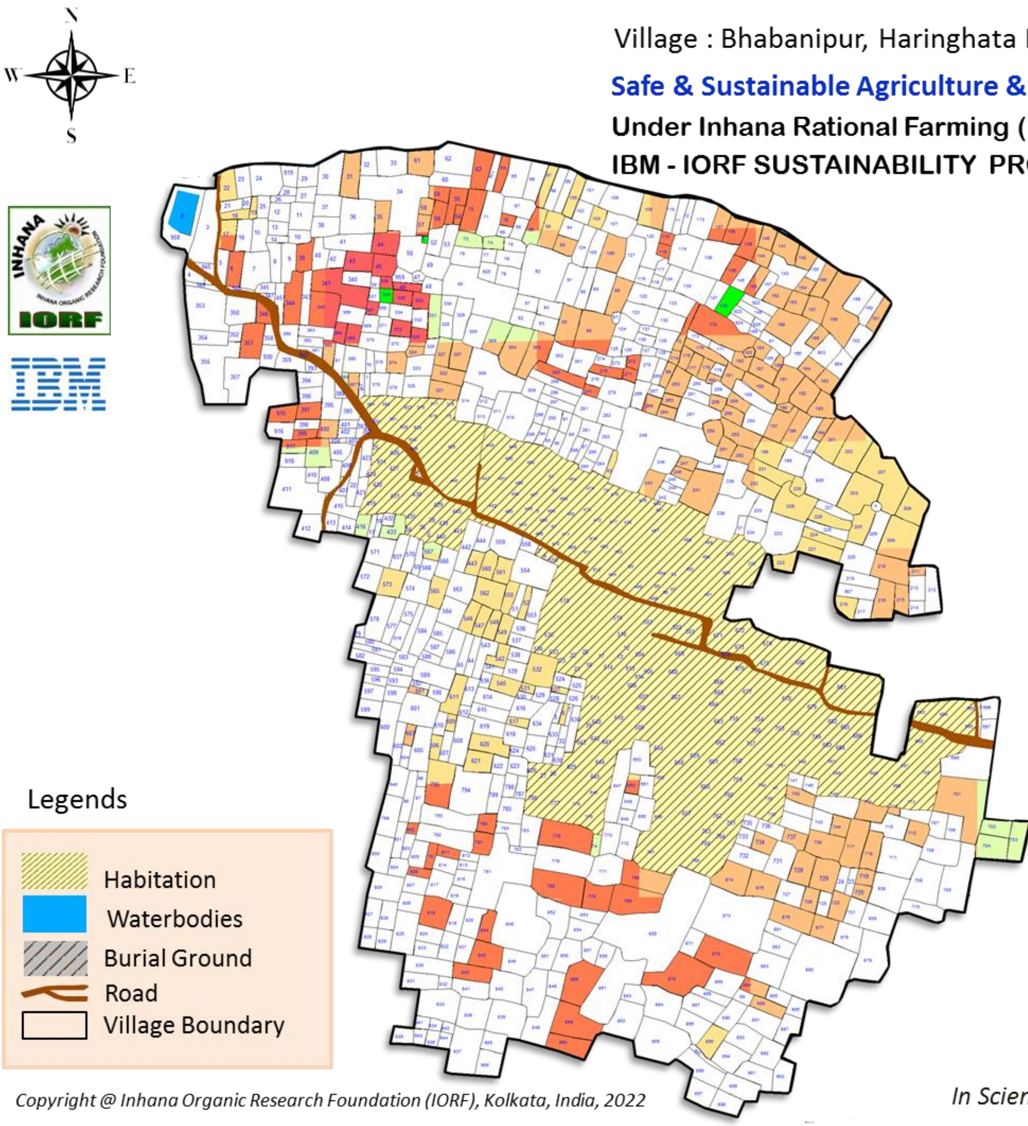

Classification of Soil Available N

200 – 240	Low
241 – 280	Low
281 – 320	Moderate
321 – 360	Moderate
361 – 400	Moderately High
401 – 440	Moderately High
441 – 480	Moderately High
481 – 520	High
521 – 560	High

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Annexure - 34

Farm Level Resource Map : Soil Available Nitrate ($mgKg^{-1}$)

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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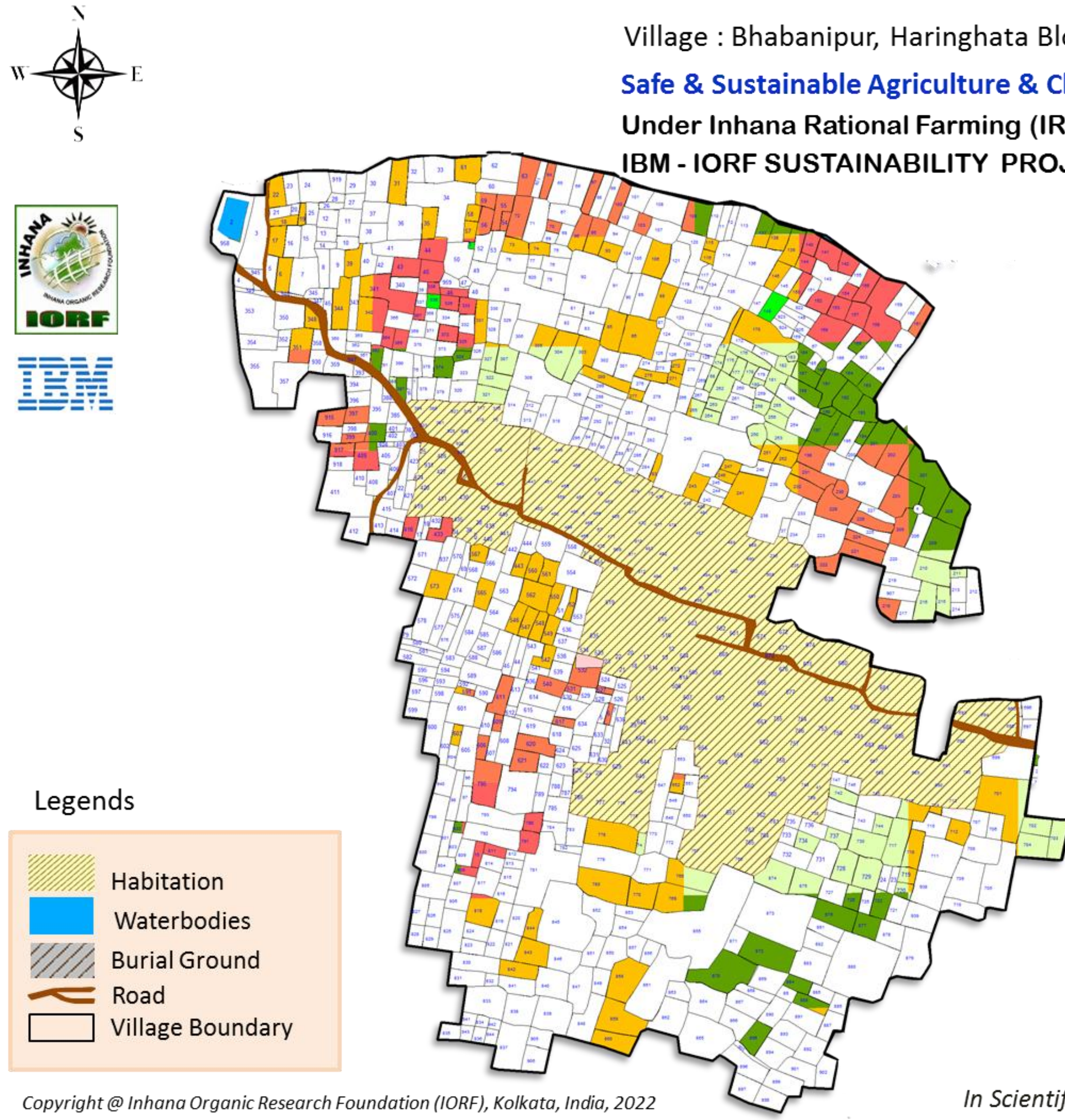

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Available NO_3

20 – 30	Moderately Good
31 – 40	Good
41 – 60	Cautious
61 -80	Very Cautious
>80	Extremely Cautious

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Annexure - 35

Farm Level Resource Map : Soil Available Phosphate (Kgha^{-1})

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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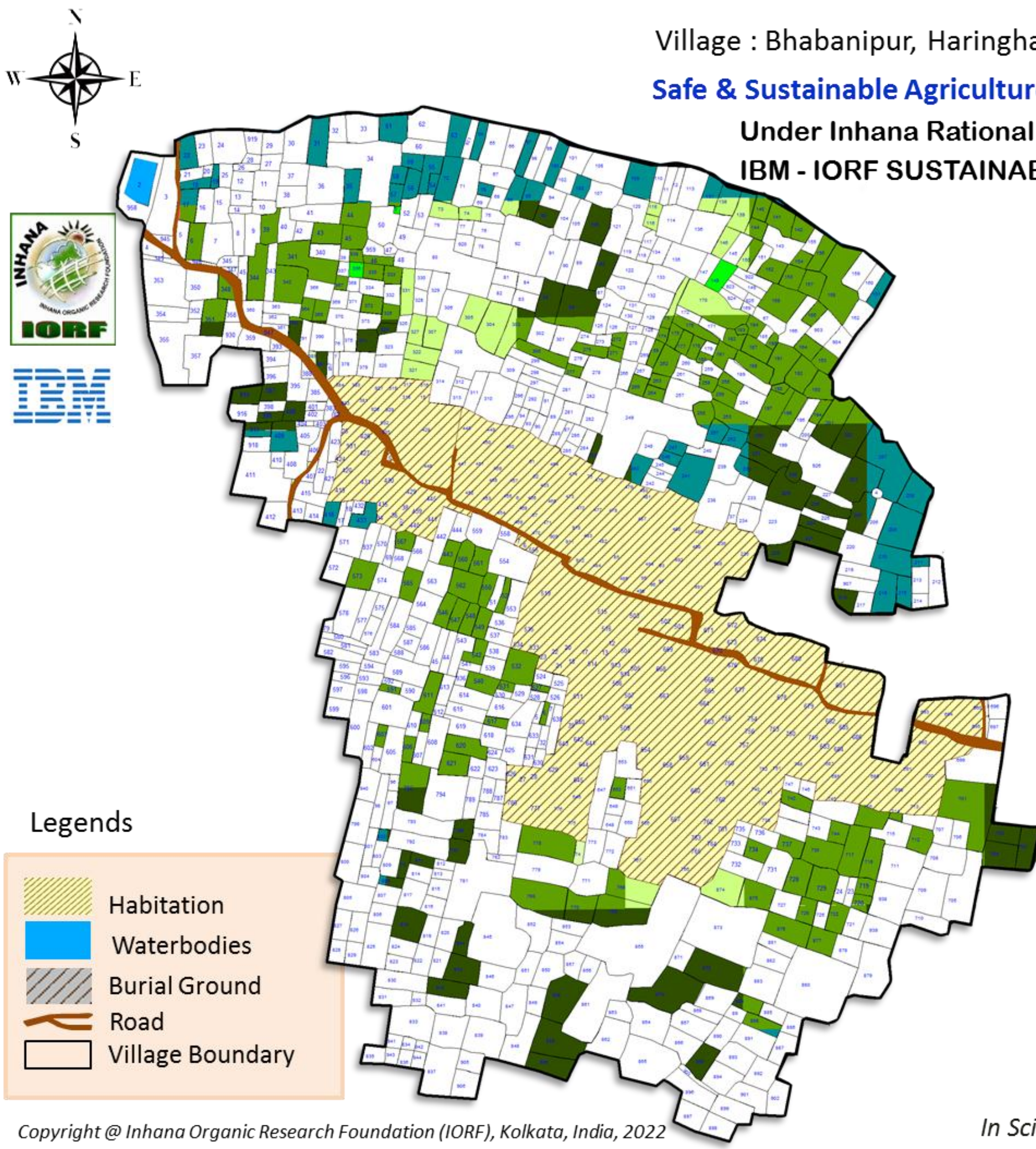

Classification of Soil Available P_2O_5

22.5 - 45	Low
46 - 70	Moderate
71 - 90	Moderately High
90 - 120	High
120 - 150	High
> 150	High

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Annexure - 36

Farm Level Resource Map : Soil Available Potash (Kgha^{-1})

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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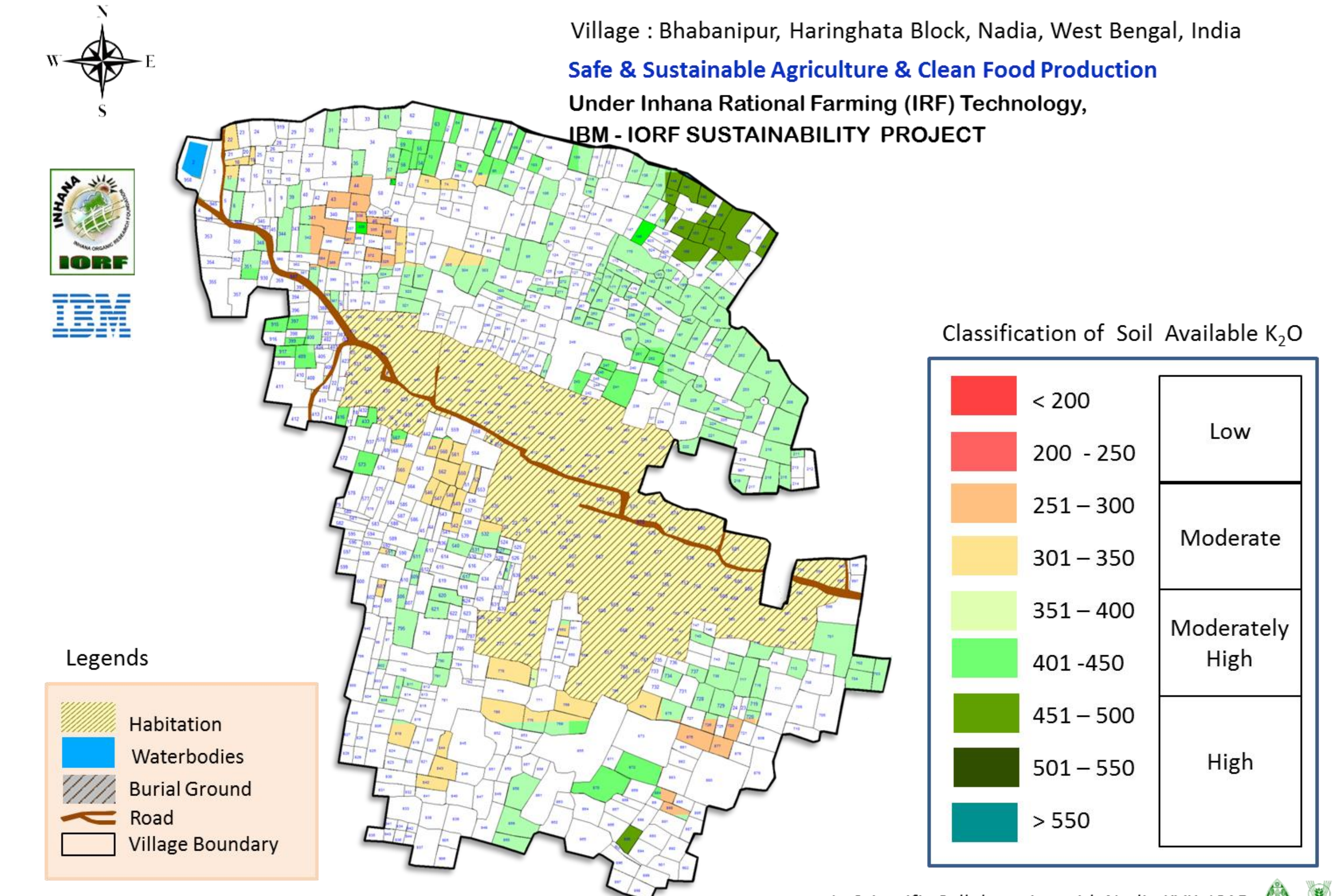

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Annexure - 37

Farm Level Resource Map : Soil Available Sulphate (Kgha^{-1})

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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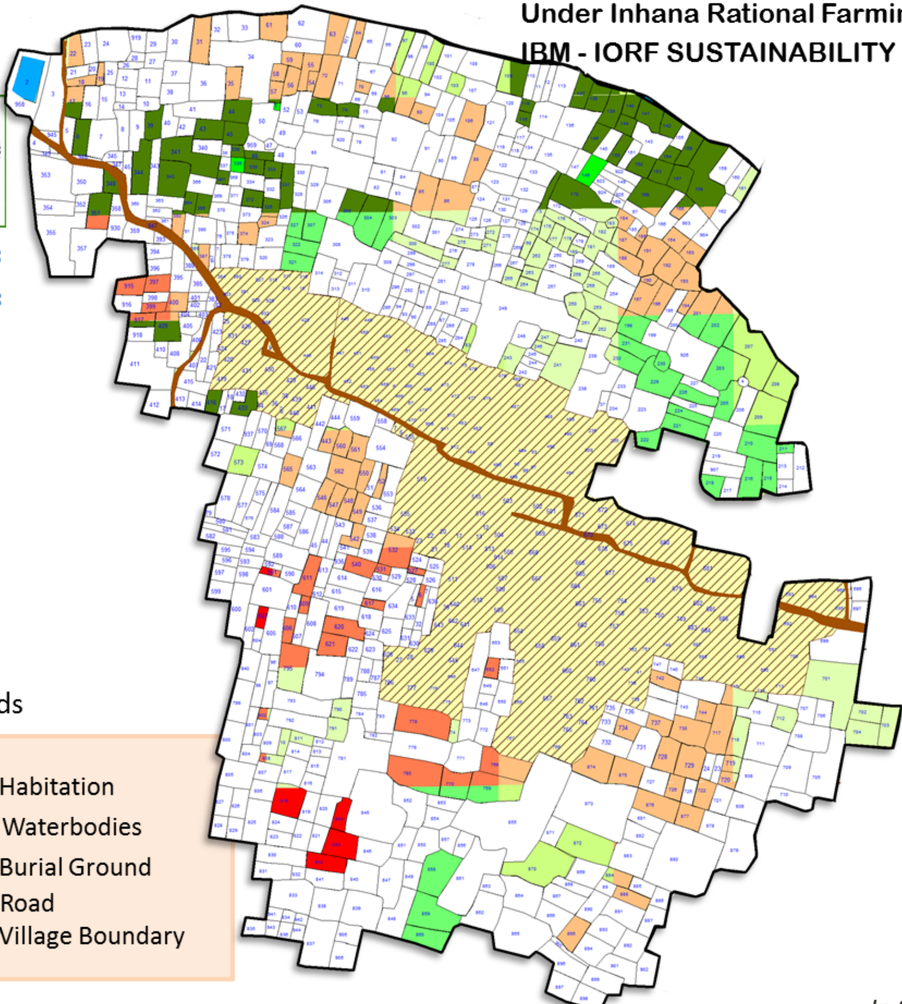

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Available SO_4

< 20	Very Low
20 – 40	Low
41 – 60	Low
61 – 80	Moderate
81 – 100	Moderate
101 – 120	Moderately High
121 – 140	Moderately High
141 – 160	High
> 160	High

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Annexure -3 8

Farm Level Resource Map : Soil Microbial Biomass Carbon (MBC)

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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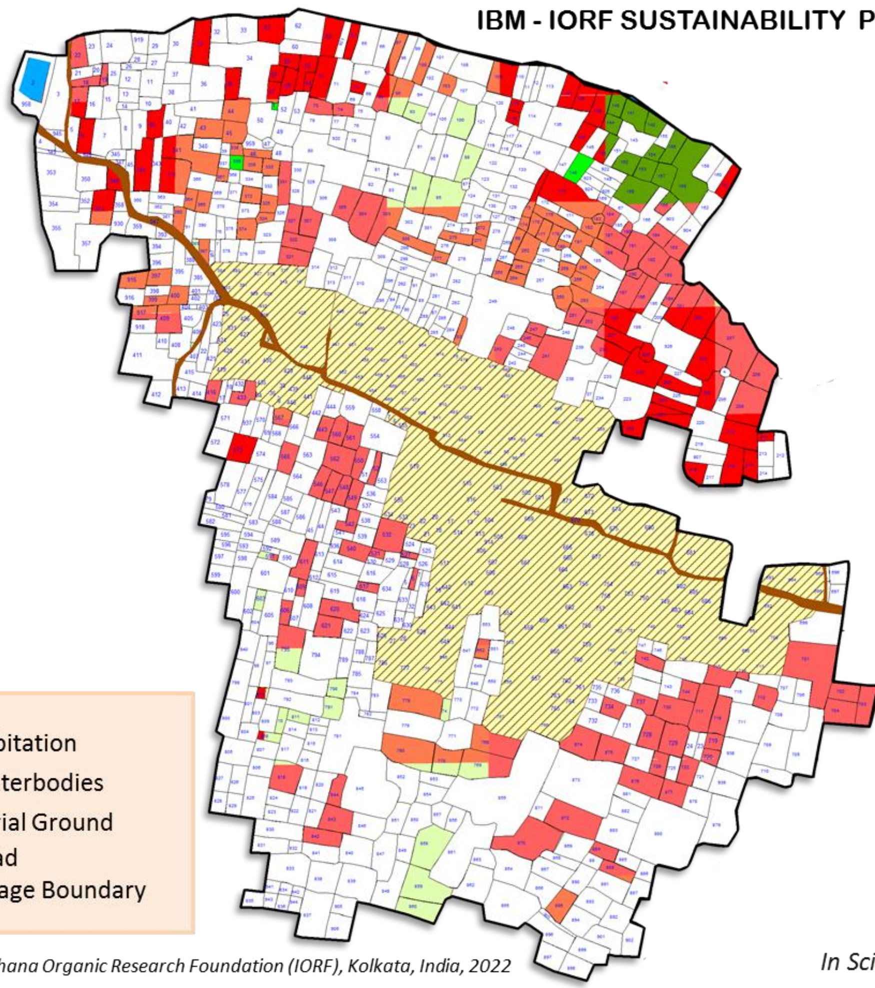

Classification of Soil Microbial Biomass Carbon (MBC)

MBC	Class
< 50	Extremely Low
50 – 100	Very Low
101 – 150	Very Low
151 – 200	Low
201 – 250	Low
251 – 300	Low
301 – 350	Moderate
351 - 400	Moderate

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Annexure - 39

Farm Level Resource Map : Fluorescein Diacetate Hydrolysis (FDAH)

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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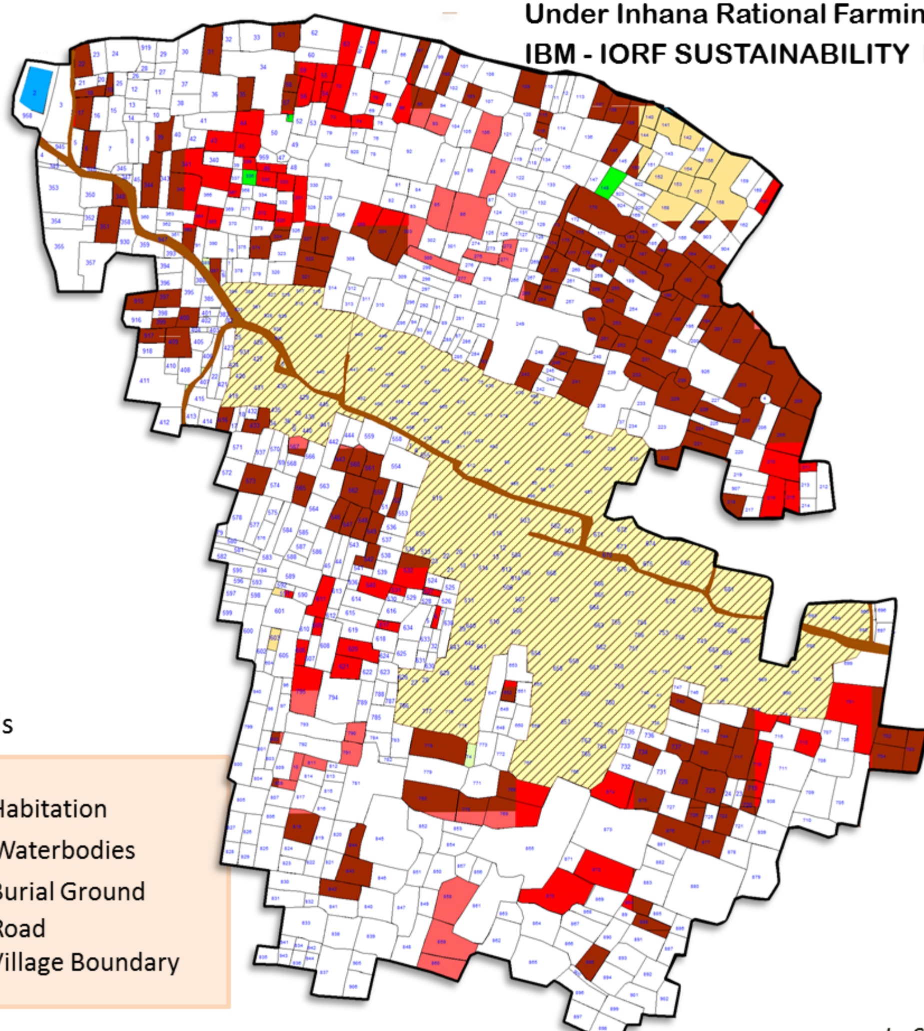

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Fluorescein Diacetate Hydrolysis (FDAH)

< 30	Extremely Low
30 – 60	Very Low
61 – 90	Low
91 – 120	Low
121 – 150	Moderate
151 - 180	Moderate

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Annexure - 40

Farm Level Resource Map : Soil Microbial Quotient(qMBC)

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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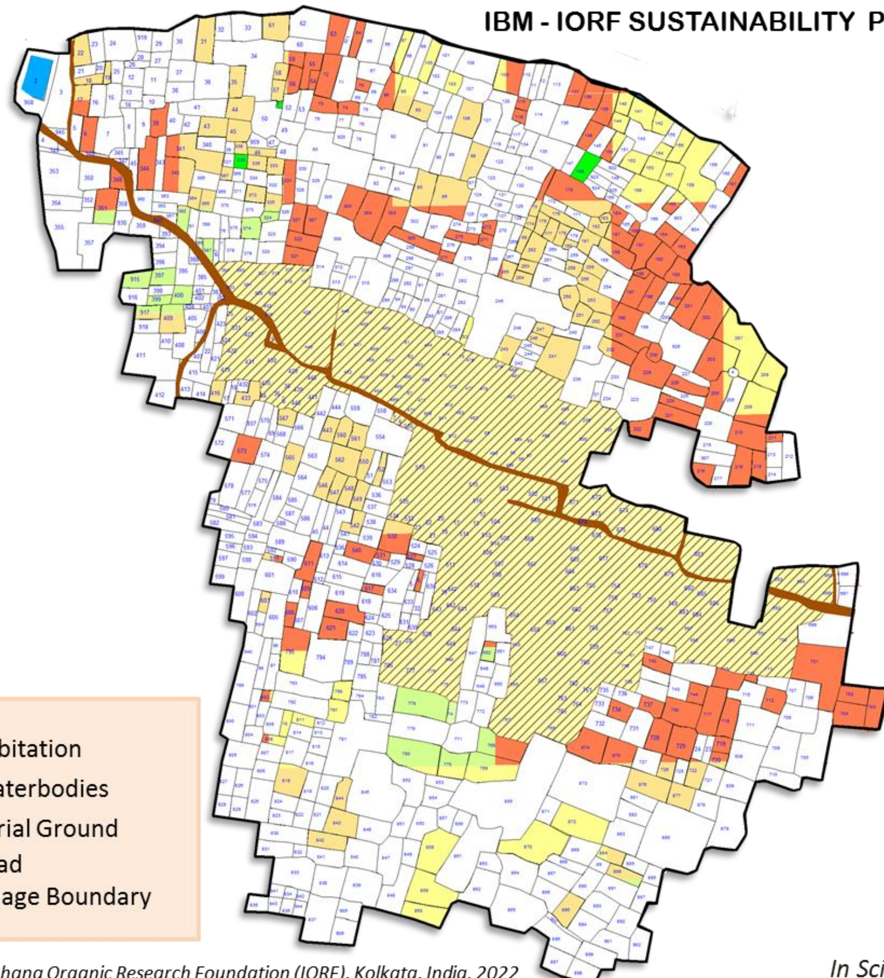

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Microbial Quotient (qMBC)

< 1.00	Very Low
1.01 – 2.00	Low
2.01 – 3.00	Moderate
3.01 – 4.00	Moderately High
4.01 – 5.00	High
5.01 – 6.00	High
> 6.00	High

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Annexure - 41

Farm Level Resource Map : Soil Microbial Metabolic Quotient(qCO_2)

Village : Bhabanipur Haringhata Block, Nadia, West Bengal, India

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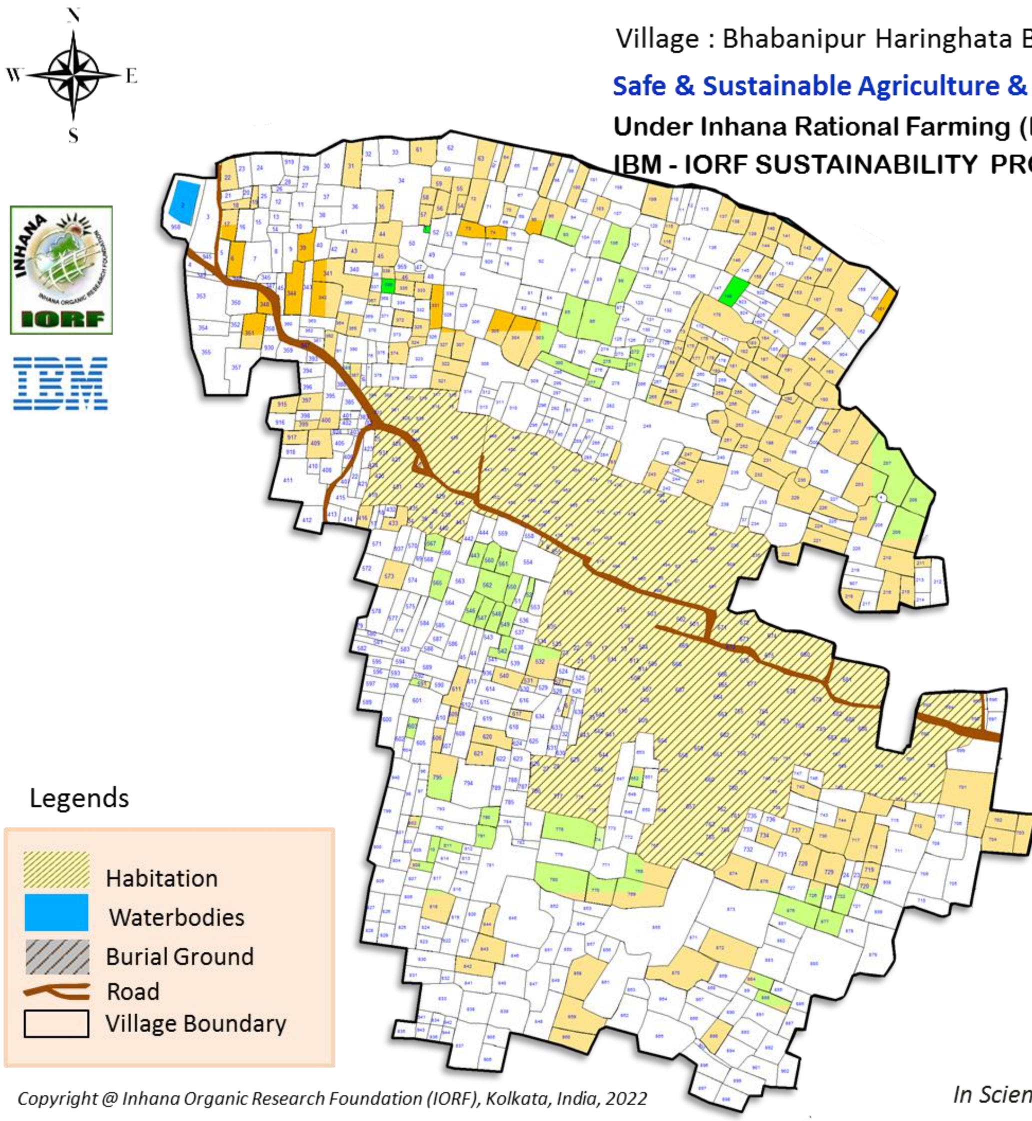

Classification of Soil Microbial Metabolic Quotient (qCO_2)

(red)	5.1 – 10.0	Stressed Condition
(orange)	2.6 – 5.0	Moderately Stressed
(light orange)	1.0 – 2.5	Slightly Stressed
(light green)	< 1.00	Very Low Population
(green)	< 1.00**	Stable Condition

** Soil Microbial Biomass >300 µg CO_2 –C / g dry soil)

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Annexure - 42

Farm Level Resource Map : Soil Fertility Index (FI)

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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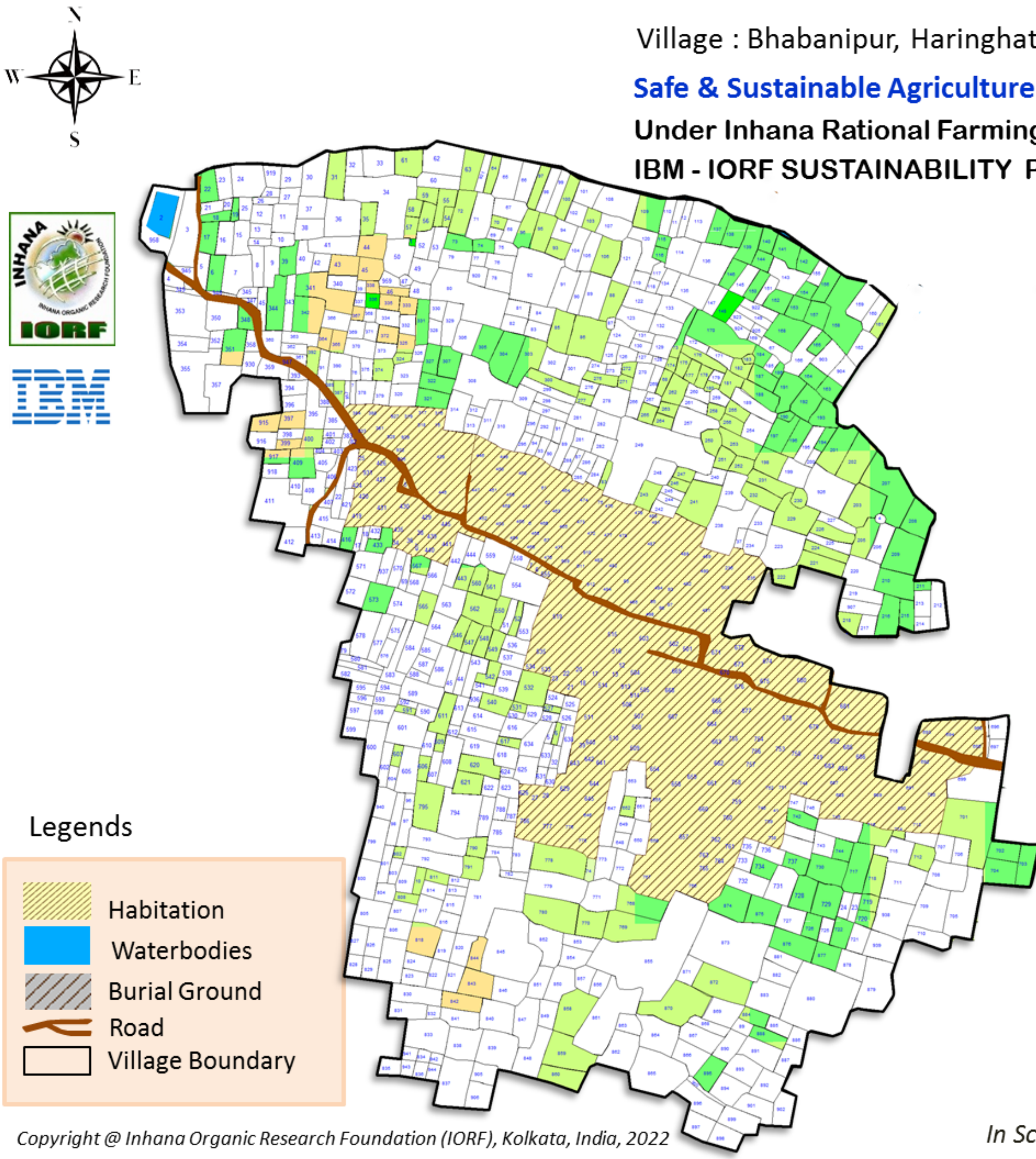

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Fertility Index

15.0 – 20.0	Moderate
20.1 – 25.0	Moderately High
25.1 – 30.0	High
30.1 – 35.0	Very High

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Annexure - 43

Farm Level Resource Map : Soil Microbial Activity Potential (MAP)

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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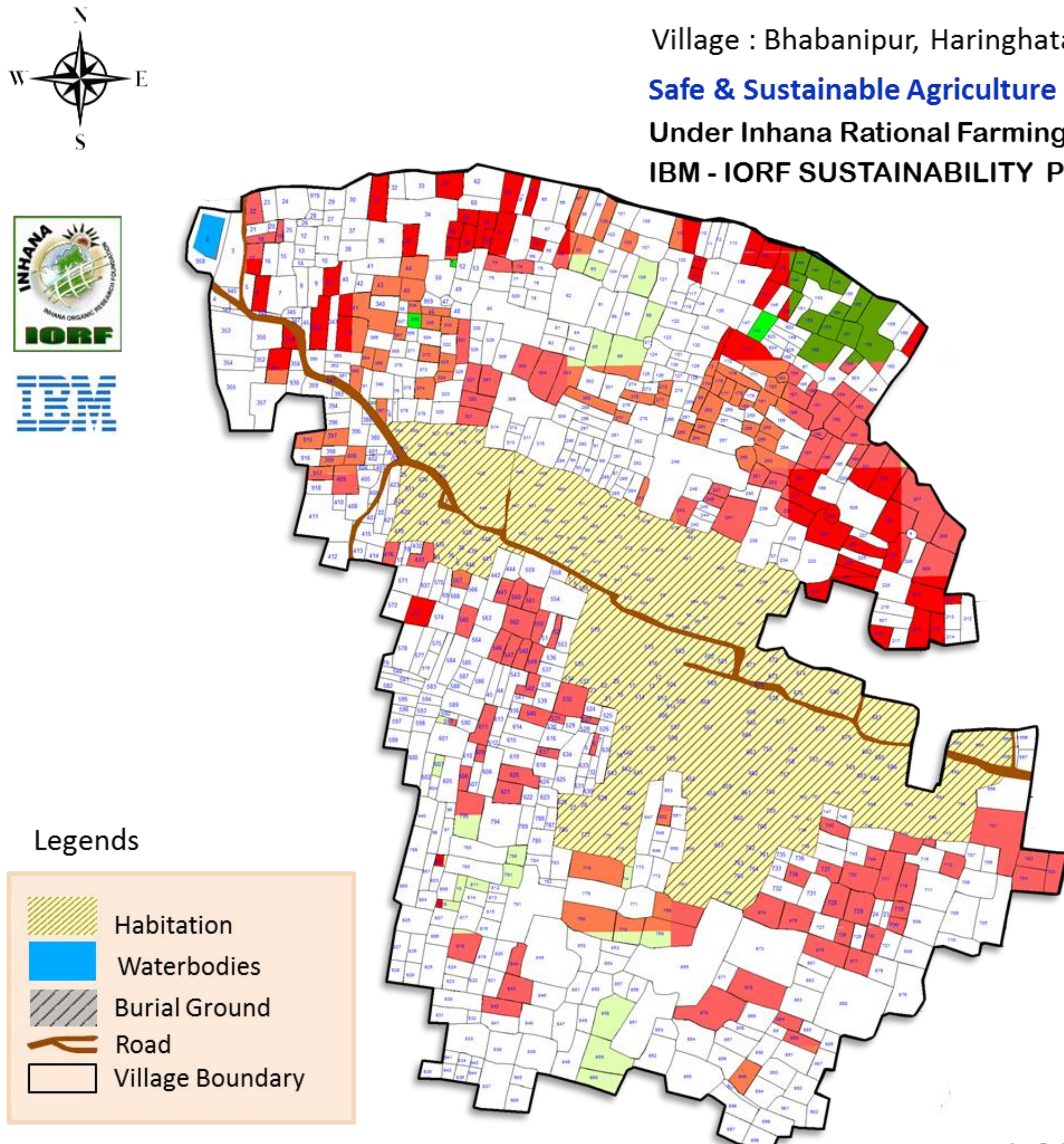

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Microbial Activity Potential (MAP)

> 4.0	Extremely Low	
4.0 – 6.0	Very Low	
6.1 – 8.0		
8.1 – 10.0	Low	
10.1 – 12.0	Moderate	
12.1 – 14.0	Moderately High	
14.1 – 16.0		
16.1 – 18.0	High	
18.1 – 20.0		

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Annexure - 44

Farm Level Resource Map : Soil Physical Index (PI)

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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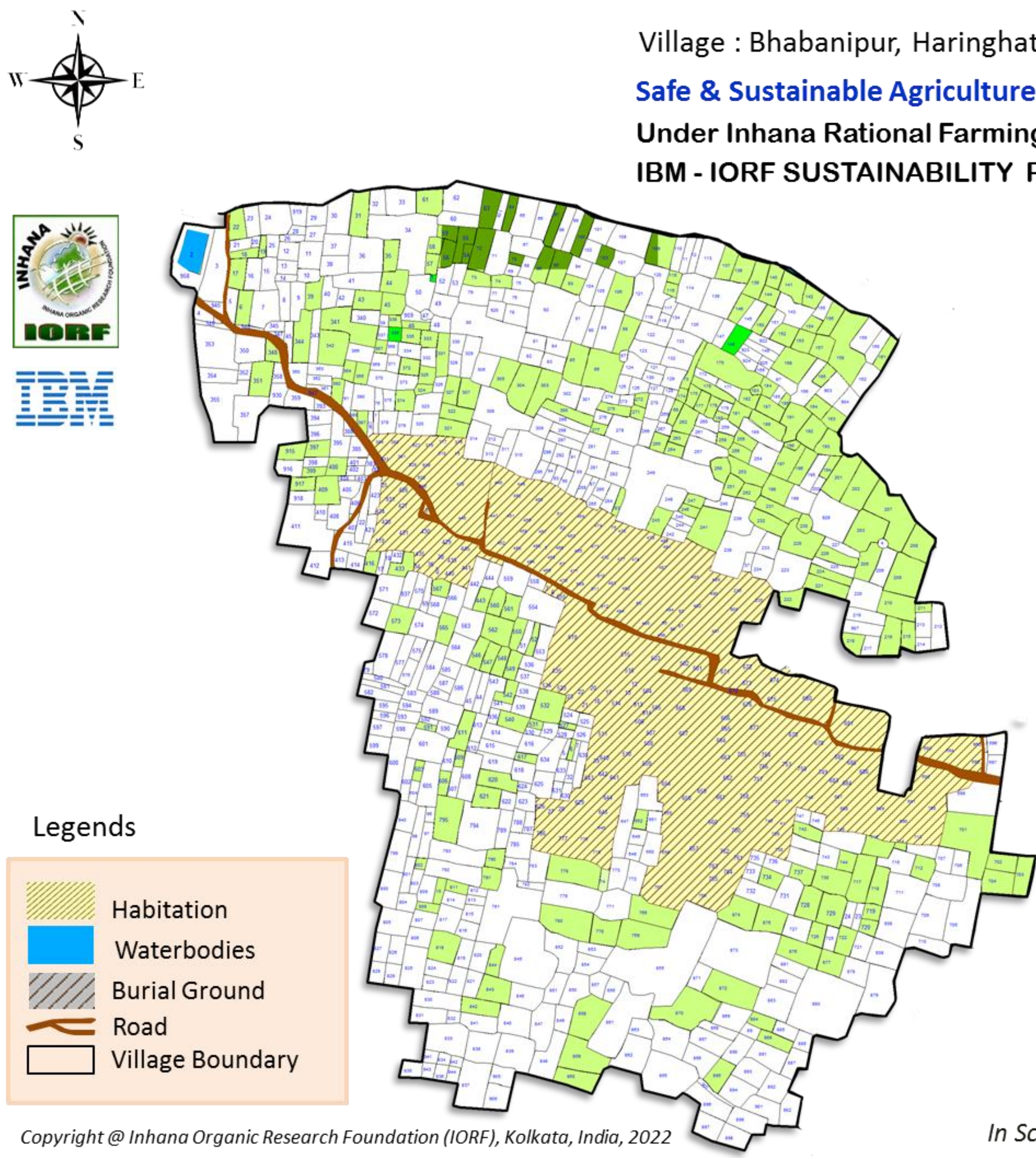

Classification of Soil Physical Index (PI)

	19.0 – 23.0	Good
	> 23.0	Very Good

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Annexure - 45

Farm Level Resource Map : Soil Quality Index (SQI)

Village : Bhabanipur, Haringhata Block, Nadia, West Bengal, India

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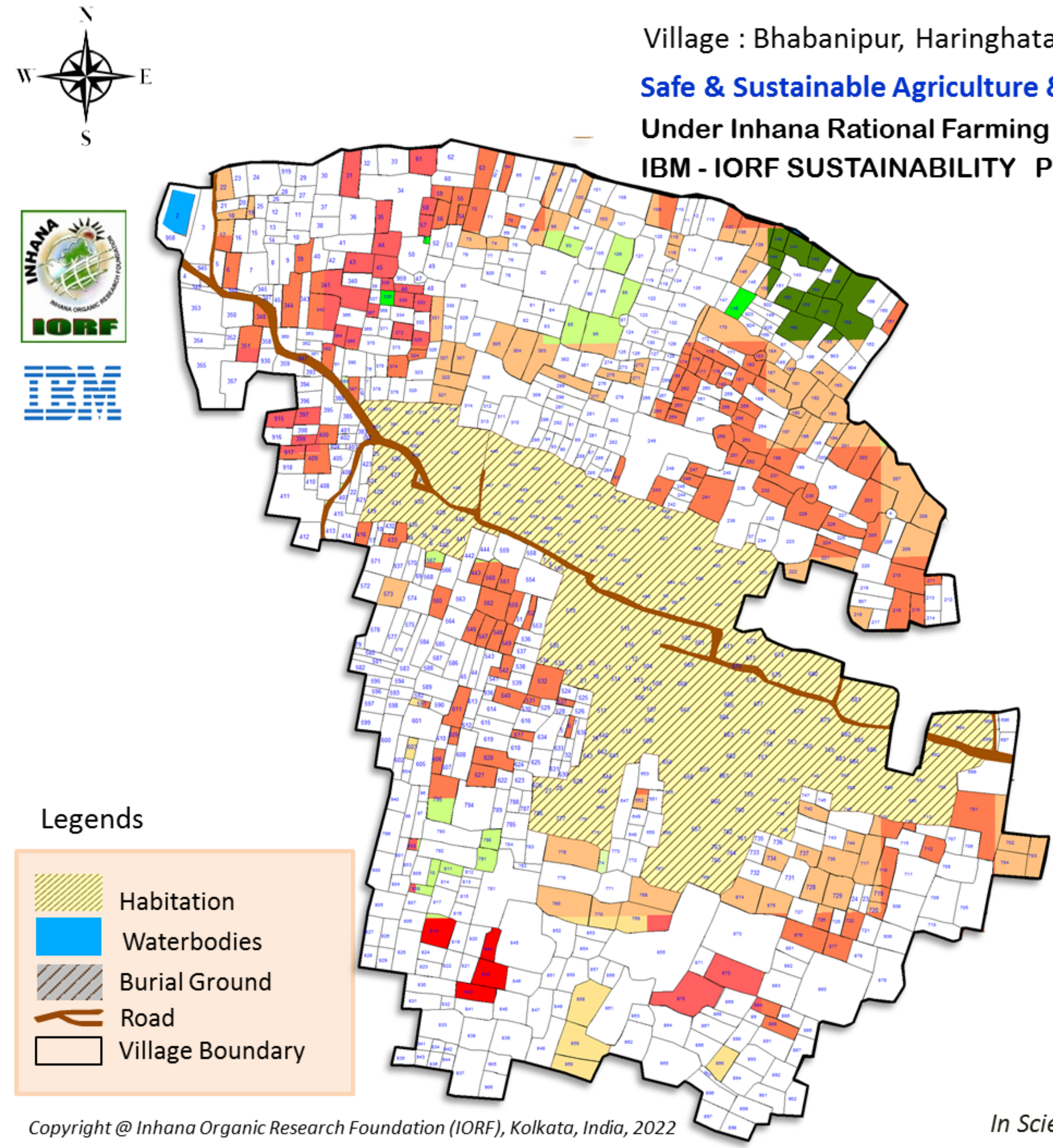

Classification of Soil Quality Index

0.35 – 0.40	Poor
0.41 – 0.45	Poor
0.46 – 0.50	Moderate
0.51 – 0.55	Moderate
0.56 – 0.60	Moderate
0.61 – 0.65	Moderately High
0.66 – 0.70	Moderately High
0.71 – 0.75	Moderately High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Farm Level Resource Map : Soil pH

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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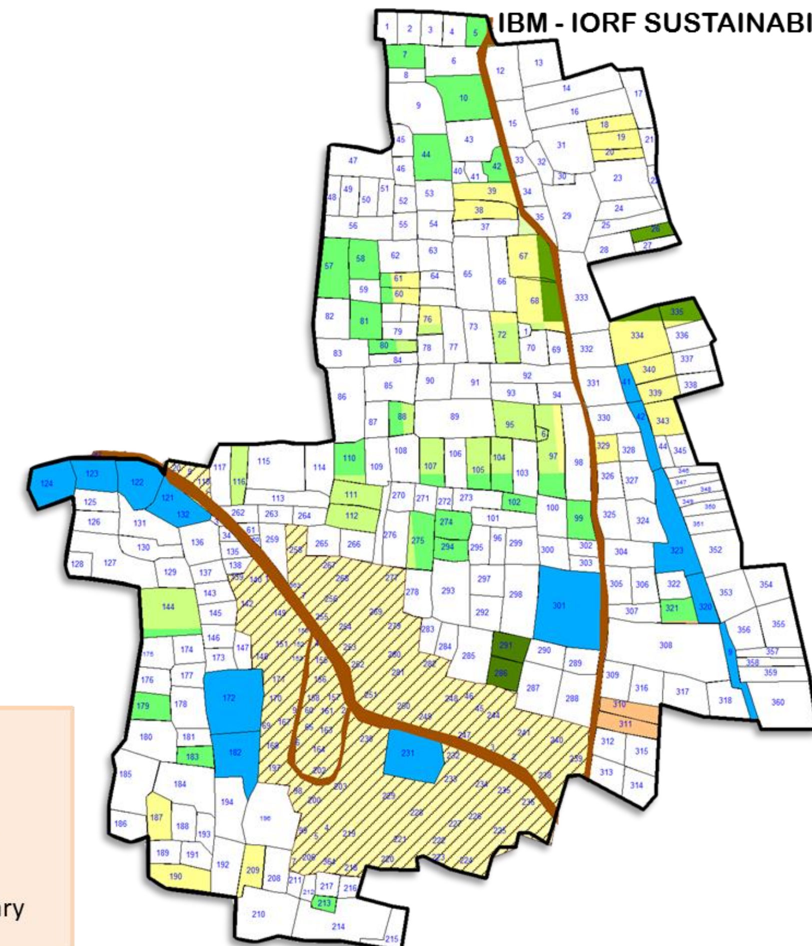

Classification of Soil pH

Soil pH	Classification
5.25 – 5.50	Moderate Limitation
5.51 – 5.75	Moderate Limitation
5.76 – 6.00	Slight Limitation
6.01 – 6.25	Slight Limitation
6.26 – 6.50	Slight Limitation
6.51 – 6.75	Slight Limitation
6.76 – 7.00	No Limitation
7.01 – 7.25	No Limitation

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Annexure - 47

Farm Level Resource Map : Soil Org. C (%)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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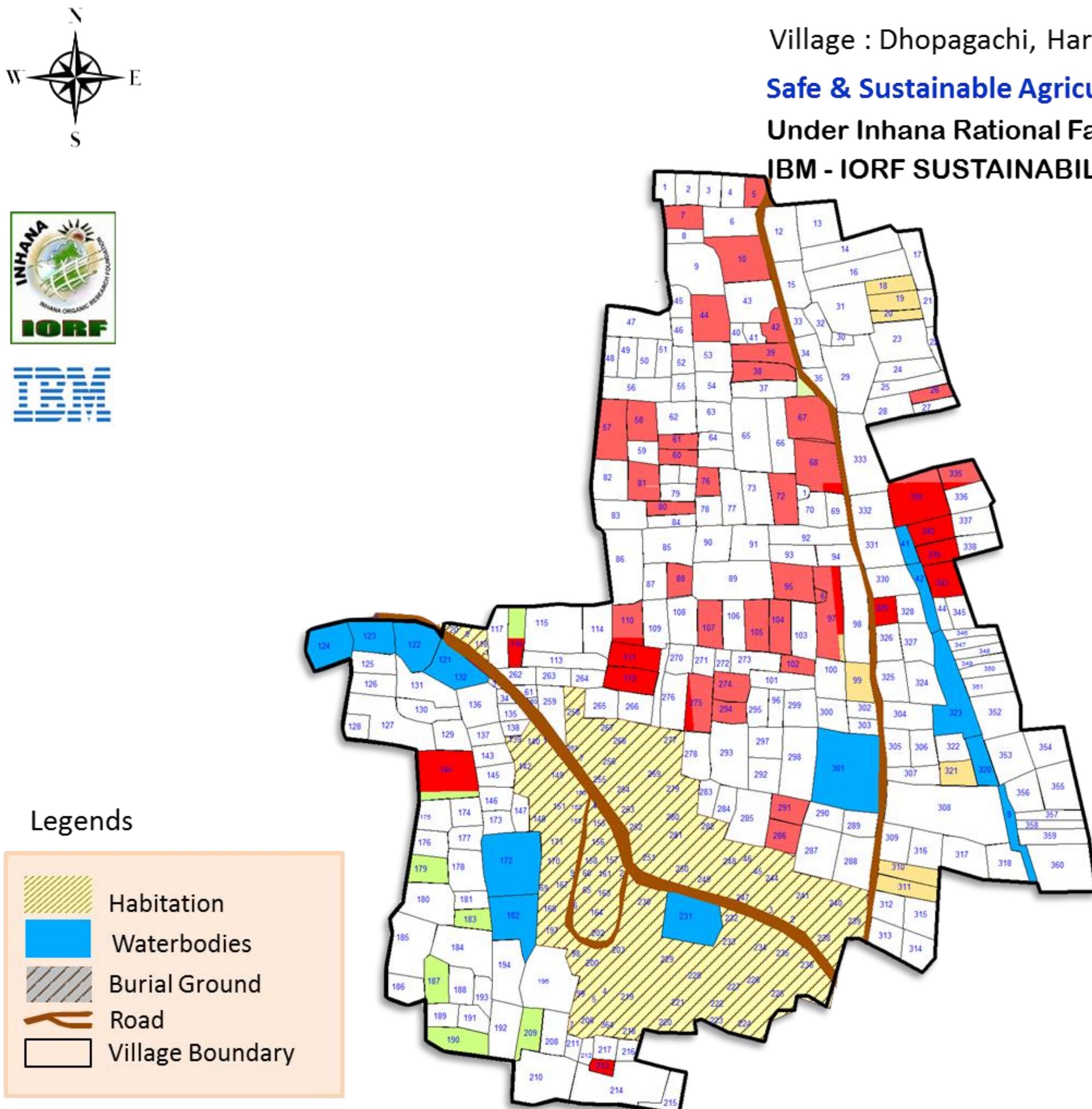

Classification of Soil Org. C

0.25 – 0.50	Very Low
0.51 – 0.75	Low
0.76 - 1.00	Moderate
1.01 – 1.25	Moderately High
1.25 – 1.50	Moderately High
1.51 – 1.75	High

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Annexure - 48

Farm Level Resource Map : Soil Available Nitrogen (Kgha^{-1})

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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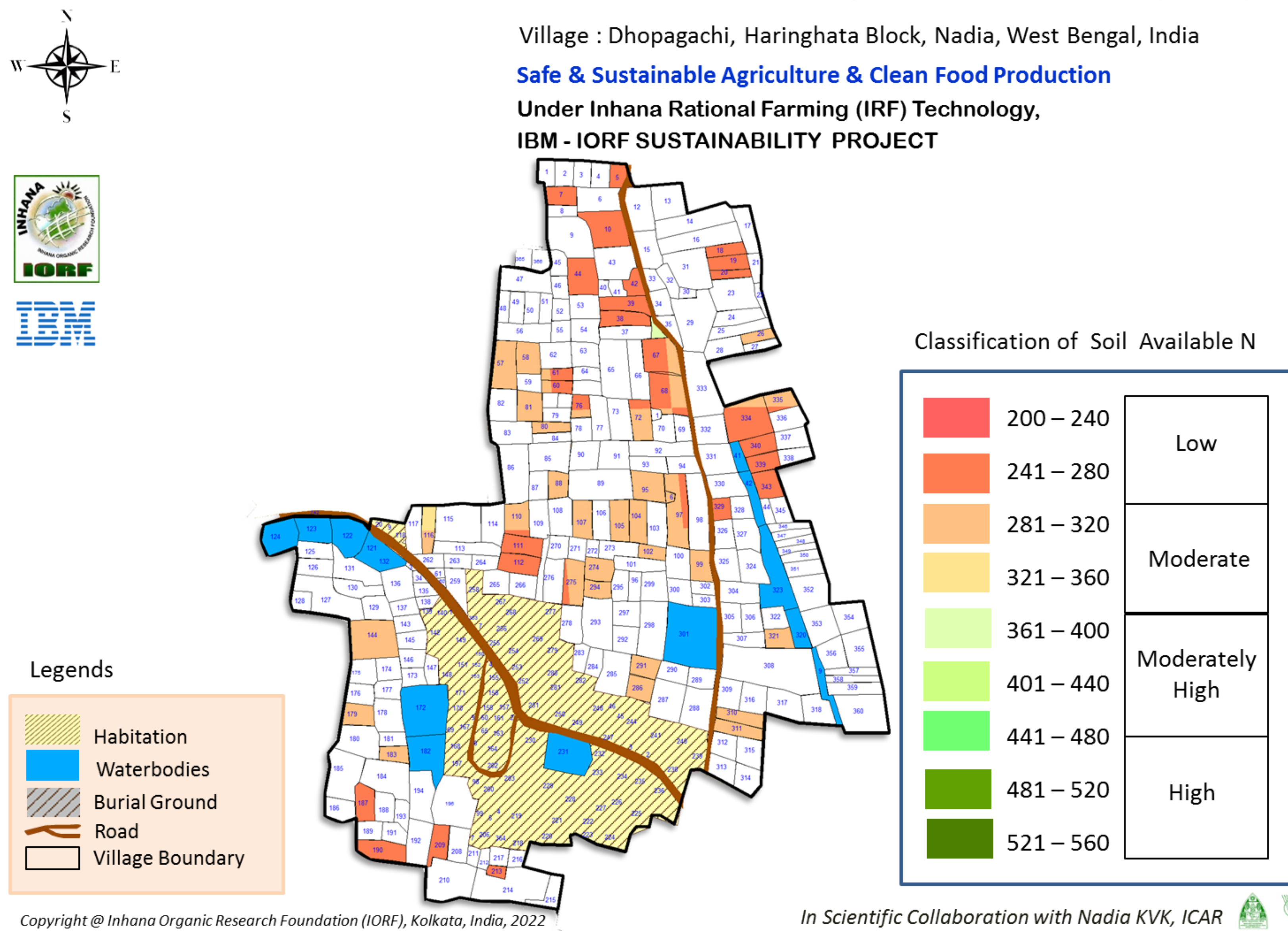

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Annexure : 49

Farm Level Resource Map : Soil Available Nitrate ($mgKg^{-1}$)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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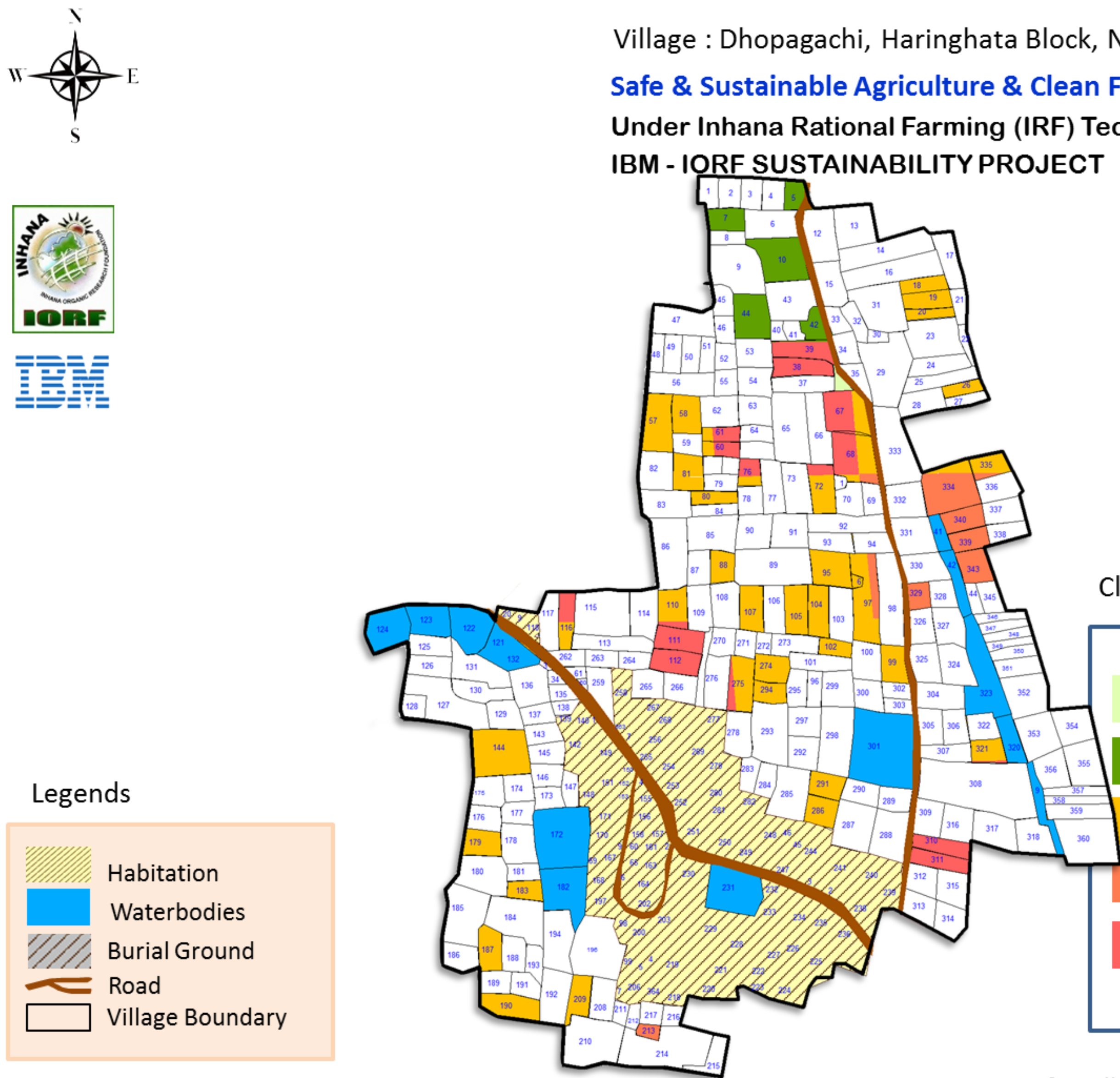

Classification of Soil Available NO_3

	20 – 30	Moderately Good
	31 – 40	Good
	41 – 60	Cautious
	61 -80	Very Cautious
	>80	Extremely Cautious

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Annexure - 50

Farm Level Resource Map : Soil Available Phosphate (Kgha^{-1})

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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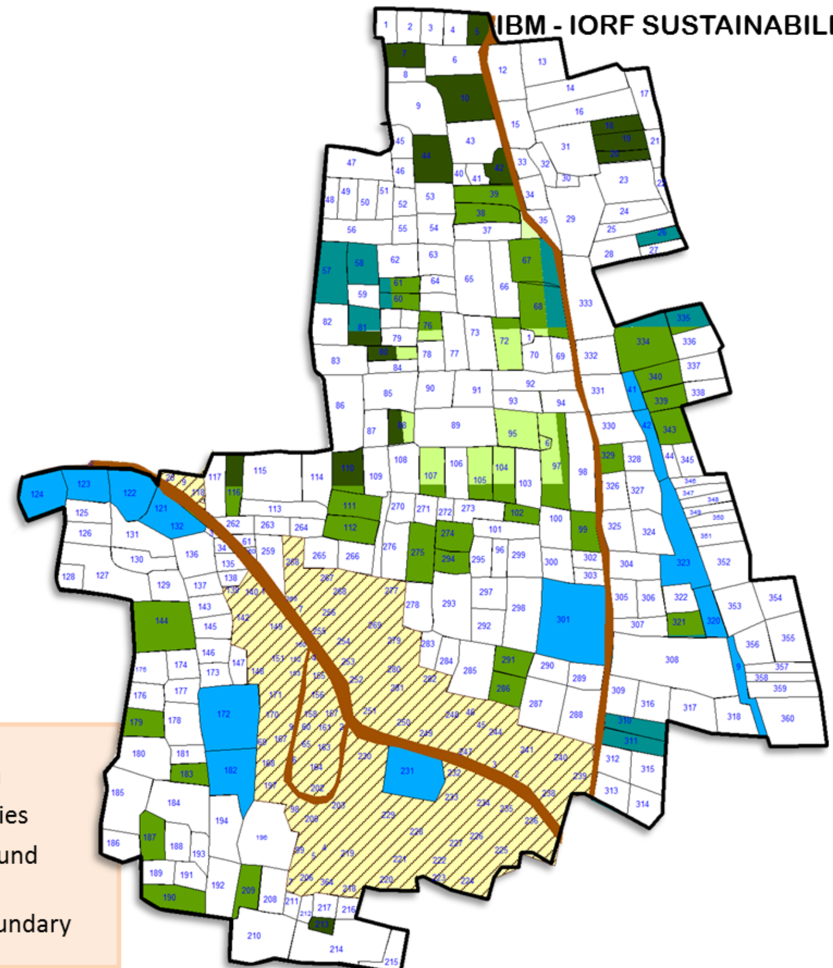

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Available P_2O_5

22.5 - 45	Low
46 - 70	Moderate
71 - 90	Moderately High
90 - 120	Moderately High
120 - 150	High
> 150	High

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Annexure - 51

Farm Level Resource Map : Soil Available Potash ($Kgha^{-1}$)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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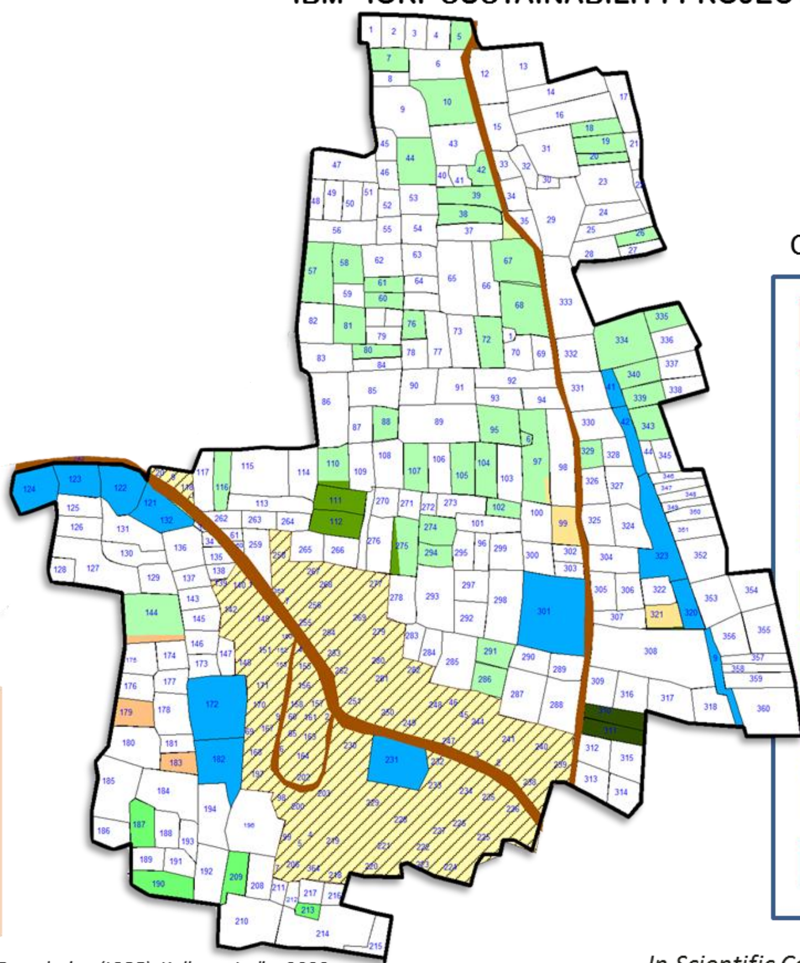

Classification of Soil Available K_2O

< 200	Low
200 - 250	Low
251 – 300	Moderate
301 – 350	Moderate
351 – 400	Moderately High
401 -450	Moderately High
451 – 500	High
501 – 550	High
> 550	High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Farm Level Resource Map : Soil Available Sulphate (Kgha^{-1})

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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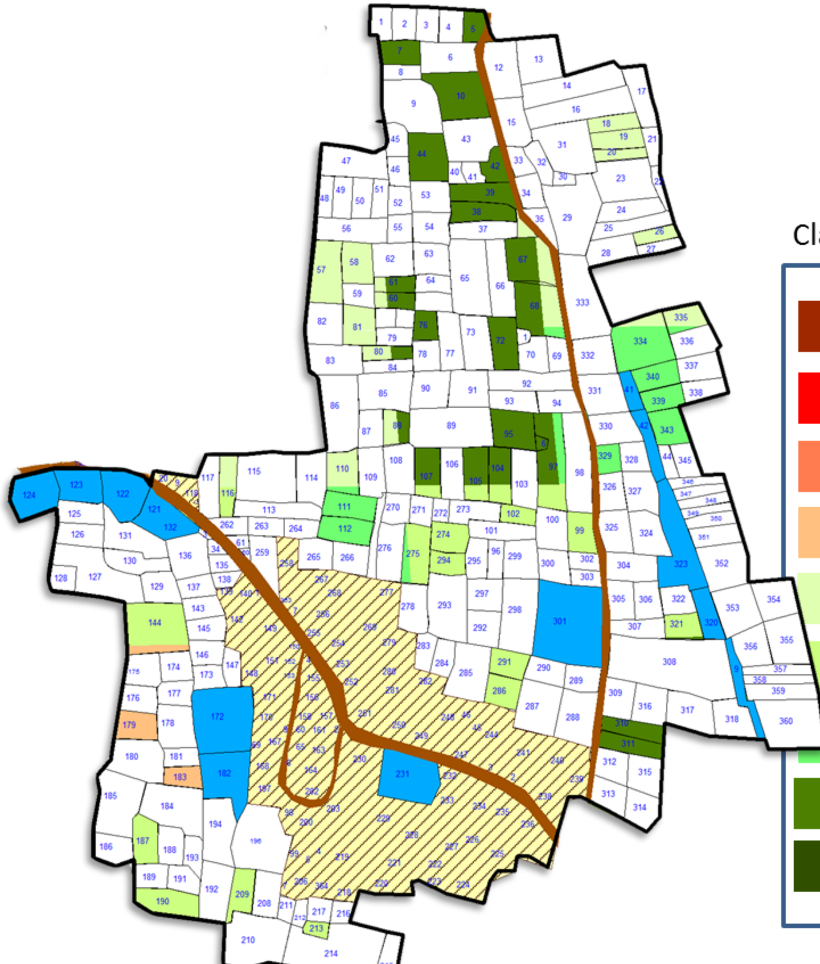

Classification of Soil Available SO_4

< 20	Very Low
20 – 40	Low
41 – 60	Low
61 – 80	Moderate
81 – 100	Moderate
101 – 120	Moderately High
121 – 140	Moderately High
141 – 160	High
> 160	High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Farm Level Resource Map : Soil Microbial Biomass Carbon (MBC)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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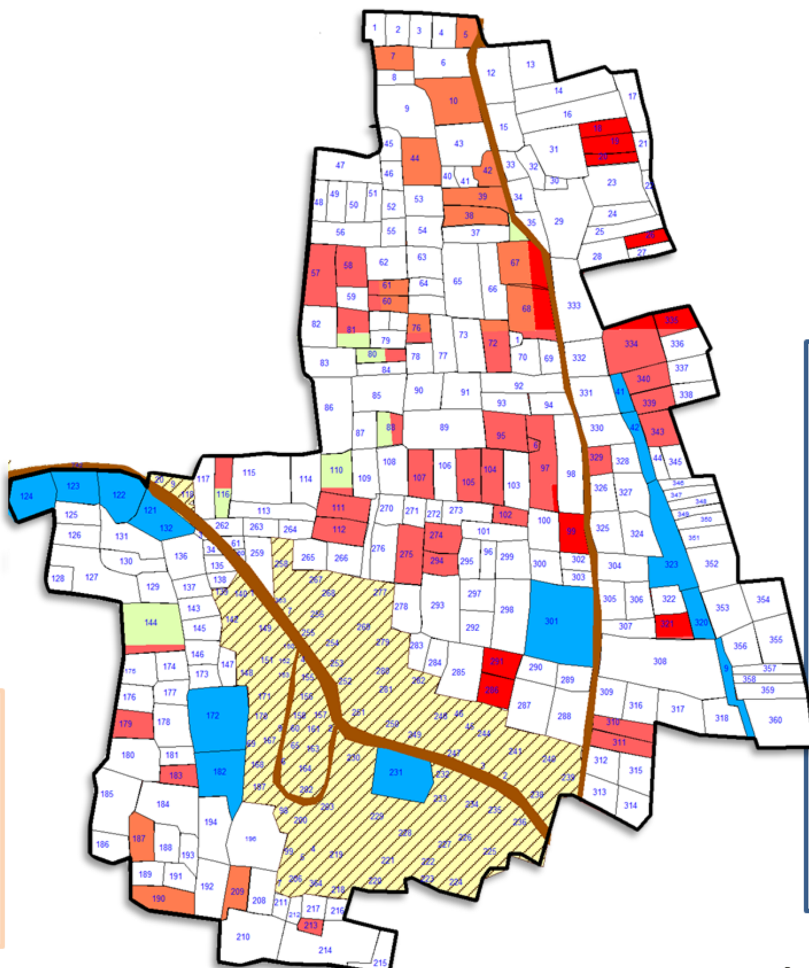

Classification of Soil Microbial Biomass Carbon (MBC)

< 50	Extremely Low
50 – 100	Very Low
101 – 150	Very Low
151 – 200	Low
201 – 250	Low
251 – 300	Low
301 – 350	Moderate
351 - 400	Moderate

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Farm Level Resource Map : Fluorescein Diacetate Hydrolysis (FDAH)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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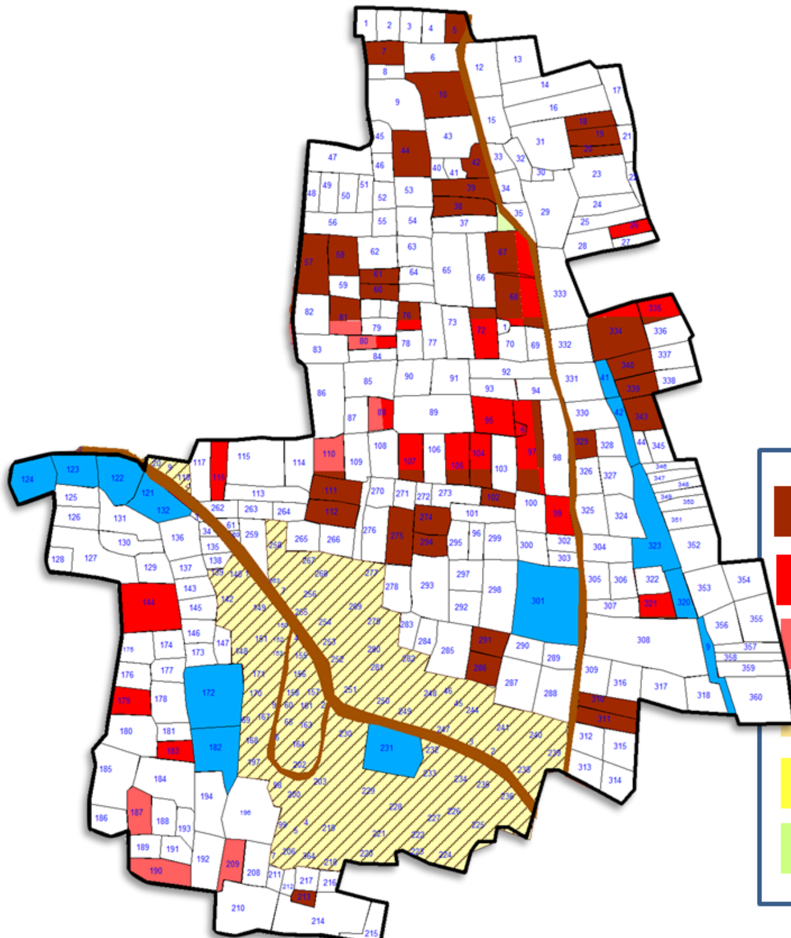

Classification of Soil Fluorescein Diacetate Hydrolysis (FDAH)

< 30	Extremely Low
30 – 60	Very Low
61 – 90	Low
91 – 120	Low
121 – 150	Moderate
151 - 180	Moderate

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Annexure - 55

Farm Level Resource Map : Soil Microbial Quotient(qMBC)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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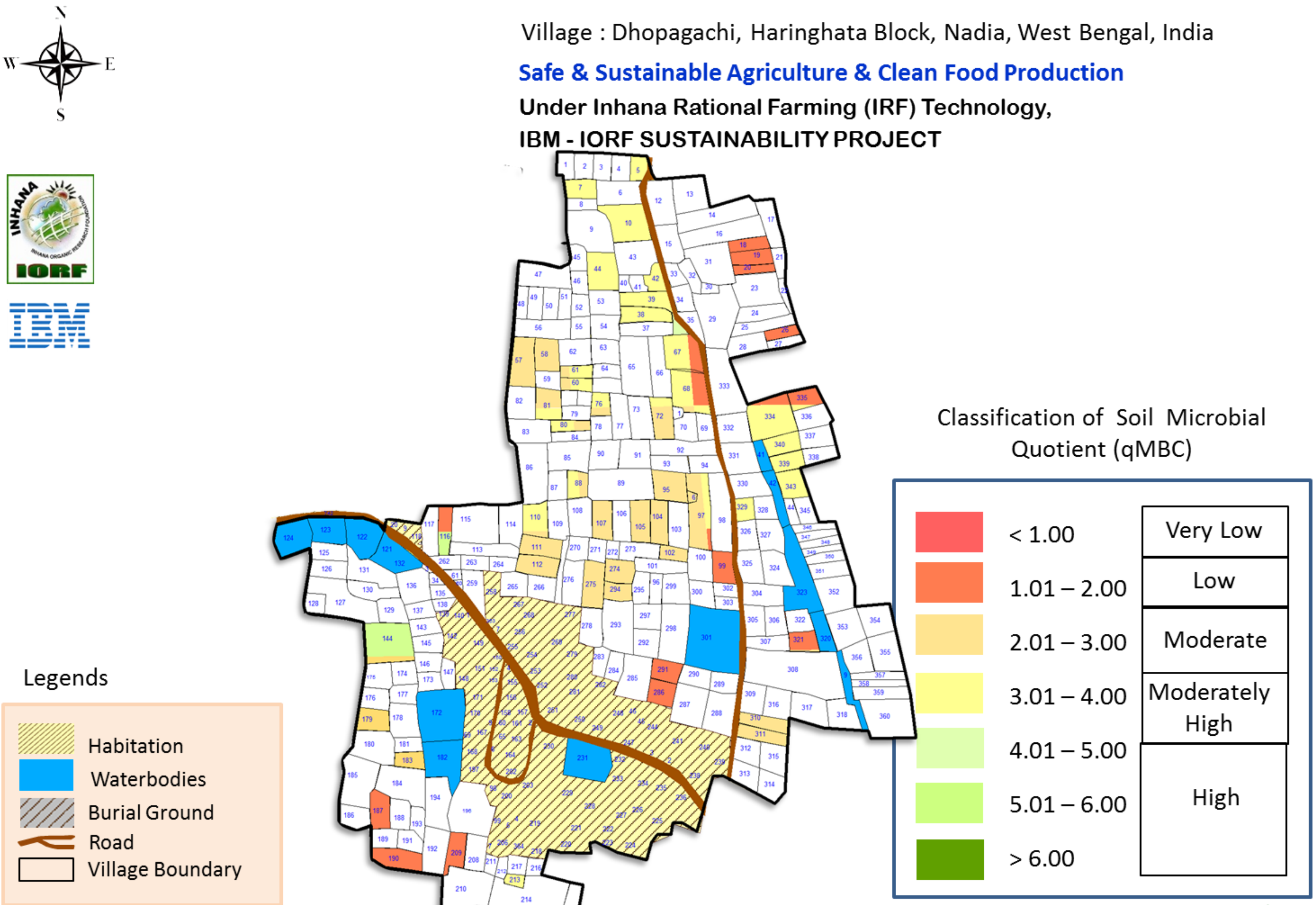

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Annexure - 56

Farm Level Resource Map : Soil Microbial Metabolic Quotient(qCO_2)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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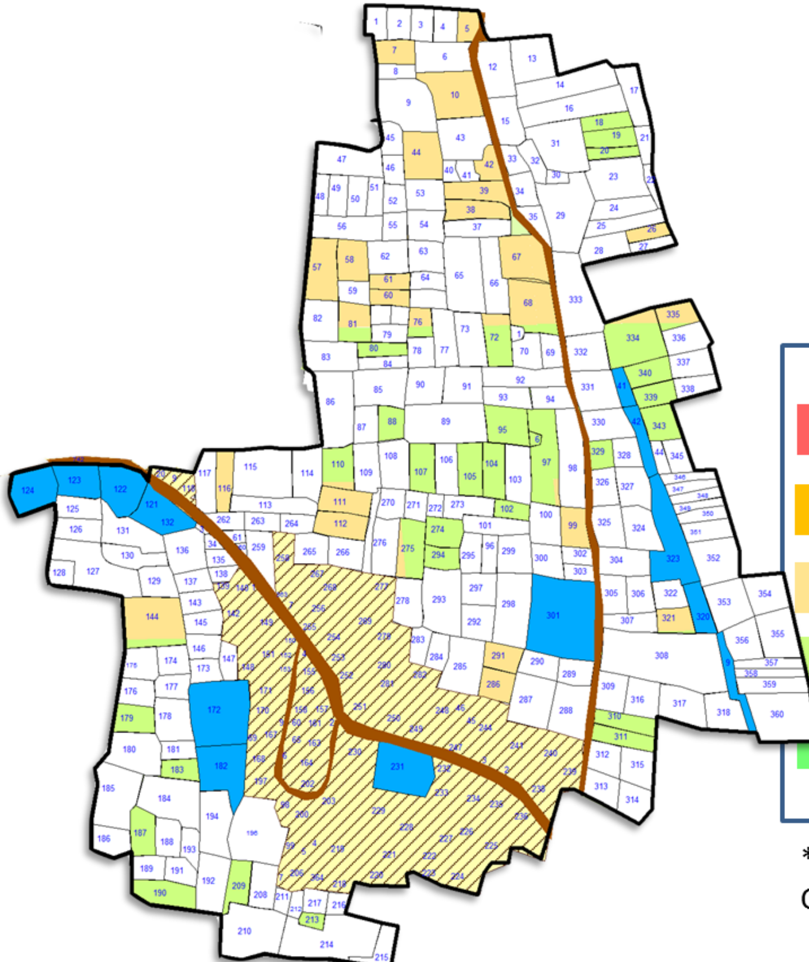

Classification of Soil Microbial Metabolic Quotient (qCO_2)

Range	Classification
5.1 – 10.0	Stressed Condition
2.6 – 5.0	Moderately Stressed
1.0 – 2.5	Slightly Stressed
< 1.00	Very Low Population
< 1.00**	Stable Condition

** Soil Microbial Biomass >300 µg CO_2 –C / g dry soil)

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Farm Level Resource Map : Soil Fertility Index (FI)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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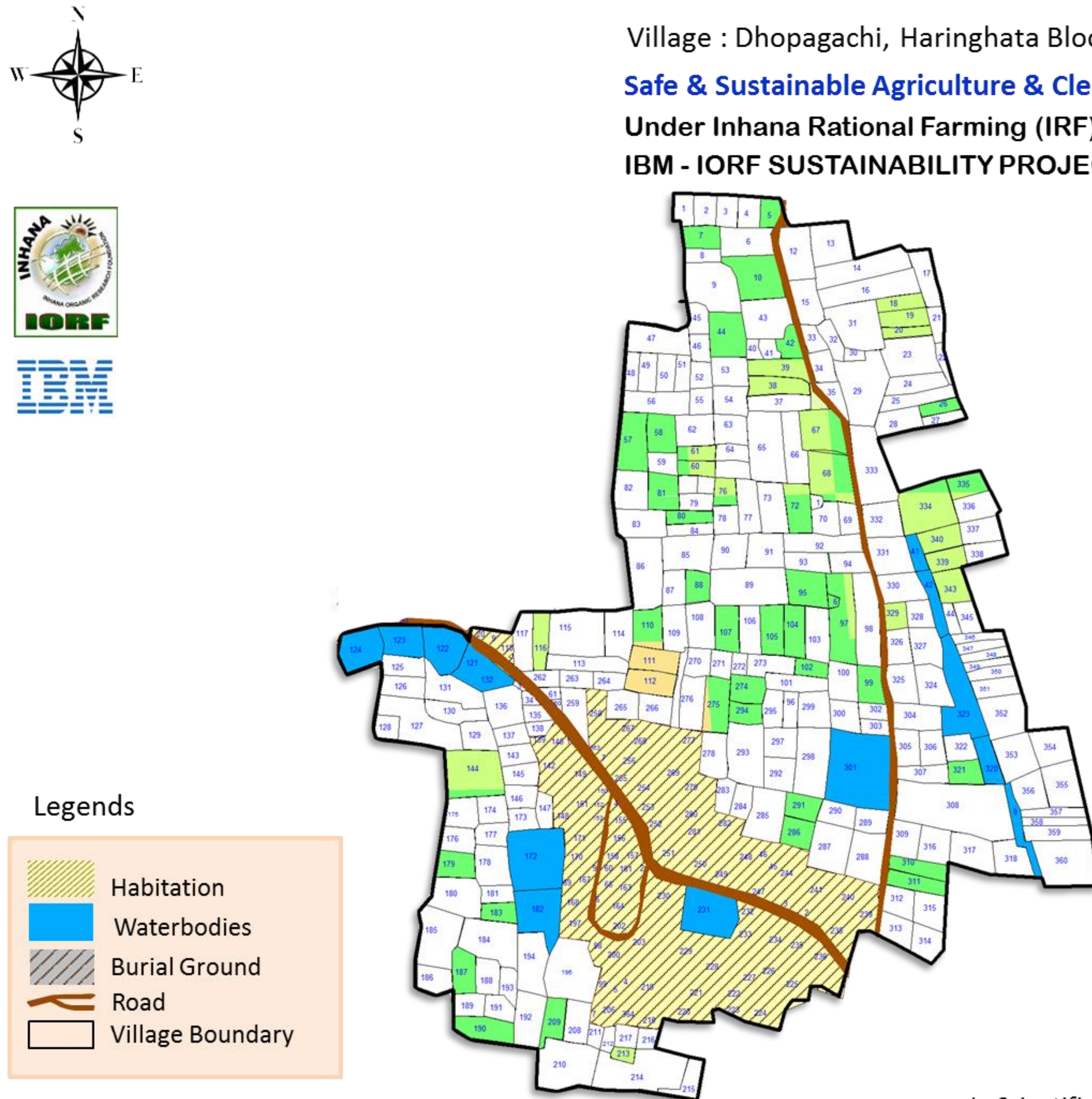

Classification of Soil Fertility Index

15.0 – 20.0	Moderate
20.1 – 25.0	Moderately High
25.1 – 30.0	High
30.1 – 35.0	Very High

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Annexure - 58

Farm Level Resource Map : Soil Microbial Activity Potential (MAP)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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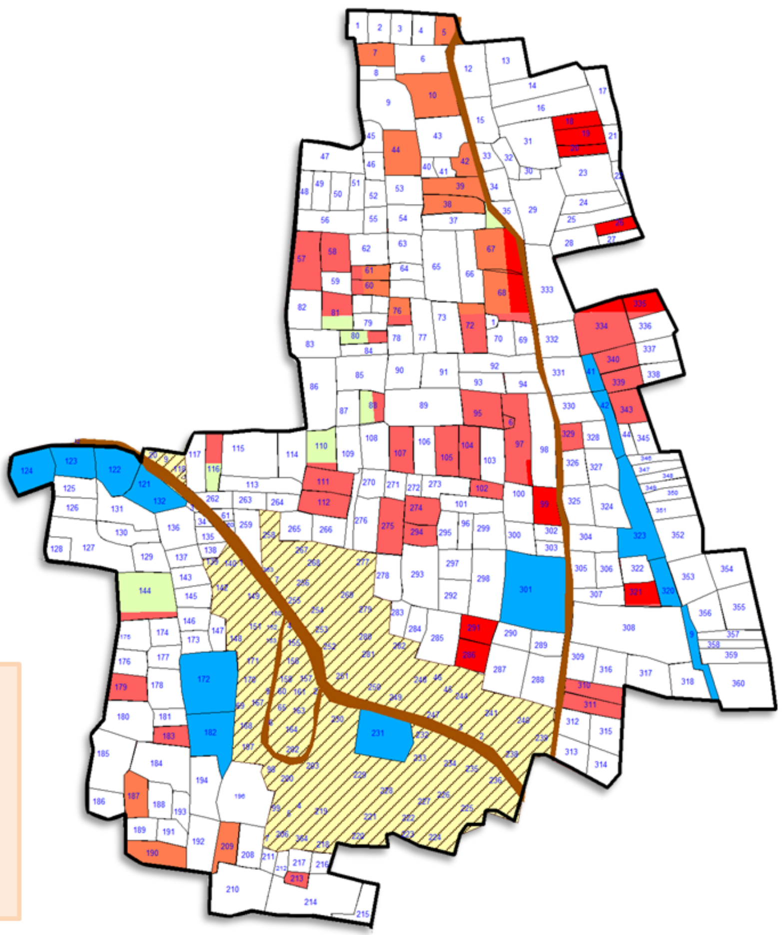

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Microbial Activity Potential (MAP)

> 4.0	Extremely Low
4.0 – 6.0	Very Low
6.1 – 8.0	Very Low
8.1 – 10.0	Low
10.1 – 12.0	Moderate
12.1 – 14.0	Moderately High
14.1 – 16.0	Moderately High
16.1 – 18.0	High
18.1 – 20.0	High

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Farm Level Resource Map : Soil Physical Index (PI)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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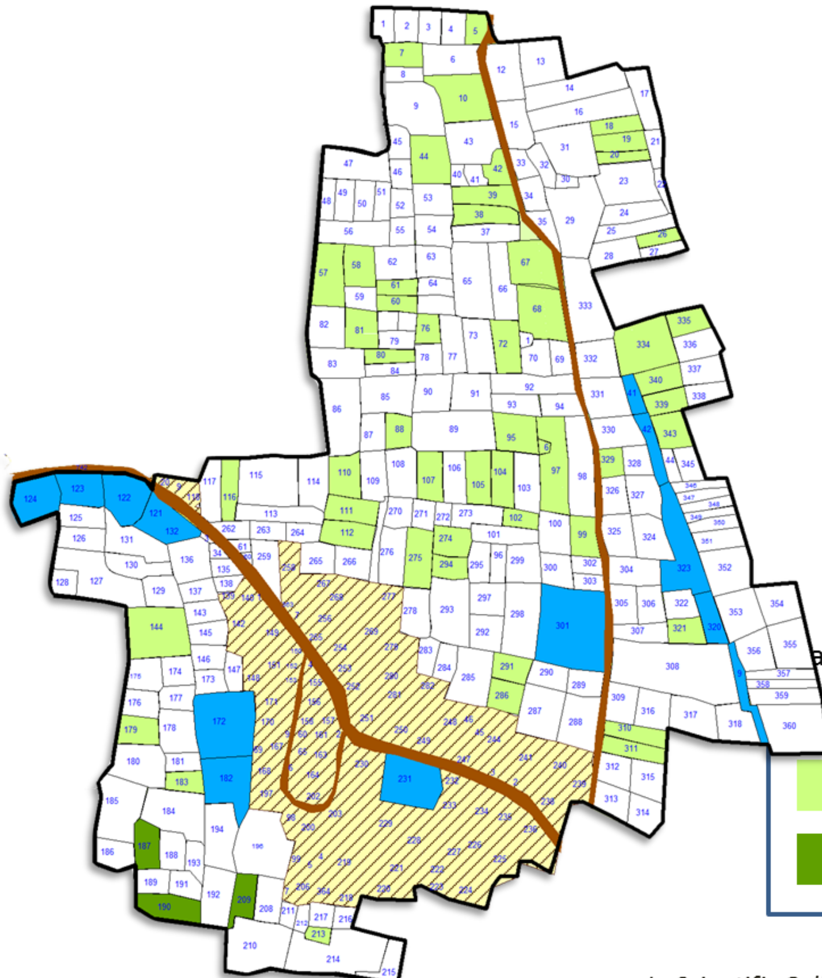

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

assification of Soil Physical Index (PI)

19.0 – 23.0	Good
> 23.0	Very Good

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Annexure - 60

Farm Level Resource Map : Soil Quality Index (SQI)

Village : Dhopagachi, Haringhata Block, Nadia, West Bengal, India

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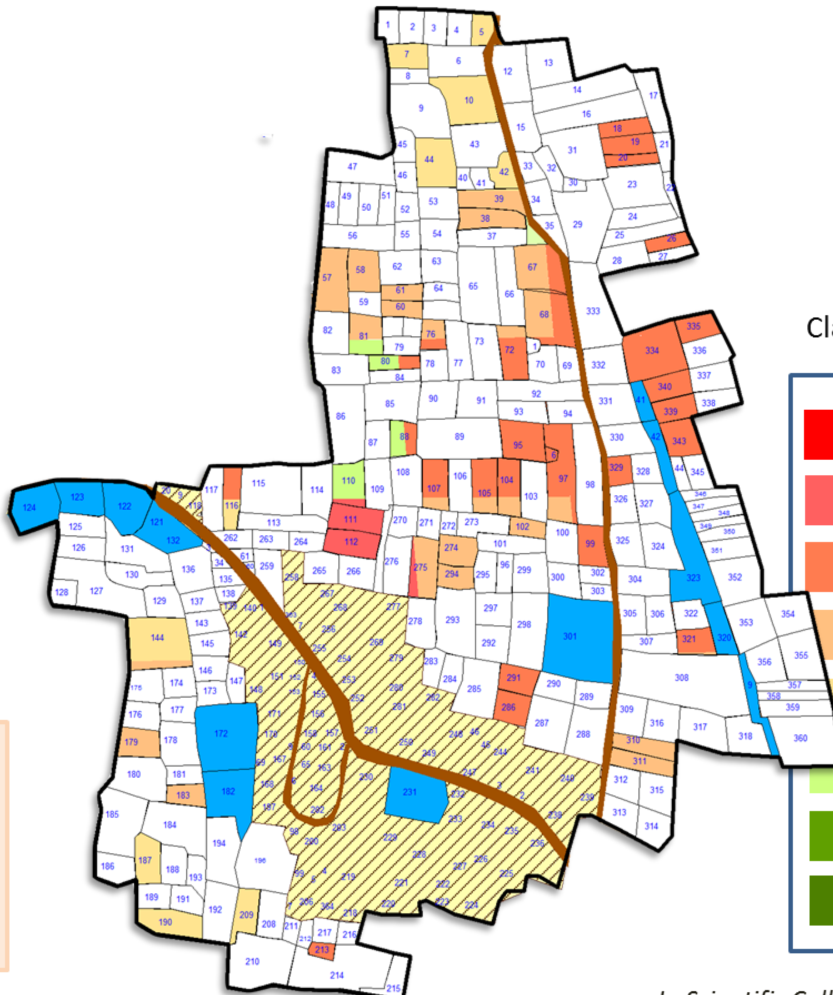

Classification of Soil Quality Index

0.35 – 0.40	Poor
0.41 – 0.45	Poor
0.46 – 0.50	Moderate
0.51 – 0.55	Moderate
0.56 – 0.60	Moderate
0.61 – 0.65	Moderately High
0.66 – 0.70	Moderately High
0.71 – 0.75	Moderately High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Annexure - 61

Farm Level Resource Map : Soil pH

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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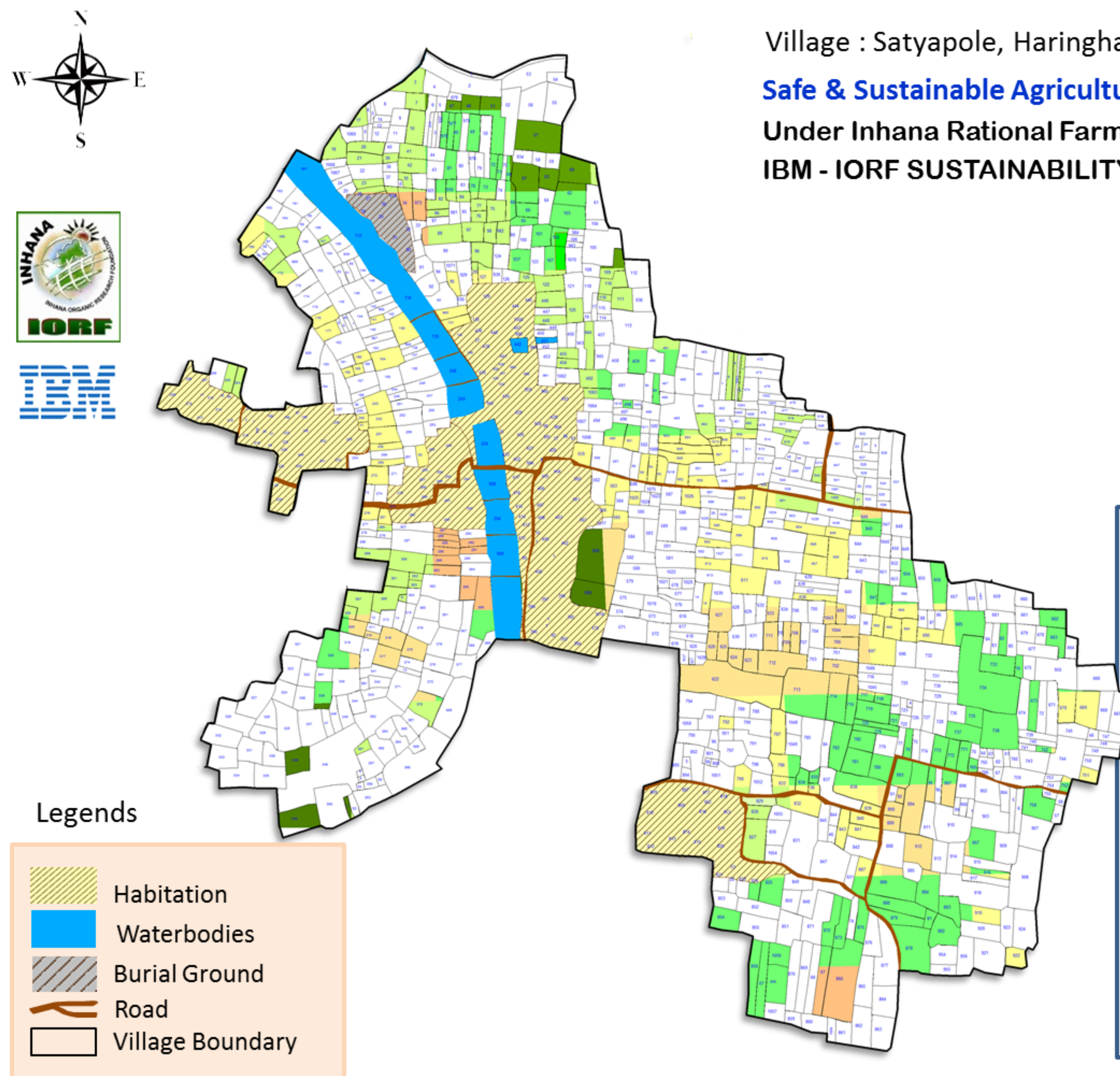

Classification of Soil pH

5.25 – 5.50	Moderate Limitation
5.51 – 5.75	Moderate Limitation
5.76 – 6.00	Slight Limitation
6.01 – 6.25	Slight Limitation
6.26 – 6.50	Slight Limitation
6.51 – 6.75	Slight Limitation
6.76 – 7.00	No Limitation
7.01 – 7.25	No Limitation

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Annexure -62

Farm Level Resource Map : Soil Org. C (%)

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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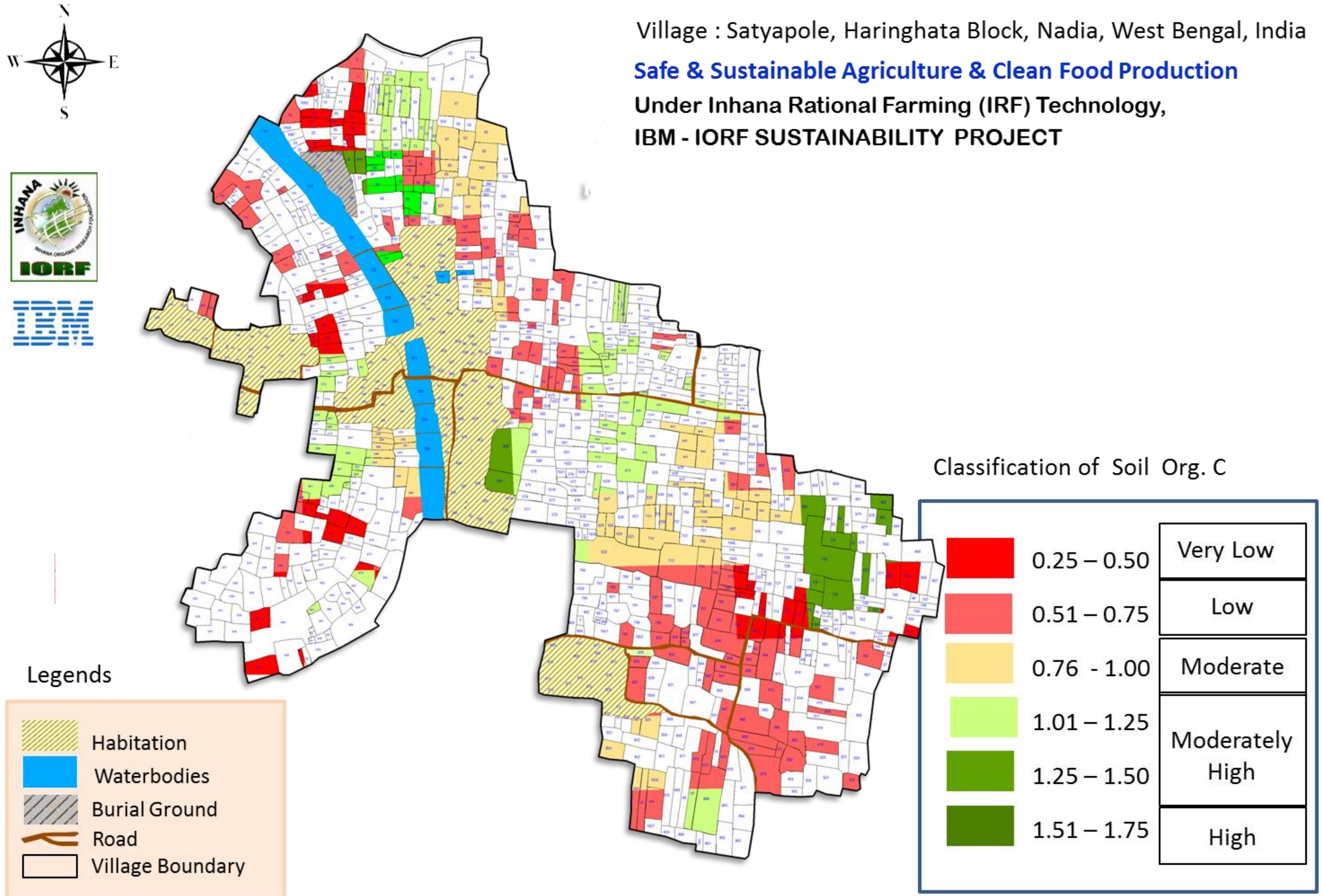

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Farm Level Resource Map : Soil Available Nitrogen (Kgha^{-1})

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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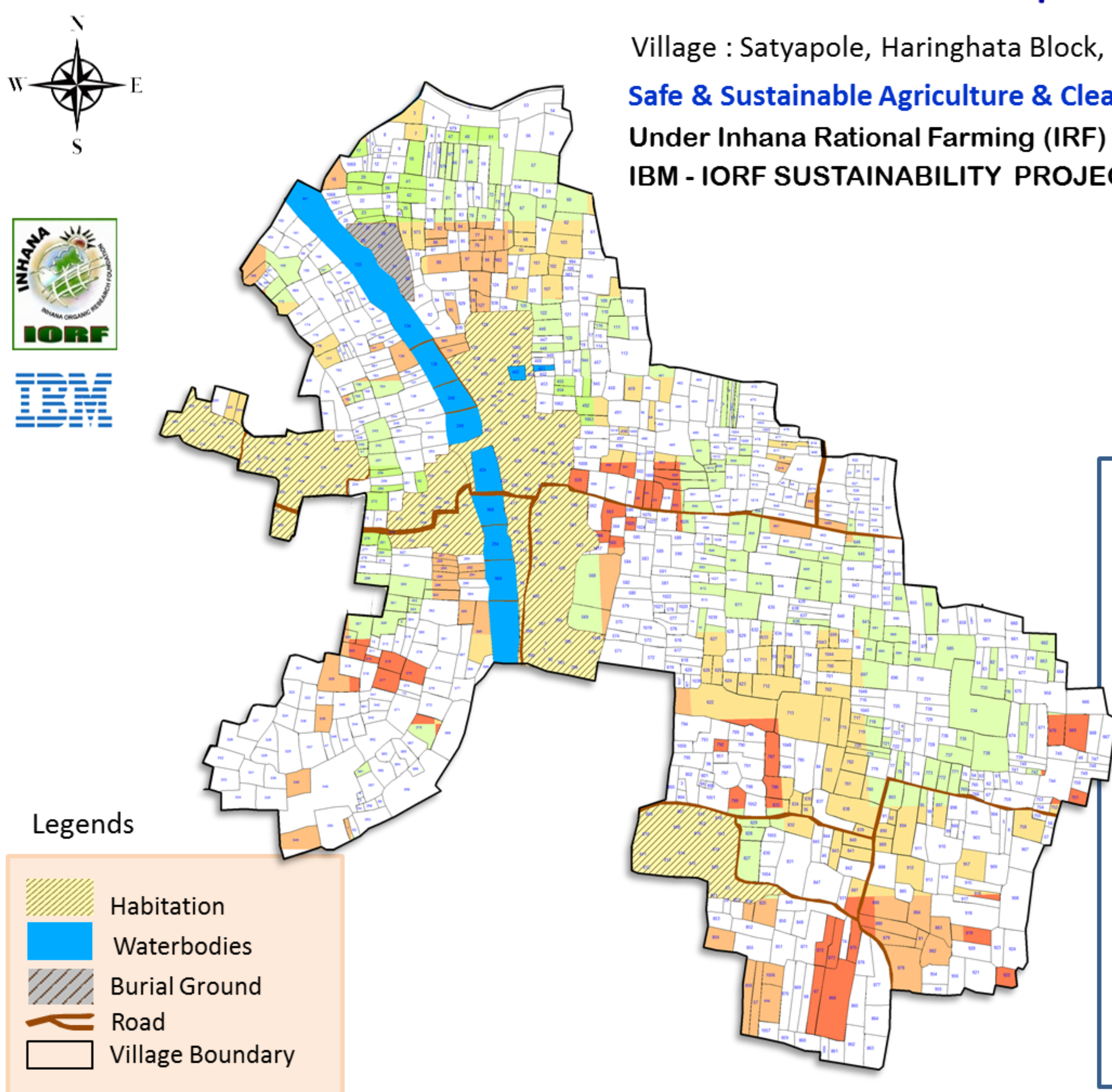

Classification of Soil Available N

200 – 240	Low
241 – 280	Low
281 – 320	Moderate
321 – 360	Moderate
361 – 400	Moderately High
401 – 440	Moderately High
441 – 480	Moderately High
481 – 520	High
521 – 560	High

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Farm Level Resource Map : Soil Available Phosphate (Kgha[-1])

Annexure - 64

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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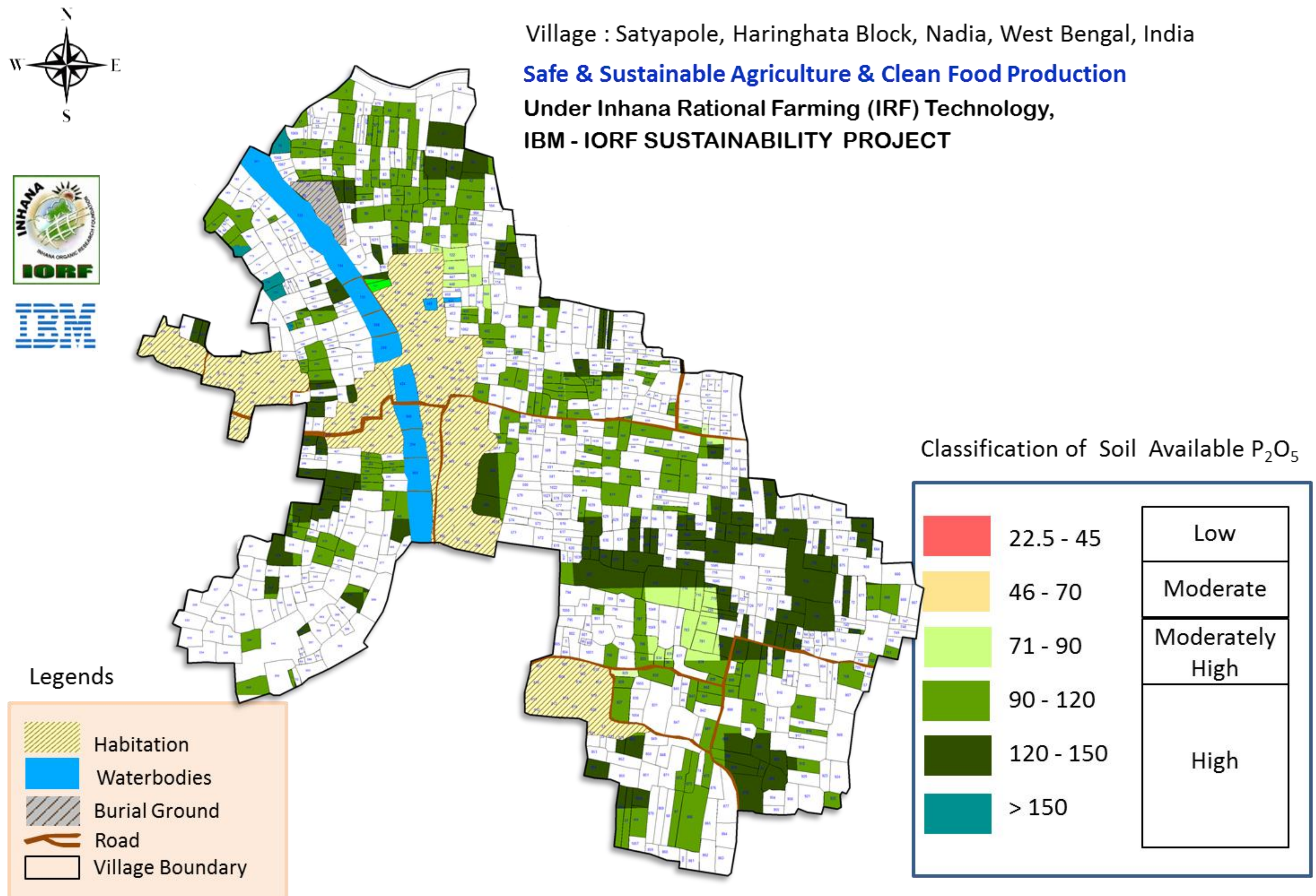

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Annexure - 65

Farm Level Resource Map : Soil Available Potash ($Kgha^{-1}$)

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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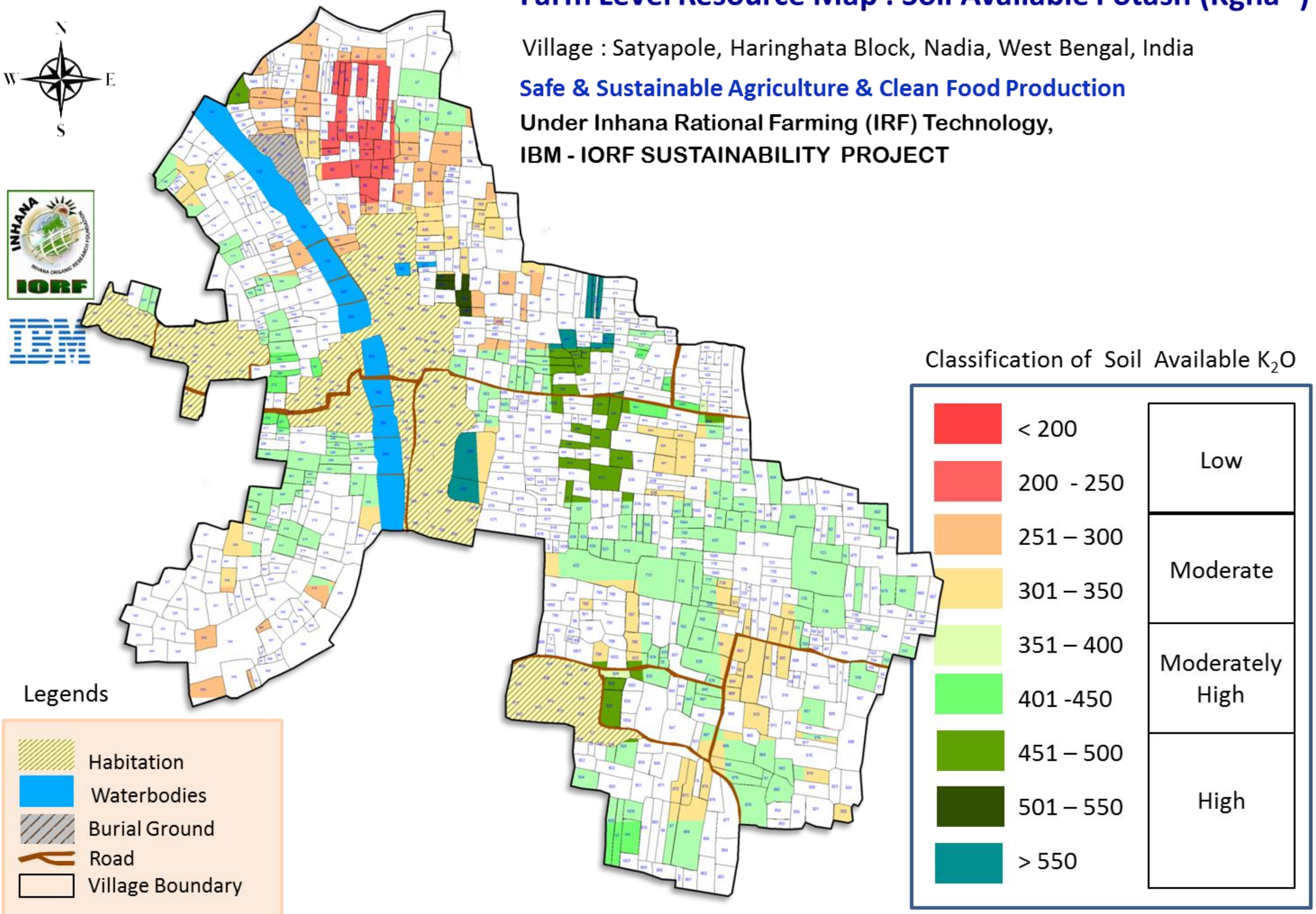

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Annexure -6 6

Farm Level Resource Map : Soil Available Sulphate (Kgha^{-1})

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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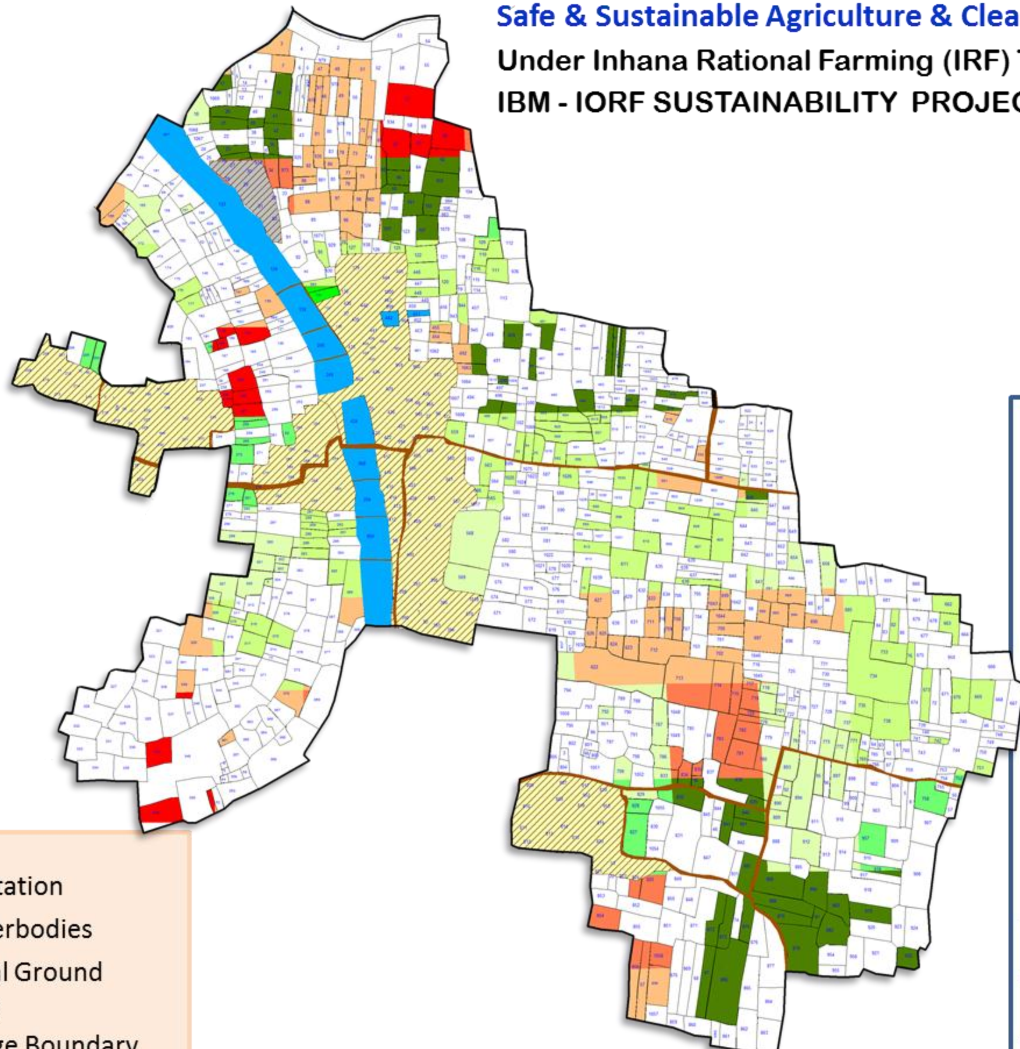

Classification of Soil Available SO_4

< 20	Very Low
20 – 40	Low
41 – 60	Low
61 – 80	Moderate
81 – 100	Moderate
101 – 120	Moderately High
121 – 140	Moderately High
141 – 160	High
> 160	High

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

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Farm Level Resource Map : Soil Available Nitrate (mgKg^{-1})

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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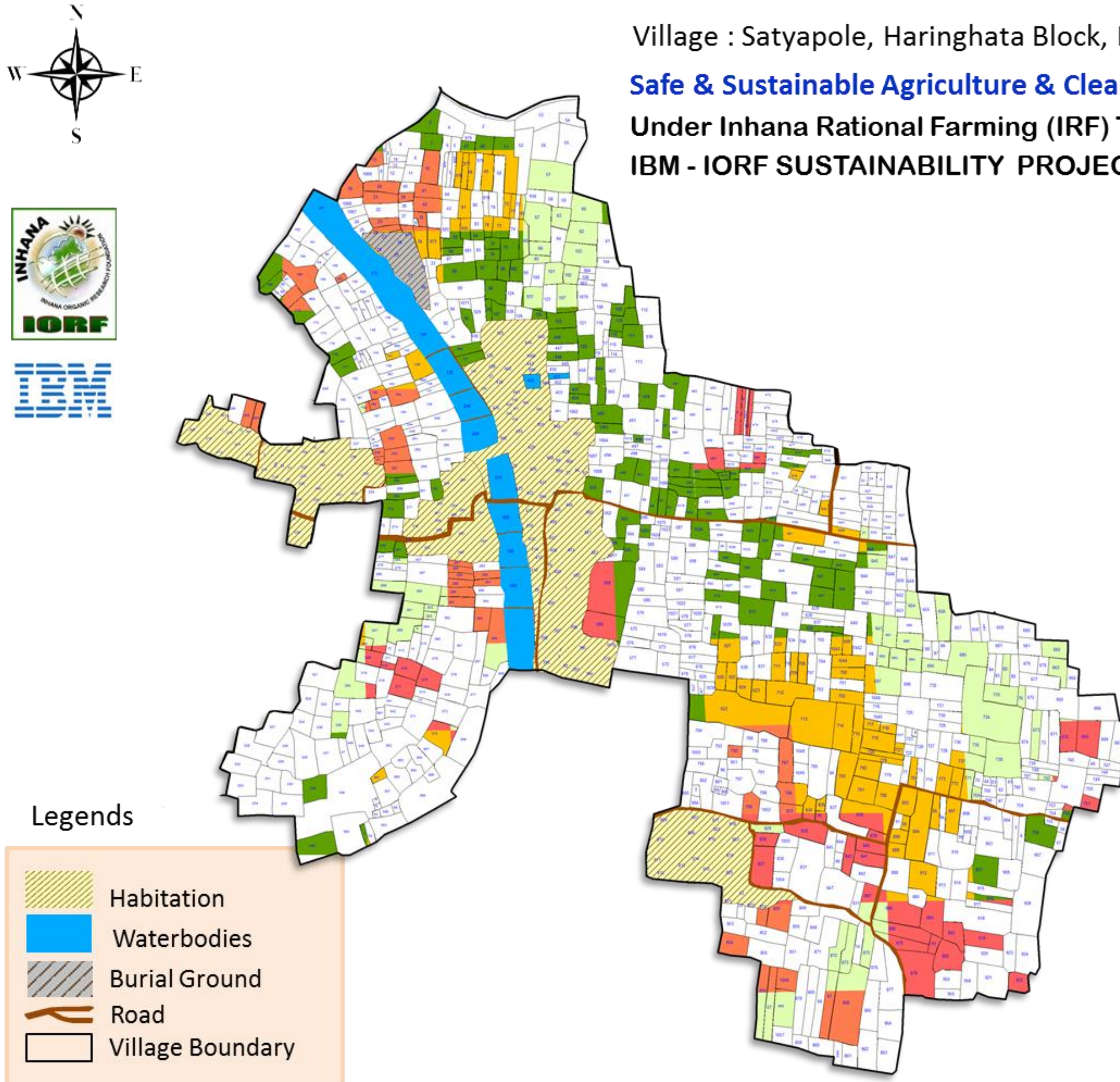

Classification of Soil Available NO_3

	20 – 30	Moderately Good
	31 – 40	Good
	41 – 60	Cautious
	61 -80	Very Cautious
	>80	Extremely Cautious

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Annexure -68

Farm Level Resource Map : Soil Microbial Biomass Carbon (MBC)

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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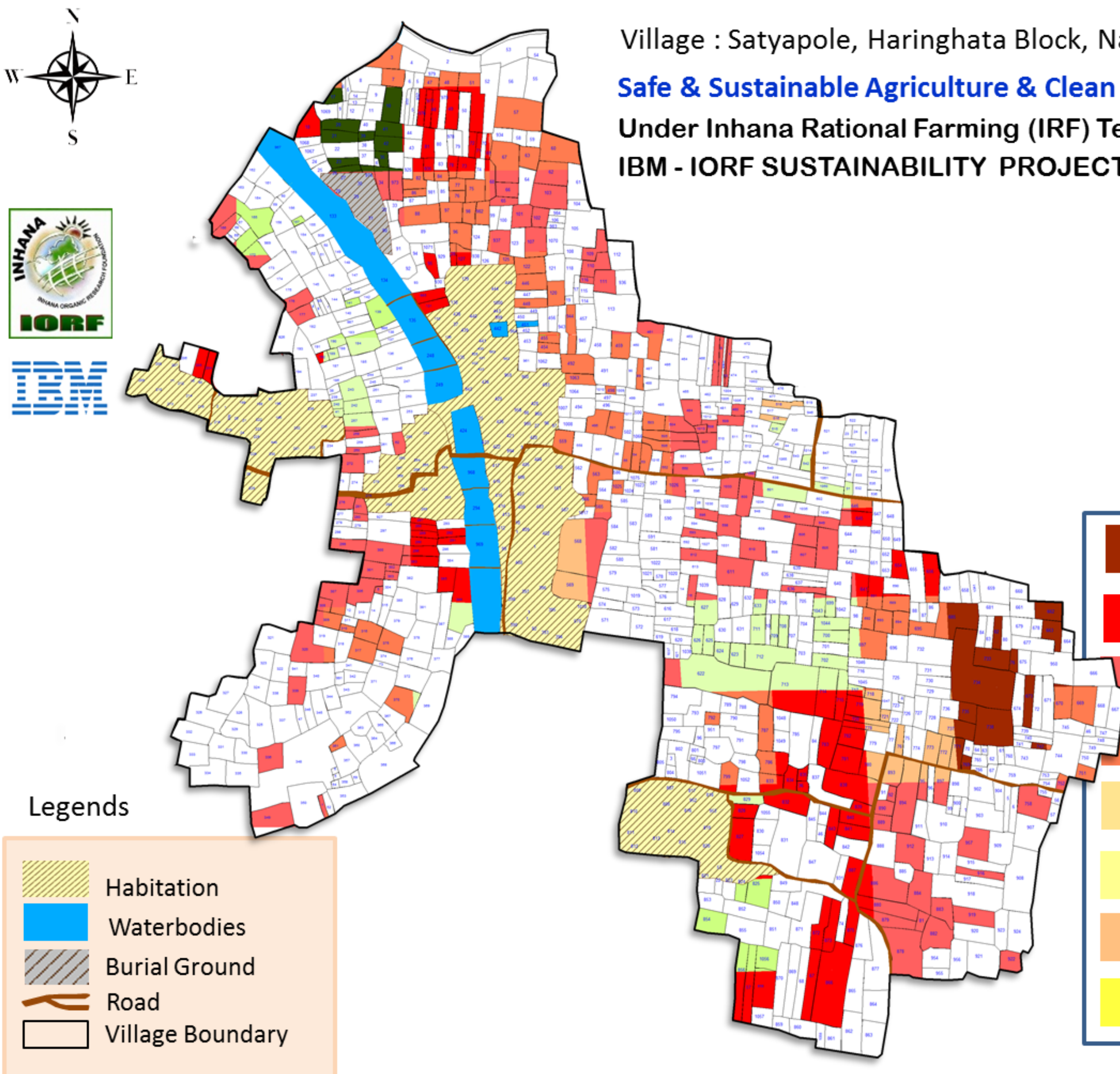

Classification of Soil Microbial Biomass Carbon (MBC)

MBC	Class
< 50	Extremely Low
50 – 100	Very Low
101 – 150	Very Low
151 – 200	Low
201 – 250	Low
251 – 300	Low
301 – 350	Moderate
351 - 400	Moderate

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Annexure -6 9

Farm Level Resource Map : Fluorescein Diacetate Hydrolysis (FDAH)

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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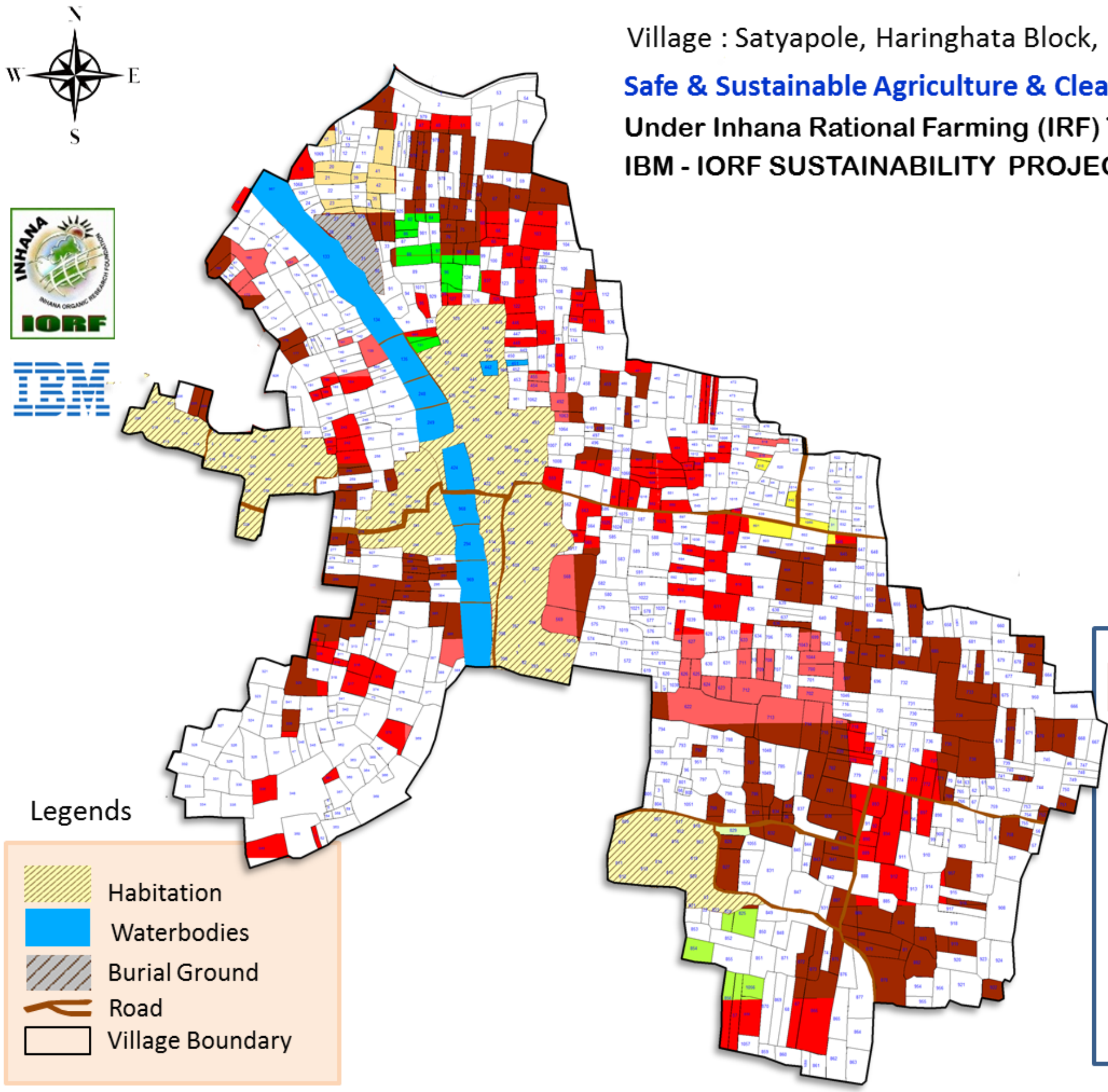

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Fluorescein Diacetate Hydrolysis (FDAH)

	< 30	Extremely Low
	30 – 60	Very Low
	61 – 90	Low
	91 – 120	Low
	121 – 150	Moderate
	151 - 180	Moderate

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Farm Level Resource Map : Soil Microbial Quotient(qMBC)

Annexure - 70

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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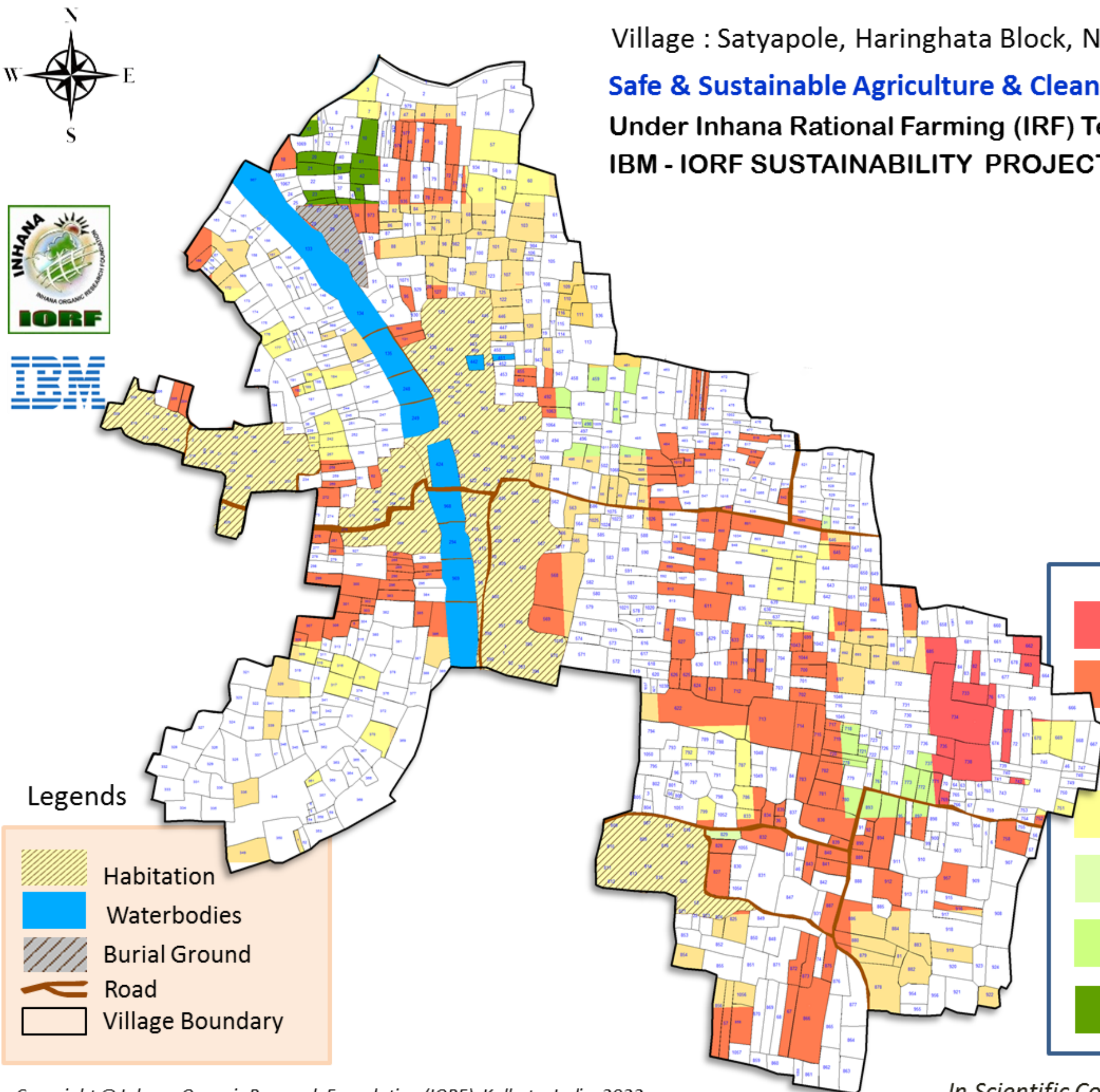

Classification of Soil Microbial Quotient (qMBC)

< 1.00	Very Low
1.01 – 2.00	Low
2.01 – 3.00	Moderate
3.01 – 4.00	Moderately High
4.01 – 5.00	High
5.01 – 6.00	High
> 6.00	High

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Farm Level Resource Map : Soil Microbial Metabolic Quotient(qCO_2)

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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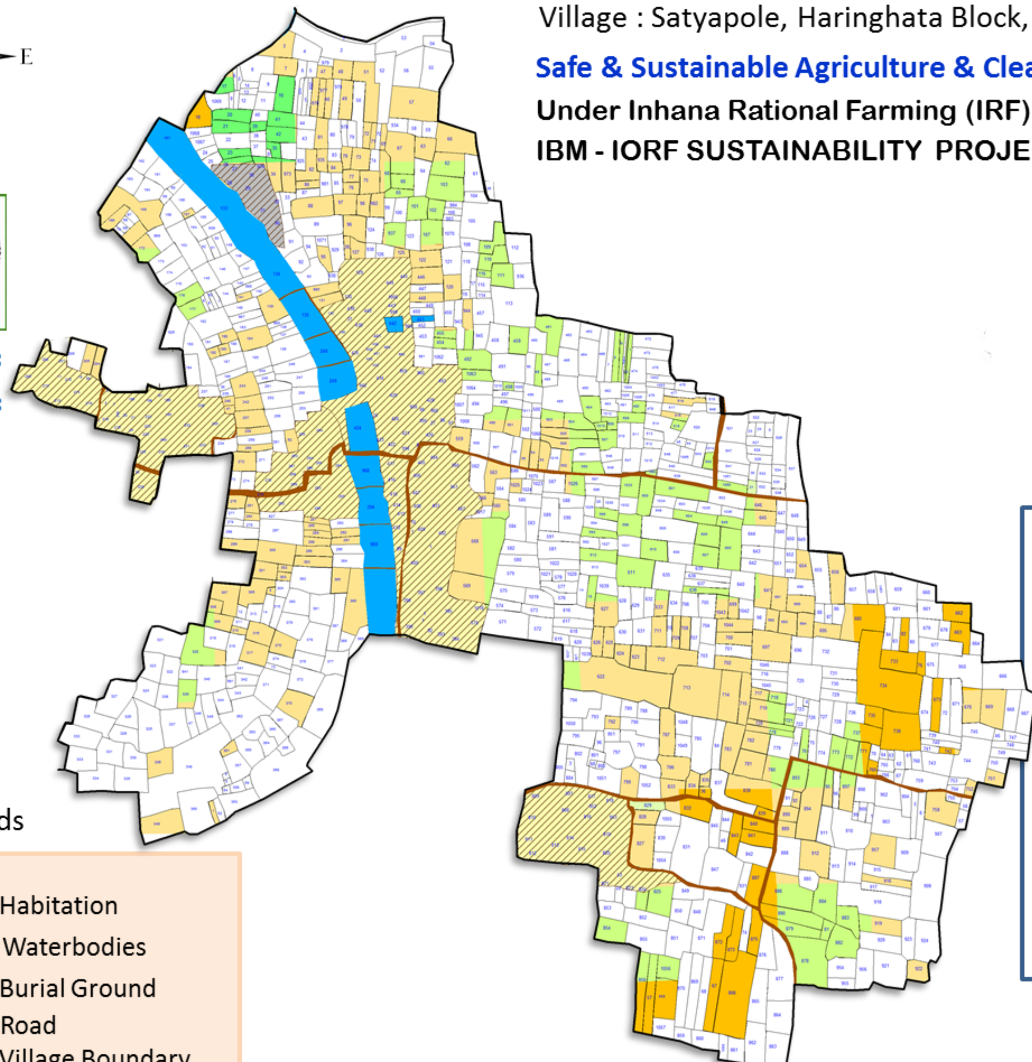

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Microbial Metabolic Quotient (qCO_2)

5.1 – 10.0	Stressed Condition
2.6 – 5.0	Moderately Stressed
1.0 – 2.5	Slightly Stressed
< 1.00	Very Low Population
< 1.00**	Stable Condition

** Soil Microbial Biomass >300 µg CO_2 –C / g dry soil)

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Farm Level Resource Map : Soil Fertility Index (FI)

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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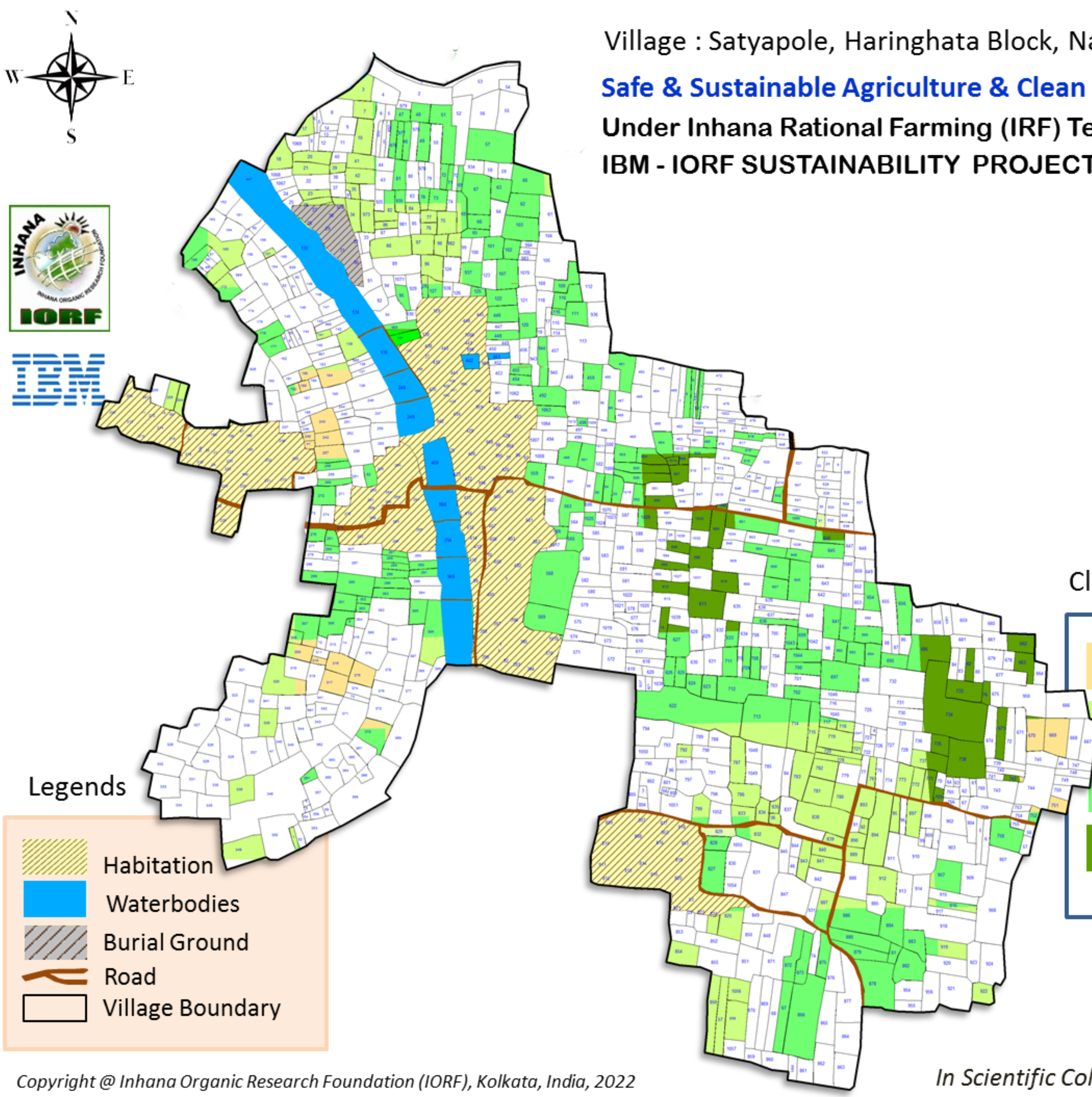

Classification of Soil Fertility Index

	15.0 – 20.0	Moderate
	20.1 – 25.0	Moderately High
	25.1 – 30.0	High
	30.1 – 35.0	Very High

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Annexure - 73

Farm Level Resource Map : Soil Microbial Activity Potential (MAP)

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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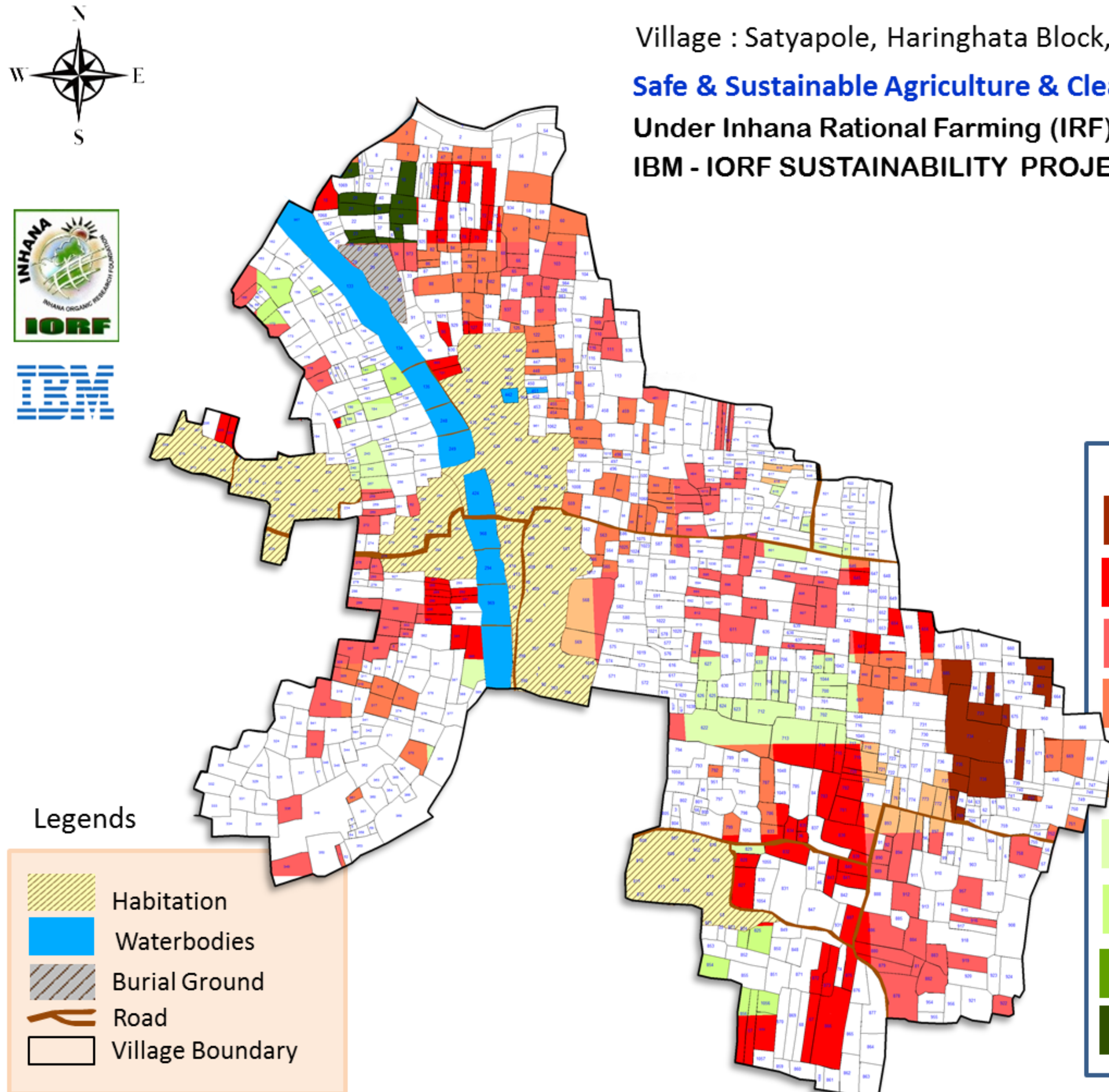

Classification of Soil Microbial Activity Potential (MAP)

> 4.0		Extremely Low
4.0 – 6.0		Very Low
6.1 – 8.0		
8.1 – 10.0		Low
10.1 – 12.0		Moderate
12.1 – 14.0		Moderately High
14.1 – 16.0		
16.1 – 18.0		High
18.1 – 20.0		

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Annexure - 74

Farm Level Resource Map : Soil Physical Index (PI)

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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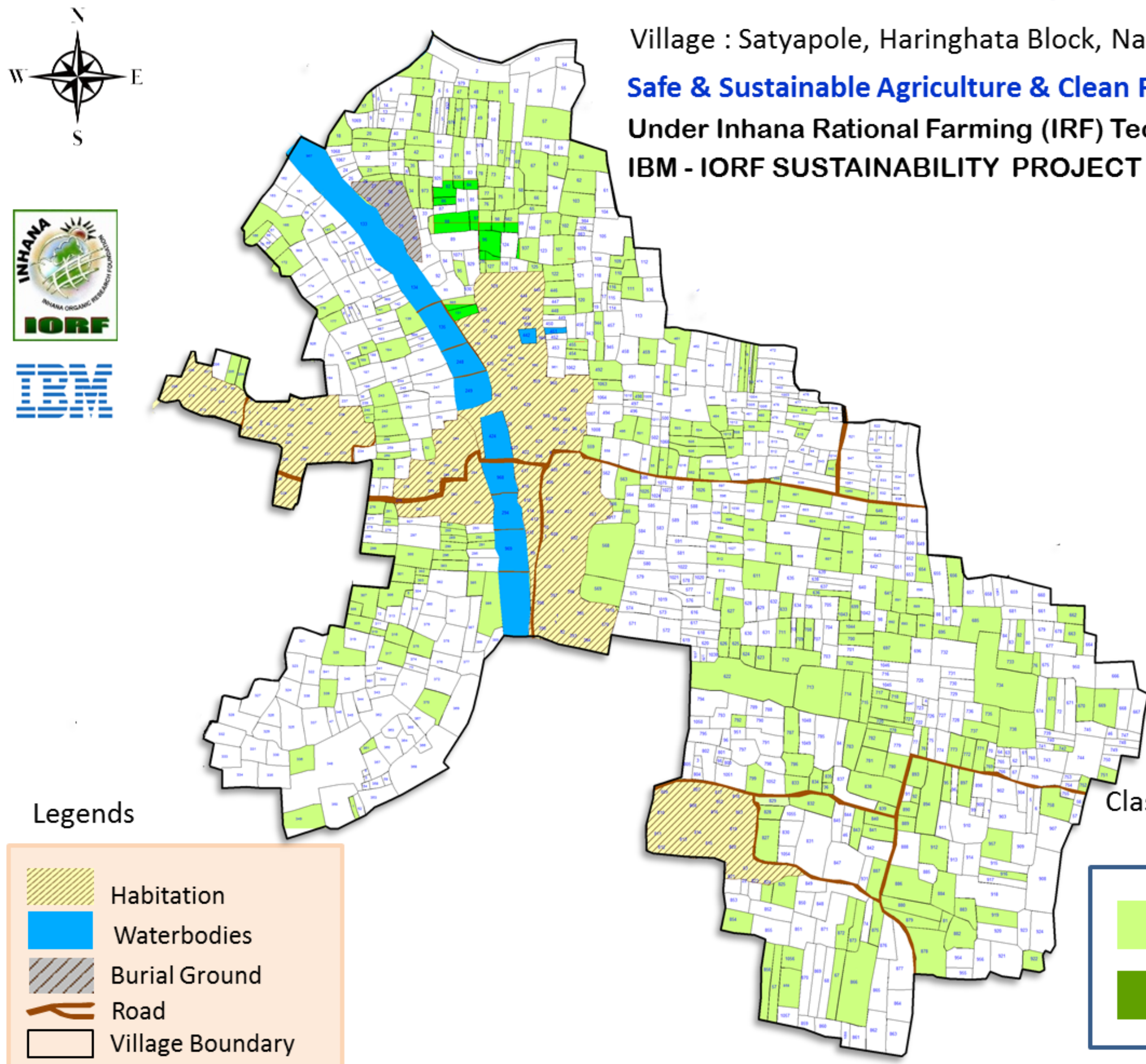

Legends

- Habitation
- Waterbodies
- Burial Ground
- Road
- Village Boundary

Classification of Soil Physical Index (PI)

	19.0 – 23.0	Good
	> 23.0	Very Good

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Farm Level Resource Map : Soil Quality Index (SQI)

Village : Satyapole, Haringhata Block, Nadia, West Bengal, India

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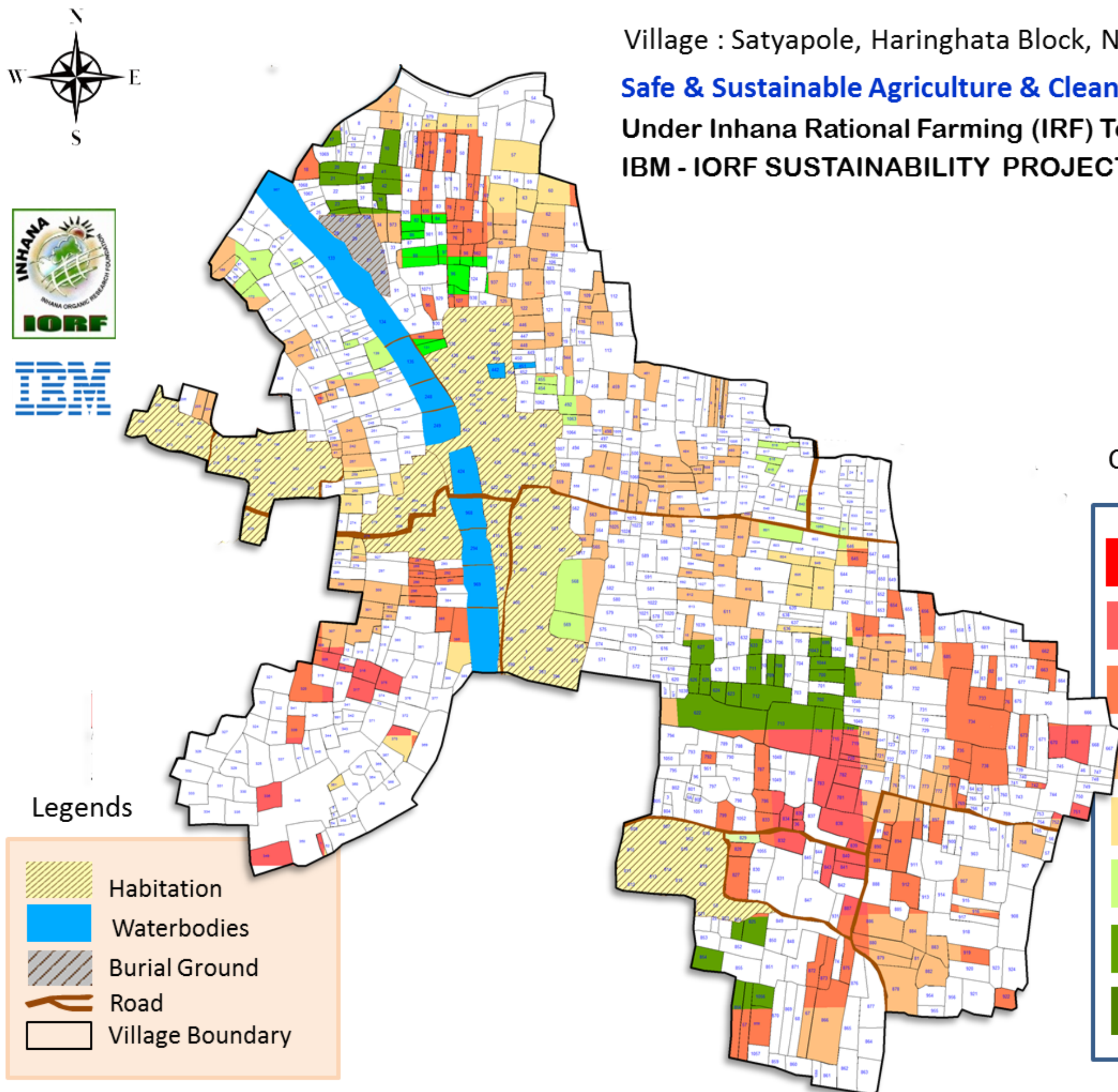

Classification of Soil Quality Index

0.35 – 0.40	Poor
0.41 – 0.45	
0.46 – 0.50	Moderate
0.51 – 0.55	
0.56 – 0.60	
0.61 – 0.65	Moderately High
0.66 – 0.70	
0.71 – 0.75	

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