Project Report

Enabling Smallholders in Odisha to Produce and Consume More Nutritious Food through Agroforestry Systems

April 2018 – March 2023

Submitted to

The Directorate of Soil Conservation and Watershed Development, Odisha Bhubaneshwar

by

World Agroforestry (ICRAF) India Program

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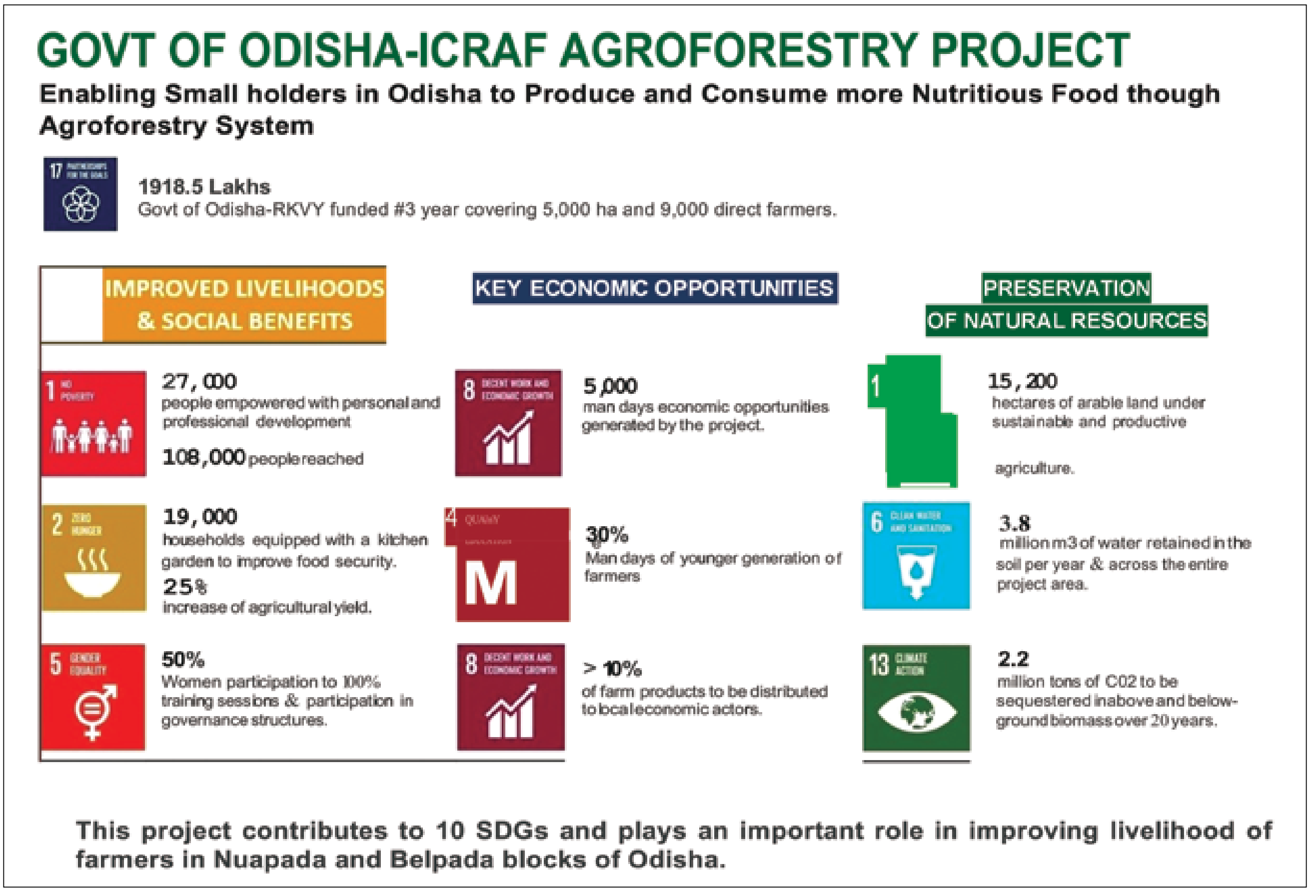
Abbreviations

OFSS	Odisha Food Security Scheme
ICAR	Indian Council of Agricultural Research
CAZRI	Central Arid Zone Research Institute
CAFRI	Central Agroforestry Research Institute
NRRI	National Rice Research Institute
OUAT	Odisha University of Agricultural Science and Technology
MPTs	Multipurpose trees
QPM	Quality planting material
WSHGs	Women’s self-help groups
OSSC	Odisha State Seed Corporation
NRM	Natural resource management
INR 1 lakh	1333.33333 USD (2023)


GOVT OF ODISHA-ICRAF AGROFORESTRY PROJECT
Enabling Small holders in Odisha to Produce and Consume more Nutritious Food though Agroforestry System
1918.5 Lakhs
Govt of Odisha-RKVY funded #3 year covering 5,000 ha and 9,000 direct farmers.
IMPROVED LIVELIHOODS & SOCIAL BENEFITS
KEY ECONOMIC OPPORTUNITIES
PRESERVATION OF NATURAL RESOURCES
27, 000
people empowered with personal and professional development
108,000 people reached
5,000
man days economic opportunities generated by the project.
15, 200
hectares of arable land under sustainable and productive agriculture.
19, 000
households equipped with a kitchen garden to improve food security.
25%
increase of agricultural yield.
30%
Man days of younger generation of farmers
3.8
million m3 of water retained in the soil per year & across the entire project area.
50%
Women participation to 100% training sessions & participation in governance structures.
> 10%
of farm products to be distributed to local economic actors.
2.2
million tons of C02 to be sequestered in above and below-ground biomass over 20 years.
This project contributes to 10 SDGs and plays an important role in improving livelihood of farmers in Nuapada and Belpada blocks of Odisha.

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1. Executive Summary

In Odisha, about 40% of children below the age of five suffer from the problem of being underweight (Nutrition Baseline Survey 2011; http://www.nrhmorissa.gov.in). This condition has been exacerbated by the low standard of living index wherein 43% of all households were in the lowest category (CCM II survey, Concurrent Monitoring, II, Odisha State, 2014-2015). Close to 83% of Odisha's people live in rural areas and about 61.80% of the 17.50 million workforce are employed in agriculture. However, the sector suffers frequent natural calamities, such as cyclones, droughts and flash floods. All these together have forced a sizable population, especially from the western Odisha districts of Balangir and Nuapada, to move out of the State under stress migration. To improve the nutritional status of communities in Odisha, it was imperative to introduce specific interventions around food that addressed the underlying determinants of malnutrition.

ICRAF in its proposal to the Department of Agriculture and Farmers Empowerment (DAFE), Government of Odisha, proposed to deploy a SMART protocol (Specific, Measurable, Achievable, Realistic and Tangible), to advocate a gradual transition and transformation of purely "field crop agricultural practices" to "agroforestry livelihoods' systems" to ensure the availability of food, including fresh fruit and vegetables and fodder for livestock, throughout the year. The proposal was approved under the Rashtriya Krishi Vikas Yojana (RKVY), Government of India.

To implement the project, Enabling Smallholders to Produce and Consume More Nutritious Food through Agroforestry Systems, a Memorandum of Agreement was signed with the Government of Odisha's Directorate of Soil Conservation and Watershed Development on 28 February 2018. The project's target areas in Balangir and Nuapada districts were drought-prone, mainly monoculturally cropped, with resource-poor, small-scale, and marginalized farmers facing the challenges of food and nutritional insecurity and stress migration.

The project aimed to support 9000 farmers within an area of 5000 ha across 20 gram panchayats (GPs; a cluster of a few villages as a seat of local governance) of Belpada Block and 10 GPs of Nuapada Block, of Balangir and Nuapada districts, respectively. The objectives of the project were, primarily, 1) creating awareness of the benefits of consuming diversified, nutritious farm produce; 2) introducing and accelerating adoption of suitable agroforestry systems; 3) generating employment and income to reduce in-country migration; 4) assessing the impact of introduced interventions; and 5) building the capacity of all stakeholders.

The project's inception workshop was held on 2 May 2018 in Bhubaneshwar under the chairmanship of the Principal Secretary of DAFE, Government of Odisha and was followed by the meeting of the State Steering Committee (SC) wherein modalities of implementation of the project were decided. Accordingly, annual action plans were developed and implemented with the approval of the SC, which, under the chairmanship of the Principal Secretary, DAFE, met every year to evaluate progress and suggest modification of activities, as necessary. Besides this, the yearly State Monitoring Committee, under the chairmanship of the Special Secretary, DAFE, Government of Odisha monitored progress, visiting work sites and obtaining feedback from farmers.

To select the project implementation areas, the project team initiated close interactions with all stakeholders and repeatedly visited the proposed areas, interacting with line departments and other partners, besides conducting a baseline survey.

The project implementation area of 5008 ha was selected in Balangir and Nuapada districts of Odisha in two blocks (one in each district) of about 149 villages in the 30 GPs (20 GPs with 108 villages in Belpada Block of Balangir and 10 GPs with 41 villages in Nuapada Block of Nuapada). Selection of participating farmers was done through scientist–farmer interaction meetings in various selected GPs as decided in discussion with Agriculture officers and other officials.

The project was implemented in close collaboration with State departments, led by the Department of Soil Conservation and Watershed Development with technical inputs from institutes of the Indian Council of Agricultural Research's Central Agroforestry Research Institute (ICAR-CAFRI) Jhansi, National Rice Research Institute (NRRI) Cuttack, Central Arid Zone Research Institute (CAZRI) Jodhpur, and Odisha University of

Agriculture and Technology (OUAT) Bhubaneswar. The project activities were implemented according to the State departments' priorities, which linked to the overall goal and outcome of the project.

The project significantly achieved all targets despite the COVID-19 pandemic. Overall, the project's performance was high against all targets, registering more than 100% achievements, except for the target of scientist–farmer interaction for selection of beneficiaries, which was restricted owing to the pandemic, though here also it was 80% achievement.

The project identified small-scale and marginalized farmers to grow paddy in agroforestry systems wherein fruit and/or multipurpose trees (MPTs) were grown on bunds (boundaries) of paddy fields. With the introduction of new varieties, increased seed replacement rate, seed priming and seed treatment, guided plant protection, and other packages of practices, the yield of paddy increased by 4208.73 tons over the district average of 2018–19 in Nuapada and by 3689.79 tons over the district average of 2018–19 in Belpada, Balangir in four years (2018–19 to 2021–22). Besides this, the bio-fortified paddy varieties CR 310 and 311 contributed to an increase of more than 10.30% protein in diets, thus, increasing per hectare availability to 8.5 tons of protein, 394 gm of zinc, and 394 gm iron, which enriched the nutrient profile.

In non-paddy-based agroforestry systems, farmers were supported with improved varieties of Kharif and Rabi season pulses in combination with other crops (for example, cotton) or monocropping, providing additional protein through increased yields.

A large number of farmers in the project area were only able to grow one crop (rice), following the harvest of which the land was fallowed, mainly because of a lack of irrigation water. ICRAF identified suitable areas to grow short-duration pulses in rice fallows. Accordingly, short-duration pulses like grass pea and green gram were introduced. Low oxalyldiaminopropionic acid (ODAP) and high-yielding varieties of grass pea (Ratan and Prateek) suitable for human consumption were introduced through *paira* cropping. These interventions resulted in rapid crop yields. Over the course of four years, a total of 3071 ha of rice-fallow was covered with grass pea, involving 7507 farmers, with an average yield of 0.45 ton/ha, which added a total of 318 MT of protein-rich food to the food supply of the communities, which otherwise was not available.

Saplings of fruit and MPTs were selected and planted as per the field's location, topography and soil type, taking into account the choices of each farmer both on a field's bunds and in the field with the main crop. Backyard nutritional gardens of individual households and on community land were supported to provide vegetables and fruits suitable for the area planted.

A total of 261,445 saplings were planted in the project area during 2018–21. Overall survival of the plants was 71.62% despite setbacks owing to stray animals, unavailability of irrigation and COVID-19 lockdowns etc. This rate was possible to achieve owing to the provision of tree guards, sub-surface irrigation, and the use of hydrogel to help retain water in the root zone.

A total of 13,400 households were supported by the project through the provision of fruit plants and vegetable seeds. The actual cost–benefit ratio realized from backyard fruit species was 1:2.97 up to 2021–22 while the projection for the next three years (2022–23 to 2024–25) was 1:7.89 and the cost–benefit ratio (vegetable production and sale of 70% produce) was estimated at 1:13.40 during the four years (2018–22).

The project established two nurseries to produce quality planting material (QPM). The nursery growers were provided with a 15-day training course on QPM at the Horticultural Institute, Government of Odisha, Khorda. The nurseries helped in storing and maintaining about 200,000 items of planting material procured from other areas for distribution to farmers besides preparing rootstocks for future grafting.

In collaboration with Odisha Livelihood Mission, 36 women's self-help groups (WSHGs) were established (20 in Belpada and 16 in Nuapada) and their members trained in producing QPM, raising vegetable seedlings, and growing saplings from seeds (moringa and teak). Production and sale of moringa, papaya, tomato and chilli seedlings enabled the WSHGs to earn Rs. 1,04,920 in 2019 and Rs. 1,69,180 in 2020. The average income of each member of the WSHGs during the four years of the project was Rs. 28,000.

ICRAF introduced innovative technologies, such as 1) an agrivoltaic system: for food and renewable energy production for smallholders; 2) hydrogel technology for improving the survival of plants during dry spells and increasing yields; 3) modified sub-surface irrigation for ensuring better survival and growth of plants; 4) biofortified seed production of paddy (CR Dhan 310); 5) geotagging activities; and 6) developing an Agroforestry Assistant smartphone application.

All the project's activities, distribution of inputs, crop demonstrations, agroforestry plantings, natural resource management interventions and others were geotagged, which also helped in monitoring the survival of plants.

To provide a strong extension support mechanism, the Agroforestry Assistant Application (AFA), a smartphone-based digital platform to accelerate sustainable agroforestry intensification for site-specific interventions, was jointly developed by ICRAF and the Government of Odisha. It was officially launched on 24 December 2021 in Bhubaneswar, Odisha.

The project organized 38 training of trainers (TOT) sessions through which 1865 people were trained in different aspects of production of nutritive food and agroforestry practices and maintenance of fruit plants, value-addition packaging and vegetable seedlings' transportation, during 2018–23.

As an exit strategy, the project successfully trained 58 youth from the project area as Krishi Vaniki Mitra (KVM) to ensure extended 'hand holding' of farmers within communities at the village level after the project's completion.

Besides the training at district and village levels, exposure visits of farmers within and outside the State were conducted. In total 22,979 people were trained (of whom 35.47% were women) during the project period.

The various interventions, including agroforestry-based natural resource management, facilitated estimated rainwater harvesting of 112,000 cm^3, equivalent to about 140 mm rain/year; part of this harvested rainwater was used as 'green water' supplemental irrigation and storage and the rest percolated as groundwater recharge. Four farm ponds harvested about 90,000 cm^3 of rainwater, of which an estimated 40,000 cm^3 was used to irrigate Rabi crops and 50,000 cm^3 contributed to groundwater recharge. In turn, more than 135,000 cm^3 of water infiltrated into the ground and groundwater improved by 2–3 m.

Bunding significantly reduced soil erosion by 75% from the pre-intervention phase (12–15 tons soil/ha) and saved 714 tons of soil from erosion.

Since the plantings are only 3–4 years old, the accumulated aboveground biomass is in a lower range, below 30 tons/ha. However, the planting on agricultural land is estimated to sequester about 12,695 tons of carbon valued at USD 63,475 in the third year, which is projected to increase to 21,160 tons of carbon valued at USD 105,800 by the fifth year and 42,320 tons of carbon valued at USD 211,600 by the tenth year.

Agricultural water management, including agroforestry-based natural resource management interventions, enhanced the provisioning of ecosystem services (for example, crop intensification and yields) and regulating ecosystem services (for example, enhancing base flow, reducing siltation and enhancing groundwater availability) in the project area and improved the microclimates.

The interventions also helped in enriching and strengthening biodiversity by way of the introduction of MPTs, bamboo and new and improved varieties of crops, vegetables and grasses in the agricultural landscape. Overall, the project has enhanced ecosystem services and improved biodiversity.

Financially, from an investment of USD 2.70 million, the total return was USD 6.70 million (a rate of return of 2.48).

The Government of Odisha commissioned a third-party assessment through Nabakrushna Choudhury Centre for Development Studies (NCDS) Bhubaneswar to assess the impact of the project. The assessment report concluded that, overall, the project made a positive impact on the ground and gave hope to project farmers, including migratory farmers, through demonstrating the potential of agroforestry to provide sustainable livelihoods.

The project's activities were captured through documentary videos, publications and success stories, including a summary video covering the four years' journey to success (https://youtu.be/jAqEtHgYvrQ).

2. Introduction and Background

Agriculture in Odisha is the mainstay of the majority of the populace and, thus, holds the key to socio-economic development of the State. Close to 83% of the people live in rural areas and about 61.80% of the 17.5 million workforce is employed in agriculture. However, the sector suffers frequent natural calamities, such as cyclones, droughts and flash floods. During the years 2011–12 through to 2016–2017, the economy of Odisha grew steadily at an annual average rate of 7.02%. During 2016–2017, Odisha achieved a double digit real growth rate of 10.39%, an increase in real per capita income to Rs 63,674, a recorded low level of price inflation of 1.30% and above 27% growth in the crop sectors, accompanied by a decline in unemployment. In 2017–18, the State anticipated a real growth rate of 7.14% and real per capital income of Rs. 67,522.

Diversified food sources are highly potent and vitally important for a nutritious and balanced diet. According to Sarkar (2015), food and nutritional security is based primarily on four elements: 1) Availability (production, storage and trade); 2) Access (income, prices, markets, public distribution and gender); 3) Utilization (food/nutrition knowledge, cultural traditions of food preparation and nutritional behaviour, health services, sanitation and hygiene); and 4) environmental sustainability. The quantity of food consumed, and the quality of diets, is affected by the knowledge, attitudes, practices and resources of households (IFAD 2015). For example, during 2005–2012, through a combination of nutrition-specific interventions, improved access to food and education, and reductions in poverty, child stunting in Maharashtra reduced from 36.50% to 24% (Haddad et al. 2014).

To improve the nutritional status of communities in Odisha, it is imperative to introduce specific interventions around food which address the underlying determinants of malnutrition. Such practices must follow the SMART protocol (Specific, Measurable, Achievable, Realistic, and Tangible) and be friendly to farmers as well as the environment.

SMART agroforestry is a gamut of practices supporting increased food and nutrition security and enhanced ecosystem services. These practices can easily be implemented in different ecological and socioeconomic settings and on different sizes of landholdings. In general, the SMART protocol advocates a gradual transition and transformation of purely “field crop agriculture-based practices” to “agroforestry-based livelihood systems” that ensure the availability of food, including fresh fruit and vegetables and fodder for livestock, throughout the year. The protocol significantly contributes to higher productivity, crop diversity, cropping intensity and resilience to natural disasters and, thus, ensures increased food availability and better nutrition over time.

The Department of Agriculture and Farmers Empowerment has been putting its best efforts into supporting farmers through schemes such as the Krushak Assistance for Livelihood and Income Augmentation, Odisha Food Security Scheme (OFSS), Mukhyamantri Krishi Udyog Yojana, Mukhyamantri Abhinav Krishi Yantripati Samman Yojana, and Odisha Free Smart Yojana for women farmers.

In April 2018, World Agroforestry (legally constituted as the International Centre for Research in Agroforestry/ICRAF; www.worldagroforestry.org) signed a Memorandum of Agreement with the Government of Odisha’s Directorate of Soil Conservation and Watershed Development to implement the project, Enabling Smallholders to Produce and Consume more Nutritious Food through Agroforestry Systems, in Balangir and Nuapada districts of Odisha. The project aimed to support 9000 farmers within an area of 5000 ha across 20 GPs of Belpada Block and 10 GPs of Nuapada Block of Balangir and Nuapada districts, respectively. The project’s target area was drought-prone, mainly monoculturally cropped, with resource-poor, small-scale and marginalized farmers facing the challenges of food and nutritional insecurity and stress migration.

2.1 Problems to be addressed

Agriculture in Odisha, like in other parts of India, significantly depends on natural phenomena rather than ‘factory farming’. Consequently, natural calamities take a toll on food grain production from year to year, which very often leads to food and nutritional insecurity and irregular and unstable incomes of the communities. Therefore, farmers need to diversify agricultural production by growing climate-resilient species (trees) that provide a 'safety net' against climatic uncertainty and additional and nutritious food. Thus, the imperative is to introduce agroforestry-based interventions around food supply and quality to increase the availability of nutritious food to communities.

In addition to an overall shortage of nutritious food, a related challenge is the intermittent availability of nutritious food throughout the year.

Therefore, modifications to the existing food production systems were required to address the problem, such as the introduction of well-designed systems to make nutritious food available the year round, replete with essential nutrients, such as carbohydrates, proteins, vitamins and minerals.

2.2 About ICRAF and partners

World Agroforestry, legally constituted as the International Center for Research in Agroforestry (ICRAF), is an international not-for-profit, research-in-development organization that aims to transform lives and landscapes through the management of tree-based systems or agroforestry.

ICRAF carries out reliable, objective and cutting-edge research into agroforestry and supports development initiatives with unbiased analyses and evidenced-based learning for sustainability. ICRAF works in more than 30 countries through networks of highly qualified and renowned multi-disciplinary teams spanning bio-physical, social and economic and policy realms.

The headquarters of ICRAF is in Nairobi, Kenya. There are six regional programmes covering major ecologies of the world. In India, ICRAF works through its Asia Directorate, which is based in New Delhi, hosted by the Indian Council of Agricultural Research (ICAR). ICRAF has very strong partnerships with several ICAR institutes and state agricultural universities. In 2019, ICRAF functionally merged with the Center for International Forestry Research, creating a new, larger entity known as CIFOR-ICRAF. The two centres remain separate legal entities and members of the CGIAR and maintain headquarters in both Nairobi and in Bogor, Indonesia.

The project has been implemented in close collaboration with line departments of the State of Odisha, led by the Department of Soil Conservation and Watershed Development. Technical inputs from institutes of ICAR — Central Agroforestry Research Institute (CAFRI), Jhansi; National Rice Research Institute (NRRI), Cuttack; Central Arid Zone Research Institute (CAZRI), Jodhpur — and the Odisha University of Agriculture and Technology (OUAT) helped in strengthening the science-led innovations in the project area. Project activities were aligned and implemented as per the State departments' priorities.

2.3 Objectives

The overall objective of the project was to enable smallholders to produce diverse and nutritious food. To achieve this, there were several specific objectives.

1. Create awareness of the benefits of consuming diversified, nutritious farm produce, including fruit and other tree-based produce, such as flowers, pods, leaves and vegetables.
2. Introduce and accelerate adoption of suitable agroforestry systems to enhance availability of nutritious food.
3. Generate employment and income to support the efforts of the Government of Odisha to reduce in-country migration.
4. Assess the impact of introduced interventions on availability of nutritious food to support better decision making for scaling up and scaling out.
5. Build capacity of all stakeholders and strengthen existing and/or create new structures to sustain the activities and impact of the project.

The above objectives were intended to be achieved through implementation of activities in four major areas.

1. Establishing the project's implementation system and understanding the project area and communities.
2. Establishing links with target communities and creating awareness about the needs and benefits of a balanced diet.
3. Introducing agroforestry-based interventions to improve nutritional security.
4. Developing capacities of stakeholders.

2.4 Initial phase: agreement signing, inception workshop and the first Steering Committee meeting

The project, Enabling Smallholders to Produce and Consume more Nutritious Food through Agroforestry Systems, was approved for funding through RKVY at the 22nd meeting of the SLSC held on 7 June 2017 [No. AG(RKVY)04/2017-9975 dated 22.06.2017]. Accordingly, a Memorandum of Agreement was signed on 28 February 2018 by the Soil Conservation and Watershed Development Directorate of the Government of Odisha and ICRAF. ICRAF received the first instalment of the budget from the Government of Odisha on 29 March 2018.

The project's inception workshop was held on 2 May 2018 in Bhubaneshwar under the chairmanship of the Principal Secretary, Department of Agriculture and Farmers' Empowerment (DAFE). The workshop was attended by more than 60 stakeholders. Government officials representing State departments of Agriculture, Watersheds, Horticulture, Forestry and Labour participated along with representatives of the four main collaborators: OUAT, the Natural Resources Management Division of ICAR, NRRI Cuttack and CAFRI Jhansi. ICRAF staff from headquarters and the New Delhi office participated.

Senior policy makers and others who attended and gave their valuable inputs were Dr Saurabh Garg, Principal Secretary, DAFE, Government of Odisha; Ms Sujata R. Karthikeyan, Director, Watershed Mission, DAFE, Government of Odisha; Sh Gagan Kumar Dhal, Commissioner of Agricultural Production, Government of Odisha; Sh Sachin R. Jadhav, Commissioner of Labour, Government of Odisha; Dr M. Muthukumar, Director, DAFE, Government of Odisha; Sh HK Panda, Director of Watershed Mission, Government of Odisha; Dr PK Roul, Dean, Extension, OUAT; Prof MM Hussion, Dean, Forestry, OUAT; Dr Sanjip Tripathi, Chief Executive, Odisha Remote Sensing Application Centre; Ms Mary Bina Surin, TATA Trust; Natiri Kumar Panda, Dabur India Ltd; and Dr Ravi Prabhu, Deputy Director-General, ICRAF, Nairobi; and Dr Javed Rizvi, Director South Asia Program, ICRAF, New Delhi.

The first steering committee meeting was held on the same day, chaired by Dr Saurabh Garg, Principal Secretary, Agriculture, Government of Odisha.

3. Understanding Realities on the Ground and the Baseline for Year 1

The first instalment of funds was received by ICRAF on 29 March when the planting season was about to start.

The implementation of the project was to be conducted on 5008 ha in Balangir and Nuapada districts of Odisha in two blocks (one in each district). Initially, a total of 180 villages from 30 village GPs were selected to implement various activities of the project but in reality we could find the existence of only 149 villages in the 30 GPs (20 GPs with 108 villages in Belpada Block of Balangir and 10 GPs with 41 villages in Nuapada Block of Nuapada). The location of GPs from each block's headquarters was found to range 8–45 km while the distance between villages in a GP ranged 2–6 km. For ease of implementation, these 149 villages were reorganised into clusters of 2–3 villages depending upon population and distance between village hamlets (in some places there was one cluster of one village).

To understand the target areas, the line departments, the varieties of crops grown by communities, the cropping patterns, the livelihoods and nutritional status of the farmers, the market links for products and to network with stakeholders, the project team initiated close interactions with all stakeholders by repeatedly visiting the target areas even before the inception workshop.

3.1 Interaction meetings, focus group discussions

We initiated interaction meetings with line departments and other partners, including with the dean of Extension Education and the dean of Forestry at OUAT, Bhubaneswar; with the directors of NRRI Cuttack; and CAFRI Jhansi.

The necessary information was collected about approved varieties of different crops for the target districts and the availability of improved seed of fortified paddy varieties and of other targeted crops. The project team, before organizing the inception workshop, met all line departments and introduced the project in both districts.

On our request, the project director of Watershed Development, Balangir and Nuapada, provided the list of small-scale and marginalized farmers who were beneficiaries of Watershed interventions in the respective blocks of the identified GPs.

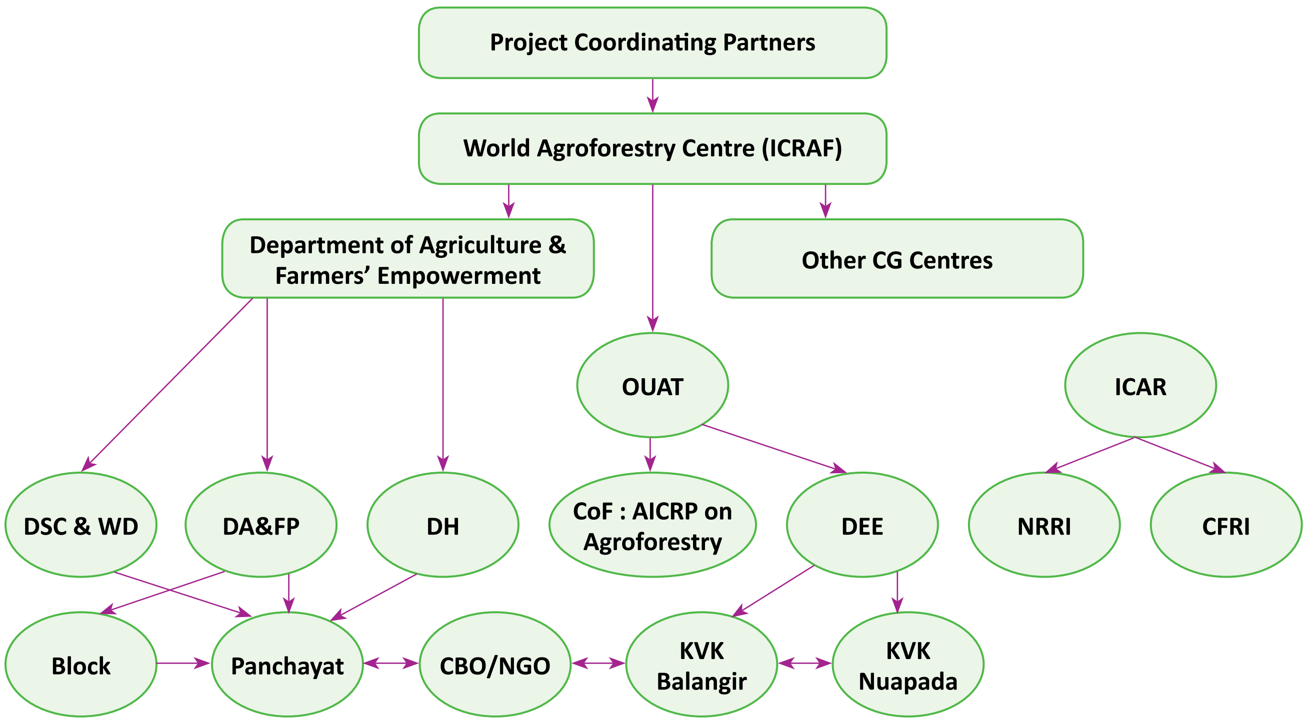


Figure 1. ICRAF and line departments at district Level

Baseline survey and participatory rural appraisal

The project team held a series of discussions with the dy directors of Agriculture at the District Agricultural Offices, assistant agricultural officers, and village agricultural workers of both the districts. The departments of Agriculture in both districts called special meetings to introduce the project and its staff to Government officers and asked all to extend full support to the project team.

The dy director of Agriculture, Nuapada facilitated interaction meetings with all village agricultural workers and agricultural overseers (VAW, AO) of the selected GPs in which the project activities were discussed, followed by organising interaction meetings with Krishi Sathi and VAWs in the selected GPs.

Similarly in Belpada, the district agricultural officer and assistant agricultural officer introduced the team to the VAWs and AOs of all 20 selected GPs of the Block. Followed by this meeting, interaction meetings were held with all the Krishi Sathi of the selected GPs wherein the VAWs and AOs also participated.

We are thankful to all the Department of Agriculture officials of Belpada for instructing their field staff (VAW, AO and Krishi Sathi) to fully cooperate and help in conducting scientist–farmer interaction meetings at village level. The Agriculture officials of Belpada Block and DAO suggested that scientist–farmer interaction meetings in various selected GPs could be the main basis for selection of participating farmers. Accordingly, at both places, 64 scientist–farmer interaction meetings were held in 30 GPs (20 in Belpada and 10 in Nuapada), from which, feedback from farmers, Sarpanch and Krishi Sathi was received.

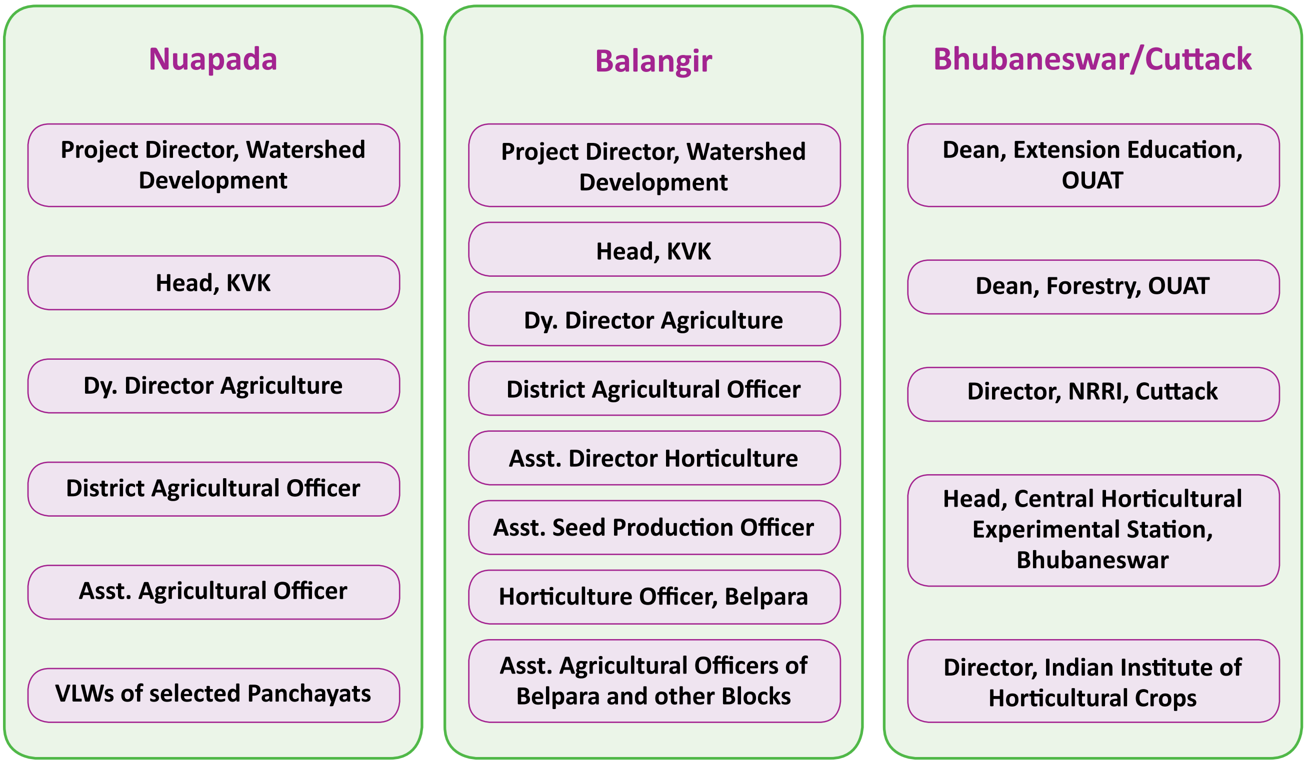


Figure 2. Stakeholders consulted by the project team

The DDA Nuapada, after studying the list of selected farmers provided by the project director of Watershed, suggested that keeping in mind this list, it was proper to select the beneficiary farmers in consultation with VAW, AO, Krishi Sathi and the Sarpanch of the concerned GP.

At Belpada, the list of farmers was prepared after the interaction meetings (scientist–farmer) and in consultation with Krishi Sathi, VAW, AO and Sarpanch of the concerned GP. This list was also shared with the Department of Agriculture officials at Nuapada. The list was prepared based on the list of farmers provided by the project director of Watershed Development. Merging the list of farmers prepared after the interaction meetings in consultation with Krishi Sathi, VAW, AO and Sarpanch and the list provided by the project director of Watershed, Nuapada led to a final list being prepared in consultation with the DDA Nuapada.

Figure 3. The project team in discussion with Odisha agriculture Government officials

Figure 4. The project team appraising VAWs and Krishi Sathis

To understand the cropping patterns and systems of agroforestry plantings, the project team interacted with farmers (figures 5 and 6). Discussions were held around the presently grown varieties of crops, their yields, pest and diseases and available markets.

Figure 5. Scientist–farmer interactions

Figure 6. Scientist–farmer interactions

Farmers in the districts expressed their concern about not being able to take a second crop during the Rabi season mainly owing to low moisture in the fields. Concerns were also raised about the survival of saplings in the fields because of stray cattle during the fallow period.

The project aimed to promote agroforestry in system mode, including both staple food crops and MPTs, thereby enhancing the production and productivity of both existing food crops (rice and pulses) by using improved varieties and associated best practices; and through introduction of MPTs to increase the overall productivity of the same unit of land.

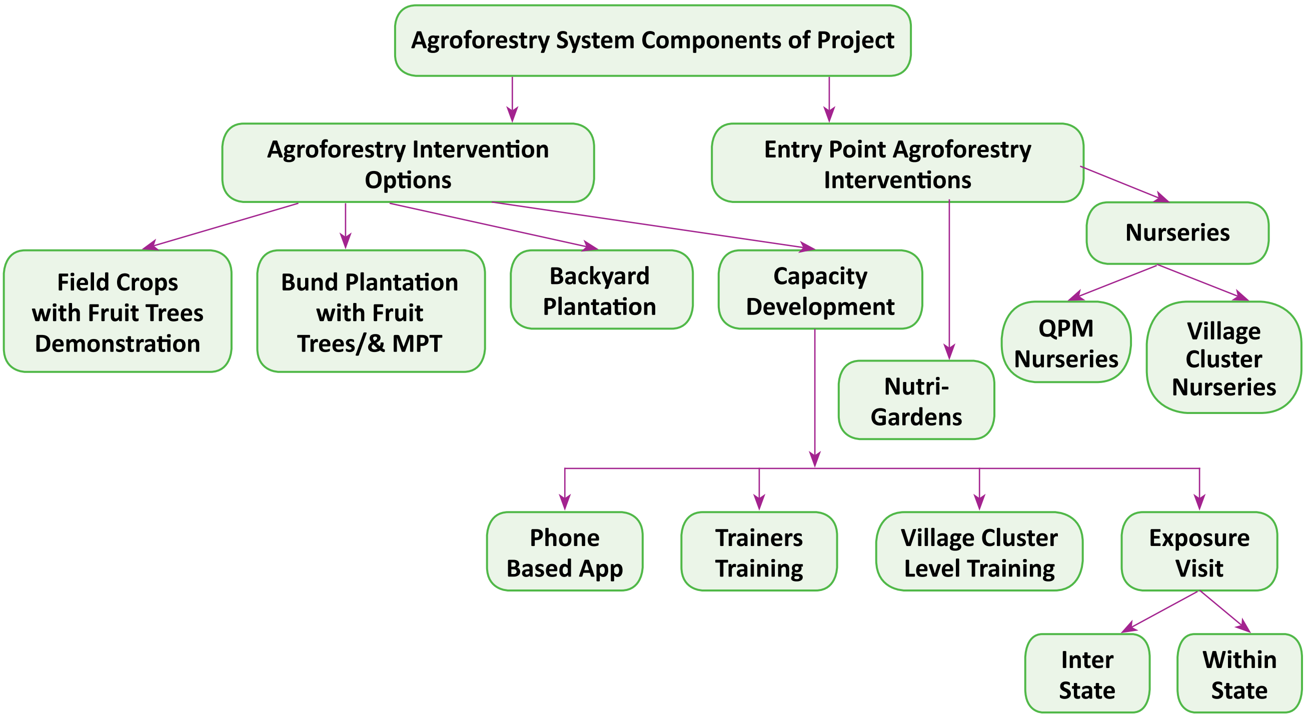


Figure 7. Activity details of the project

Considering this, the project team worked with the target communities to select, and introduce, the right kinds of crops and trees, providing the best options to participating farmers.

With focus group discussions (FGD) at community level in both the districts and with other stakeholders (mainly staff of Agriculture, Soil and Water Conservation, Horticulture etc), lists of farmers' preferences were drawn up and inputs were procured in terms of cereals and pulses. Selection of planting material was done considering the crop to be grown, microclimate, soil type and requirements of farmers. Among the planting material, improved varieties of mango, apple ber, guava, aonla, jackfruit, teak etc were procured from local nurseries and from other States, but only from those nurseries which were accredited by State or centre departments.

Understanding crop dynamics at district level

Paddy: Paddy has been the main crop in both the districts during the Kharif season. In Nuapada, farmers were growing more paddy because the land was more appropriate in comparison to Balangir. To obtain information on the varieties grown by farmers in different seasons, FGDs were held with communities, also involving the line departments and the KVKs of both districts. MTU-1010, MTU 1001, Sahbhagi and Swarna were identified as the most preferred varieties, which are duly recommended by the Government of Odisha, OUAT and NRRI. Newly developed fortified paddy CR Dhan 310 and CR Dhan 311 with high protein were varieties released by NRRI during 2016 and were identified for introduction in areas with under 125 days crop maturity period. CR Dhan 310 contains 10.30% protein; CR Dhan 311 contains 10.10% protein and 20 ppm zinc while conventional varieties have 6% protein only. CR Dhan 310 was developed from the popular rice variety Naveen by using one high protein germplasm, ARC-10075, collected from Assam.

Some farmers (10–15%) who have access to water (bore) also grow paddy in the Rabi season. Farmers with lowland fields prefer long duration crop growth periods above 140 days, middle altitudes prefer 120–125 days and upland areas prefer 90–100 days.

Table 1. Existing crops in project area (pre-project land use)

Season, crop	Nuapada	Belpada
Kharif season		
Paddy	MTU 1001, MTU 1010, MTU 7029, Swarna, Sahbhagi, Kanda Giri, Pusa, Jagannath	MTU 1001, MTU 1010, Swarna, Sahbhagi, Pooja, Silky, Parijaat rice
Black gram (Biri)	Local	Local
Green gram	Local	Local, IMP2-3
Pigeon pea	Local	Upas-120
Groundnut	Local & Kadri-6	Local & Kadri-6
Cotton	Very few	Tulsi & Parijaat
Rabi season: completely fallow (only farmers with irrigation grow paddy: 4–5 farmers per village)		
Mango	Amarpali, Dusheri	Amrapali, Dusheri
Papaya	Local	Local
Guava	Local	Local
Eucalyptus	Traditional and improved (new plants)	Traditional and improved (new plants)
Teak	Traditional and improved (new plants)	Traditional and improved (new plants)

Note: The information above was used to select and order first-year crop varieties for farmers.

Pulses: Black gram was farmers' preferred pulse, grown in the Kharif season. Green gram was grown in both Kharif and Rabi, however, cultivation during Rabi was restricted to farms with irrigation. Farmers on average used their own grain from the previous year as seed and were not aware of the recommended varieties, except those farmers who were progressive.

Both OUAT and line departments recommended recently released high-yielding varieties IPM 2-3 and IPM 2-14 of moong; and PU-31 and Shekhar-1 of black gram for this area but the area grown with pulses was very low, with very few farmers growing them in upland areas.

Grass pea: Few farmers from both blocks reported growing grass pea and only on a very limited area after the paddy harvest in the Rabi season. The indigenous varieties had oxalyldiaminopropionic acid (ODAP) ranging 0.5 to 2.5 ppm; ODAP content more than 0.15 ppm is toxic and hazardous to health.

Farmers had no knowledge of new and improved varieties like Ratan, Nirmal, Prateek with ODAP less than 0.15 ppm, which are safe to consume. As a viable alternative, and targeting the Rabi fallow period, the project team in consultation with stakeholders introduced low ODAP grass pea in rice fallow as a second crop in the area, with proper technological interventions.

Cotton: Cotton is rarely grown in Nuapada Block but covers the majority of Belpada Block in the Kharif season. Its coverage is not reported in Government records because the Government does not encourage growing BT cotton.

Other crops: A very few farmers (2–5%) reported growing sesamum in Belpada, sugarcane in the Rabi season in Belpada and groundnut and maize in both blocks (8–10%).

Agroforestry (horticultural (fruit) and MPTs with crops): Farmers in the target area were mainly growing mango and guava, generally in their backyards. For timber, mainly eucalyptus and teak were grown but in limited numbers. Eucalyptus was grown by a few farmers on their land while teak was grown in forest areas, without any planting symmetry.

Farmers did not have any knowledge of agroforestry systems, that is, growing trees with other crops, and were hesitant about growing any type of tree species owing to the perceived adverse effects of canopy shadow on field crops.

The project aimed to promote smaller ('short') canopied fruit species on bunds and in mixed cropping in fields with canopy management technology, demonstrating that with proper management there would not be any loss of crop yields but rather lead to an increase in diversity of nutritional food. The short canopy mango variety, Amrapali, was mostly selected by farmers although some chose Dusheri and Totapuri. In consultation with line departments and during scientist–farmer interactions, it was decided to introduce guava (VNR and L 49), drumstick (PKM 1), papaya (Red lady), apple ber, aonla (NA-7) as fruit species for nutritional availability and teak, bamboo, jackfruit and custard apple as MPTs.

Household dietary diversity is defined as the number of different food groups consumed over a given reference period. The Household Dietary Diversity Score (HDDS) or Individual Dietary Diversity Score (IDDS) are attractive proxies for food security because a more diversified diet is an important outcome and is also correlated with such factors as calorific and protein adequacy, percentage of protein from animal source foods and household incomes (Hoddinot and Yohannes 2002). Dietary diversity was calculated for households (HDDS) or for individuals within the household (IDDS). Data of the consumption of food were collected using a 24-hour recall method wherein household members responsible for food preparation were respondents, focusing only on foods consumed within the home during the previous 24 hours.

A food consumption score (FCS) was added. Values were recorded as the number of times within seven days different food groups were consumed, which is different from the usual way of recording the number of days of consumption in the last week. In the latter approach, often a household would fail to provide exact information; and approximation can provide a misleading picture. Food not prepared in the home (for example, hotel food) was not to be included because this rarely represents household-level food security. Using the dietary diversity score, the consumption of animal source foods can also be determined. The FCS is a more comprehensive indicator based on dietary diversity, food dietary diversity, food frequency and relative nutritional importance. The Months of Adequate Household Food Provisioning captures the combined effects of a range of interventions, such as improved production, storage and increased household purchasing power.

As is evident from Figure 8, the food consumption score for the majority of households in Nuapada was around 120 whereas it was less than 100 in Balangir. We conclude from these scores that households in Nuapada were more aware of their dietary requirements and were above the acceptable food consumption threshold. Balangir was also above the acceptable threshold but was less than ideal, that is, 112.

Dietary diversity scores were calculated for children, women and whole households. As can be seen in Figure 8, it was far less than the minimum level in the case of children, where the scores were 5 for Nuapada and less than 3 for Balangir whereas they should be around 8. In the case of women, scores were 6 for Balangir and ranged 6.5–7 for Nuapada whereas they should be 10. These results clearly show that households eat food but diversity is missing in all categories. Because of low diet diversity, children are more malnourished. A high score above 10 indicates that households are eating diverse kinds of food, thus, are economically in good condition and aware of food and nutrition security.

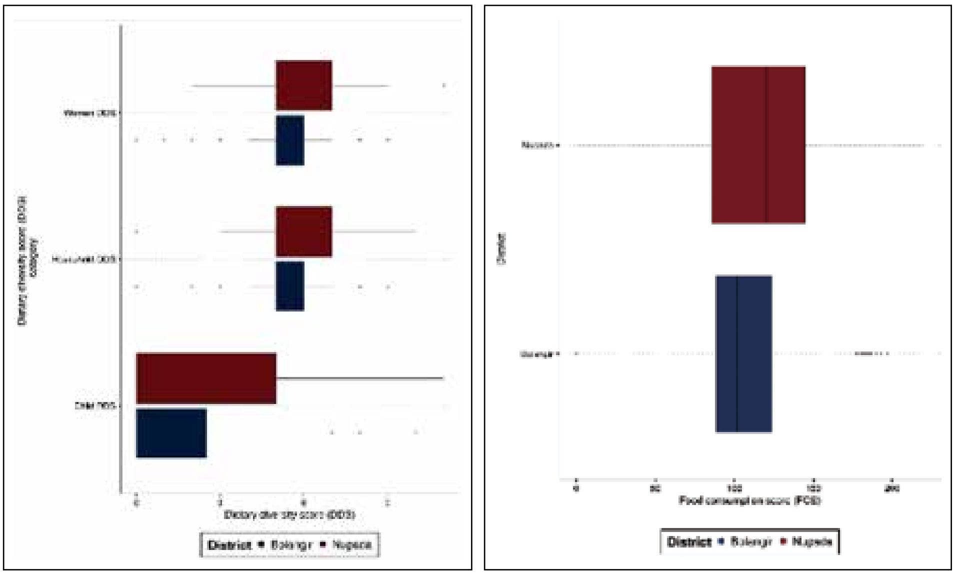


Figure 8. Household dietary diversity (DDS) and food consumption score (FCS)

Note: Thresholds: Poor food consumption: 0–28; Borderline food consumption: 28.5–35; Acceptable food consumption: > 35.

In addition to an overall shortage of nutritious food, another challenge was unavailability of such food throughout the year. Therefore, modifications in the existing food production systems were required to address this problem. Governments often had recourse to distribution of vitamin pills or fortified flour, which is not a sustainable approach. Introduction of well-designed food production systems to make food available year-round with essential ingredients, such as carbohydrates, proteins, vitamins and minerals, was the ultimate aim of the project. This was possible only through agroforestry-based interventions. A well-designed 'nutri-garden' is a classic example of such a food production system (Figure 9).

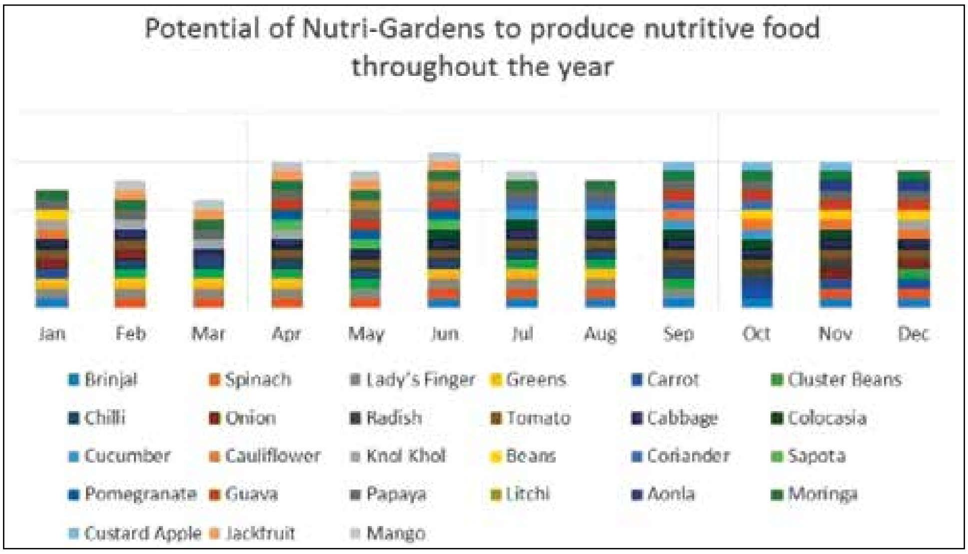


Figure 9. A well-designed nutri-garden provides nutritious food throughout the year

In consideration of all of the above, it was decided to introduce modifications of existing monocropping through an agroforestry system approach with cereals (biofortified rice), pulses (including low ODAP grass pea in rice fallow) crop cultivation with fruit and other MPTs in fields, bunds and nutritional gardens in backyards with fruits and vegetables, in a sustainable mode.

4. Project Implementation: System Mode Approach

The project area is drought-prone, mainly mono-cropped and represented by resource-poor, small-scale and marginalized farmers facing the challenges of food and nutritional insecurity and distress migration.

The project has been implemented in close collaboration with state departments, led by the Department of Soil Conservation and Watershed Development. Also, technical inputs from institutes of ICAR — CAFRI Jhansi, NRRI Cuttack, Central Arid Zone Research Institute (CAZRI) Jodhpur, and OUAT Bhubaneswar — helped in strengthening science-led innovations in the project area.

Project activities were implemented over the last four years according to the state departments' priorities. Each activity was in one way or another linked to the overall goal and outcome of the project. Below are narratives providing information, particularly on the impact, of each intervention.

The project significantly achieved against each target despite the COVID-19 pandemic. Overall, the project's performance was high against all targets, registering more than 100% achievements, except for the target of scientist–farmer interaction for selection of beneficiaries, which was restricted by the pandemic, where it was 80% (Table 2).

Table 2. Overall achievements during 2018–2022 against targets

	Activity	Revised in SC II Target	Achievement					
		2018–2021 (for three years)	2018–19	2019–20	2020–21	2021–22	Unit	%
1.	Scientist–farmer interaction for selection of beneficiaries (nos.)	80	61	-	3	-	64	80
2.	Sequence crop demonstration (ha)	1224	275	714	750	1321	3060	250
	Single crop demonstration (Kharif) (ha)	1400	670	666	776	540	2652	189
	Intercrop demonstration (Kharif) (ha)	400	0	200	200	734	1134	283
	Kharif groundnut (ha)	Added as per the suggestion of PS during 2nd SC meeting	0	12	75	-	87	
	Kharif black gram (ha)		0	15	236	340	591	
	Kharif green gram (ha)		0	15	85	321	421	
	Rabi green gram (ha)		0	0	25	41	66	
3.	Agroforestry mango @ 15 plants / ha (ha)	504	945	1422 Cont.	1726	902	2628	261
4.	Agroforestry guava @ 15 plants / ha (ha)	504						
5.	Bund plantation with fruit trees / misc. trees @ 20 plants / ha (ha)	4032	1484	4184	4534	-	4534	112
6.	Establishment of QPM nurseries (nos.)	2	2	2	2	2	2	100
7.	Village nursery (nos.)	36	0	36	36	36	36	100
8.	Pilot nutrition gardens (nos.)	15	4	15	15	15	15	100
9.	Backyard gardens (HHs)	5400	2860	4775	7691	5709	13400	248
10.	Water infiltration interventions (acre)	200	0	0	140 +60	50	250	125

5. Major Activities

The major activities — including agroforestry technology and crop demonstrations, bund plantings and backyard gardens, establishment of nurseries, smartphone application development, water infiltration, capacity development etc — led to achievement of the following major goals.

- Availability of nutrition on a sustained basis through increased production and productivity of nutritious food.
- Reduction in rice-fallow areas during the Rabi season.
- Livelihoods' development through enhanced income and supporting migratory farmers.
- Availability of vitamins and minerals in food.
- Smartphone application for easy access to various climate-resilient technologies for the agroforestry system approach.
- Availability of life-saving irrigation to crops during Rabi through natural resource management activities.
- Capacity development of farmers.

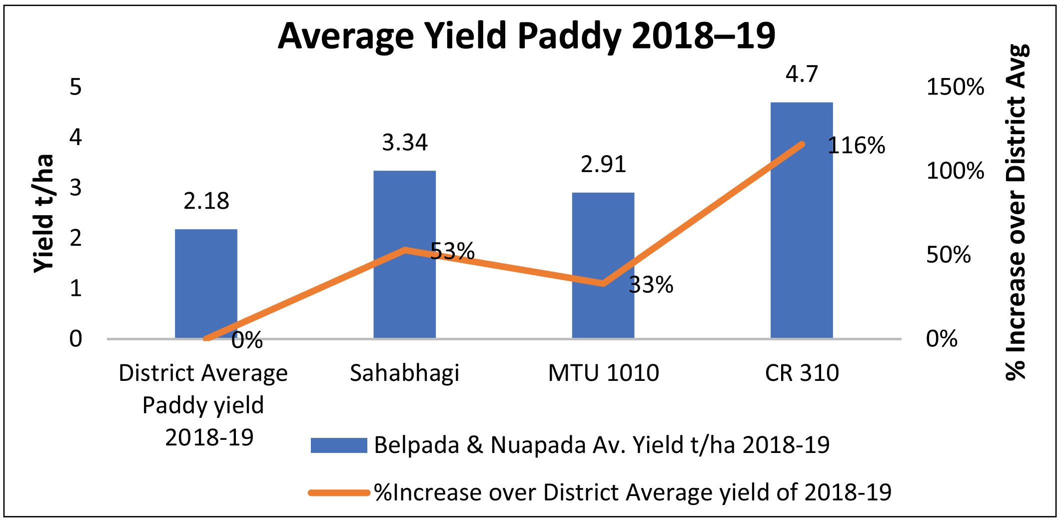
5.1 Nutritional availability on a sustained basis through increased production and productivity of nutritive food

Paddy-based agroforestry systems

Paddy is the main crop grown in the Balangir and Nuapada districts of Odisha. A significant share of paddy is cultivated by farmers in the Kharif season, only once a year owing to irrigation water unavailability. A low seed replacement rate of 21.54–22% (quoted in NRRI's *Annual report* 2020) is one of the primary reasons for the reduced paddy yield in the districts.

The project identified small-scale and marginalized farmers to grow paddy under agroforestry systems wherein fruit and/or MPTs were grown on bunds of paddy fields. The introduction of newly developed varieties increased paddy productivity as evidenced by crop-cutting experiments (minimum of three farmers' fields) and overall farmers' yields reported during 2018–19 and 2021–22. In addition, ten varieties of paddy, including CR 101-Ankit and CR 201 (118 days crop) were introduced on uplands (less than 120 days) because the majority of farmers were growing Sahabhagi. In the medium duration of paddy (120–130 days), new varieties, like DRR 44, Mandakini and CR 304, were introduced.

The major intervention was the introduction of biofortified CR Dhan 310 and CR Dhan 311, with the highest protein content (10.10–10.30%) as compared to conventional varieties with 6% protein content.



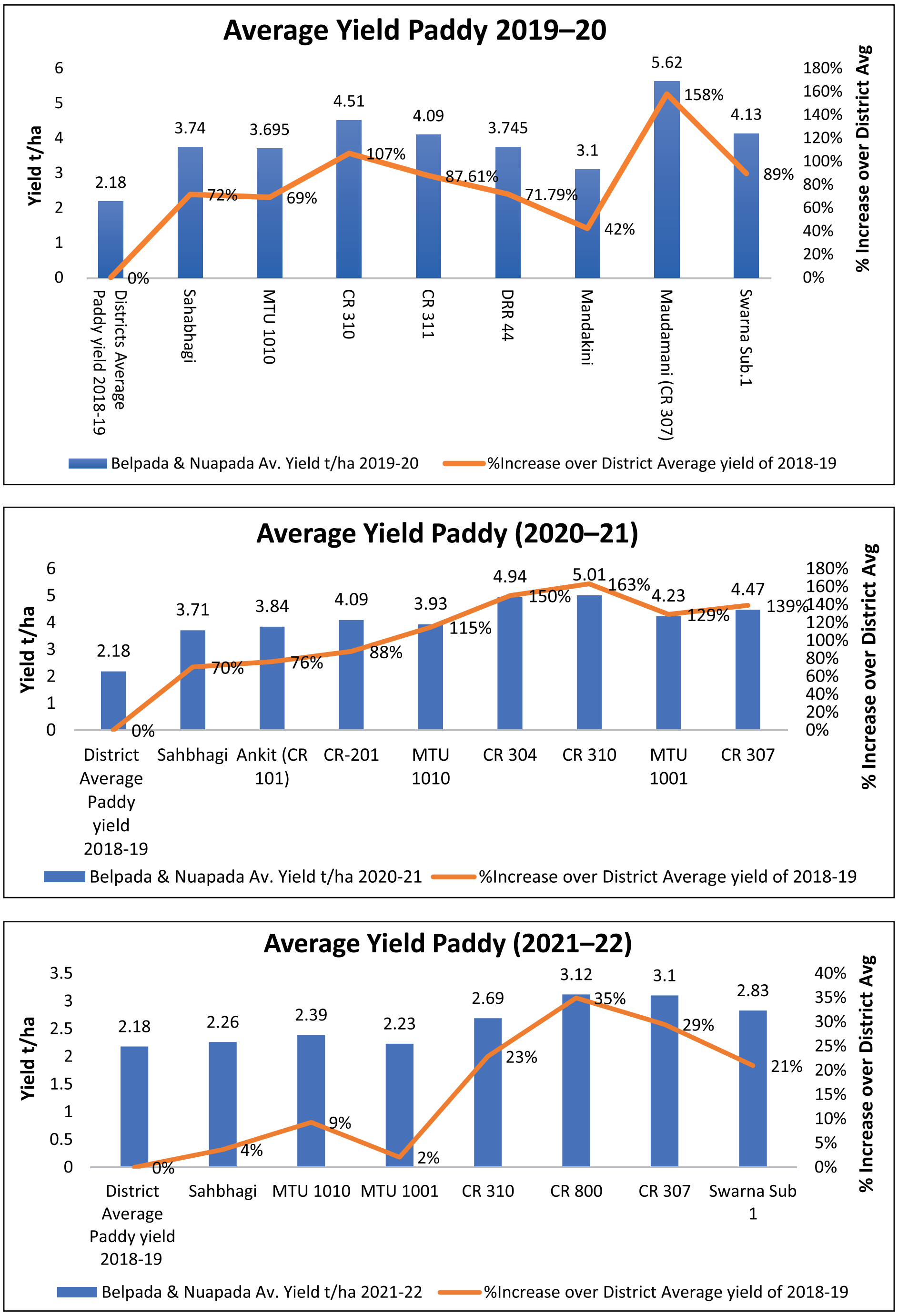


Figure 10. Average yield of paddy in the two districts, 2018–22

Among long-duration paddy (140 and above days), CR Dhan 307 was introduced as a replacement with the majority of farmers who grew SS-1. The project introduced another high-yielding variety for this duration (140 days) under rainfed conditions — CR 800 — during 2021. Over three years, the target was to cover 1008 ha in Kharif and 500 ha in Rabi seasons every year (3024 ha during Kharif and 1500 ha during Rabi, totalling 4524 ha).

Against this, in the four years (including the no-cost extension period of 2021–22), the project covered 5712 ha paddy, 2146 ha pulses and 87 ha groundnut during the Kharif and 3136 ha during the Rabi seasons, totalling 11,081 ha (Table 1).

Increase in production of paddy and its economic value (2018–19 and 2021–22)

With the introduction of new varieties, increased seed replacement rate, seed priming and seed treatment, guided plant protection and other packages of practices, the yield of paddy increased by 4208.73 tons over the district average of 2018–19 in Nuapada (984.81 tons, 965.16 tons, 1525.58 tons and 733.18 tons during 2018–19, 2019–20, 2020–21 and 2021–22 respectively; and by 3689.79 tons over the district average of 2018–19 in Belpada, Balangir (192.5, 1335.77, 1502.01 and 659.51 tons during 2018–19, 2019–20, 2020–21 and 2021–22, respectively).

The value of this additional gain over the district average of the two districts was Rs. 14,21,730 (@Rs.1,800/q minimum support price of 2018). An individual farmer in Belpada, Balangir could obtain additional gain over the district average by Rs. 6359 during 2018–19, Rs. 15,084 during 2019–20, Rs. 13,377 during 2020–21 and Rs. 2243 during 2021–22 (drought conditions during early and mid-season of paddy growth), while Nuapada farmers could obtain additional gain over the district average of Rs 10,861 during 2018–19, Rs. 16,389 during 2019–20, Rs.17172 during 2020–21 and Rs. 5.725 during 2021–22 (drought conditions during early and mid-season of paddy growth). The reduced additional income over the district average in both the districts during 2020–21 was due to the COVID-19 pandemic's adverse effect on field management and to the compound adverse effects of the pandemic and drought during the mid-paddy-growth season of 2021–22.

Among the total beneficiaries in Nuapada, 25% during 2019–20, 49.15% during 2020–21 and 86.46% during 2021–22 (no-cost extension period) were migrant farmers who obtained an additional gain over the district average. Similarly, in Belpada, about 27% of migratory farmers during 2019–20, 40% during 2020–21, and 81.12% during 2021–22 received additional gain over the district average. Besides this, the bio-fortified paddy varieties CR 310 and 311 contributed to more than 10.30% protein in diets, thus, increasing per hectare availability of 8.50 ton of protein, 394 gm of zinc, and 394 gm iron, which enriched the nutrient profile.

Since the introduction of Maudamani (CR 307) during 2019–20, the variety has been the best performer year-round in the long-duration variety. During 2020–21, the maximum yield was recorded in CR Dhan 310. Overall, Ankit (CR Dhan 101) and CR 201 were performing well in short duration, CR Dhan 310 and CR 304 in the medium duration and CR 307 (Maudamani) and CR 800 in long-duration paddy.

Non-paddy-based agroforestry systems

In the non-paddy-based agroforestry systems, pulses and oilseeds were mainly grown with fruit trees in the fields and on bunds. Among pulses, black gram and moong bean were the preferred crops grown by farmers in the Kharif season. Apart from the progressive farmers, most farmers were not aware of the recommended varieties and used the previous year's grain as seeds.

Both OUAT and line departments recommended recently released high-yielding varieties, such as IPM 2-3 and IPM 2-14 of moong; and PU-31 and Shekher-1 of black gram. During Kharif, PU 31, IPM-2-14 were also introduced.

The project introduced varieties, recommended for Odisha, of moong, black gram and red gram. Moreover, in Rabi, a pulse – the grass pea variety Ratan — was introduced for the first time, at the project site. This provided additional yield up to 630 kg/ha from fallow land. The farmers were satisfied with the introduction of the new varieties and yield performance.

Over the three years (2018–21), the project covered 750 ha during the Rabi season each year and increased coverage to 1321 ha during 2021–22, with a total coverage of 3070 ha.

Further, diversified cropping systems with high Fe, high Zn rice and pulses are expected to increase the targeted village households' earnings and **lower malnutrition** by at **least 8–10%** in the two districts.

5.2 Reduction of rice-fallow area through agroforestry interventions

A large number of farmers in the project area were only able to grow one crop (rice) per year, following harvest of which the land was fallowed, mainly because of a lack of irrigation water. Through another initiative, ICRAF identified suitable areas to grow short-duration pulses in rice fallows. Accordingly, short-duration pulses like grass pea and green gram were introduced. Low β-N-oxalyl-L-α — ODAP — high-yielding varieties of grass pea (Ratan and Prateek) suitable for human consumption were introduced through *paira* cropping, seed priming and seed treatment, and spraying of 2% urea on foliage with fungicide (SAAF). These interventions resulted in rapid crop yields.

In Nuapada, a total of 1678 ha were covered in four years, with an average yield of 0.44 ton/ha. In total, 4195 farmers were supported during the four years, of whom 31.56% were migratory.

In Belpada, a total of 3312 farmers were supported in four years, receiving an average yield of 0.45 ton/ha, of whom 44.59% were migratory.

Over the course of four years, a total of 3071 ha rice-fallow was covered with grass pea, involving 7507 farmers with an average yield of 0.45 ton/ha, which added a total of 318 MT of protein-rich food to the food supply of the communities, which otherwise was not available.

On average, a gain of Rs. 6441 per farmer during 2018–19, Rs. 6608 during 2019–20, Rs. 4760 during 2020–21 and Rs. 7000 during 2021–22 was observed in Nuapada while in Belpada average gains of Rs. 6360 during 2018–19, Rs. 5950 during 2019–20, Rs. 7000 during 2020–21 and Rs. 8174 during 2021–22 per farmer were realised.

On average, a gain of Rs. 6443 per year was made during 2018–19 to 2021–22 by each of the 7507 farmers, which was otherwise not available to them in the project area.

The value of this additional gain over the district average of the two districts was Rs. 5,06,350 @ Rs. 3500 per Qt (no minimum price fixed by Government, so prevailing price during 2018–19 sold by farmers).

Monitoring of change in area of rice-fallow through geo-informatics

Using geo-informatic technology, the changes in rice-fallow area were monitored. The maps below show the predominance of rice-fallow in the northern part of the project area compared to the southern part, which is dominated by a double-cropping, paddy–pulses sequence.

Within a year of project intervention (2018–19 to 2019–20), the area of rice-fallow declined from 43.37% to 42.91% , representing a reduction of 238.20 ha.

Similarly, in the southern part of the project area, the double-cropping, paddy–pulses sequence was observed in 2018–19 across an area of 8746.56 ha (16.86%), which expanded by 122.50 ha in 2019–20 (an increase of 0.24%). The results were published internationally in 2021: https://www.sciencedirect.com/science/article/pii/S2666049021000086 (Singh et al. 2021).

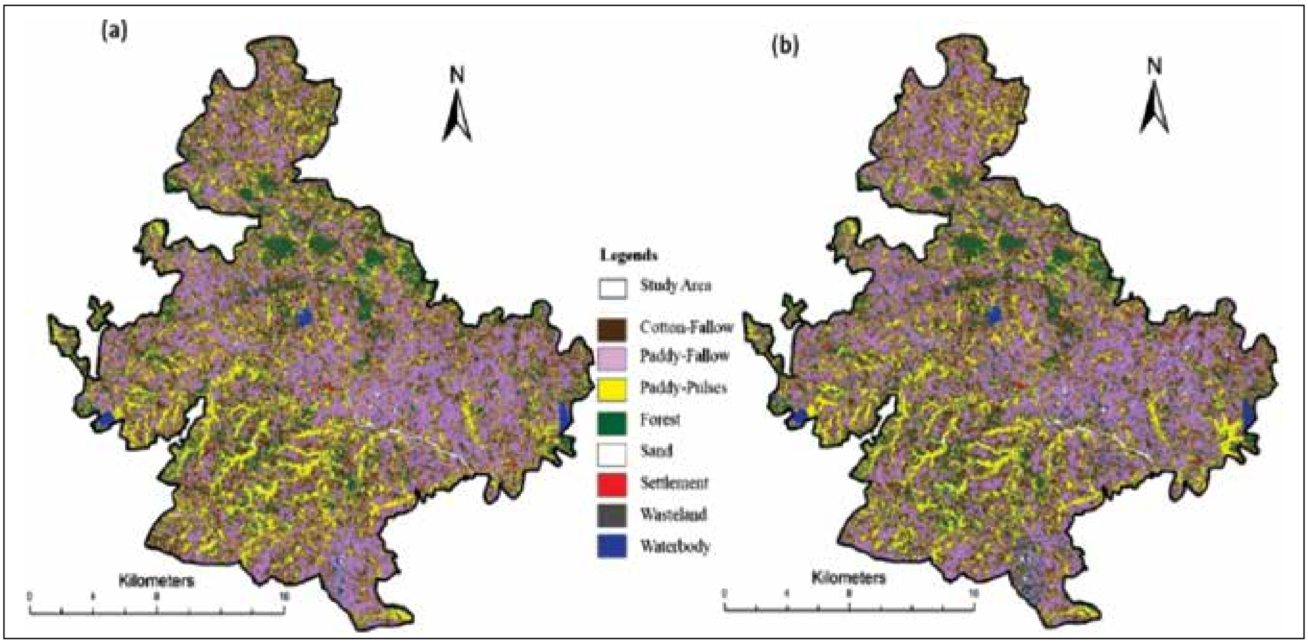


Figure 11. Crop area estimations (crop type maps), 2018–19 to 2019–20

Source: ICRAF

5.3 Tree-based interventions

With the abovementioned improved crop varieties having better nutrient values and higher yields, all farmers were provided with six fruit tree saplings per acre, that is, 15 plants per hectare, to be planted in fields along with the main crop in such a way that the yield of the main crop would not be adversely affected by tree shade in the future.

The saplings of fruit and MPTs were selected as per the field's location, topography and soil type, keeping in mind the choices of each farmer. For the backyard nutritional garden of individual households and communities (at schools), vegetables suitable for the area and fruit species were selected separately.

Fruit trees and MPTs were also distributed to farmers for planting on bunds. All the saplings and vegetable seeds were procured from Government-accredited nurseries in different States. For bund planting, saplings were provided at eight plants per acre, that is, 20 plants per hectare.

The saplings along with the main crop's seeds and other inputs (fertilizer at recommended doses, seed treatment chemicals, plant protection chemicals etc) were given to each selected farmer every year at the start of the crop season. Saplings were provided to farmers mainly during Kharif while papaya and moringa plants were provided during Kharif and also Rabi. With each sapling, farmers were given chemicals to prevent termite attack.

Saplings were provided for planting with paddy (main crop) in different types of lowland, with pulses and cotton intercropped with pigeon pea, on bunds, and in backyard nutri-gardens and model agroforestry systems where large numbers of fruit and MPT saplings were planted. Intercropping was done with other crops and vegetables with the aim of increasing income and nutritional security.

Table 3. Agroforestry saplings planted during 2018–19 to 2021–22

Species	No. of planted saplings				Total no. of planted saplings during 2018–21
	2018	2019	2020	2021	
Mango (Amrapali)	17,973	25,400	10,986	11,491	65,850
Apple ber (Green)	15,005	19,200	7786	7628	49,619
Guava (L49/VNR)	14,599	20,746	8828	6093	50,266
Custard apple (Balangir)	3658	2954	608	500	7720
Lemon (Kaffir lime)	2860	3915	2300	3000	12,075
Aonla (NA-7)	1200	1500	700	2000	5400
Jackfruit (Thailand baromese)		1900	1200		3100
Drumstick (PKM-1)	4230	5835	8812	11,468	30,345
Papaya (Red lady)	1860	2950	5198	5759	15,767
Teak	500	650	7000	3777	11,927
Bamboo (vulgaris / nutan)	200	400	8000	776	9376
Totals	**62,085**	**85,450**	**61,418**	**52,492**	**261,445**

Table 4. Agroforestry saplings surviving in agroforestry system with crops, 2018–19 to 2021–22

Species	No. of surviving saplings				Total no. of surviving saplings, 2018–21	% Overall survival
	2018	2019	2020	2021		2018–2021
Mango (Amrapali)	7649	21,181	9139	9174	47,143	71.59
Apple ber (Green)	5299	15,068	5643	5458	31,468	63.42
Guava (L49/VNR)	5273	17,324	7066	5285	34,948	69.52
Custard apple (Balanagar)	566	2463	512	337	3878	50.23
Lemon (Kaffir lime)	2202	3145	1748	2280	9375	77.64
Aonla (NA-7)	228	1170	452	1419	3269	60.54

Species	No. of surviving saplings				Total no. of surviving saplings, 2018–21	% Overall survival
	2018	2019	2020	2021		2018–2021
Jackfruit (Thailand baromese)		1508	964		2472	79.74
Drumstick (PKM 1)	2961	4777	5992	8262	21,992	72.47
Papaya (Red lady)	1680	2660	4512	5184	14,036	89.02
Teak	344	585	6052	3300	10,281	86.20
Bamboo (vulgaris / nutan)	168	360	7140	711	8379	89.36
Totals	26,370	70,241	49,220	41,410	187,241	71.62

Table 5. Combined sapling survival data

Total no. of planted saplings = 261, 445				Surviving saplings at end of project = 186,789					Average survival rate = 71.62%			
No. of saplings in different activities of agroforestry	Saplings planted during 2018–19	Surviving no. of saplings	% survival	Saplings planted during 2019–20	Surviving no. of saplings	% survival	Saplings planted during 2020-21	Surviving no. of saplings	% survival	Surviving no. of saplings	Surviving no. of saplings	% survival
Species	Year 2018	Year		Year 2019	Year		Year 2020	Total		Year 2021	Year	
Mango (Amrapali)	17,973	7649	42.55	25,400	21,181	83.39	10,986	9139	83.18	11,491	9174	79.83
A. Ber (Green)	15,005	5299	35.31	19,200	15,068	78.48	7786	5643	72.47	7628	5458	71.55
Guava (L49/VNR)	14,599	5273	36.12	20,746	17,324	83.50	8828	7066	80.04	6093	5285	86.74
C. Apple (Balangir)	3658	566	15.47	2954	2463	83.38	608	512	84.21	500	337	67.4
Lemon (Kaffir lime)	2860	2202	76.99	3915	3145	80.33	2300	1748	76.0	3000	2280	76.0
Aonla (NA7)	1200	228	19	1500	1170	78.0	700	452	64.57	2000	1419	70.95
Jackfruit (Thailand baromese)				1900	1508	79.37	1200	964	80.33			
Drumstick (PKM1)	4230	2961	70	5835	4777	81.87	8812	5992	67.99	11,468	8262	72.04
Papaya (Red lady)	1860	1680	90.32	2950	2660	90.17	5198	4512	86.80	5759	5184	90.01
Teak	500	344	68.8	650	585	90.0	7000	6052	86.45	3777	3300	87.37
Bamboo (vulgaris / nutan)	200	168	84	400	360	90.0	8000	7140	89.25	776	711	91.62
Totals	62,085	26,370	42.47	85,450	70,241	82.20	61,418	49,220	80.13	52492	41410	78.88

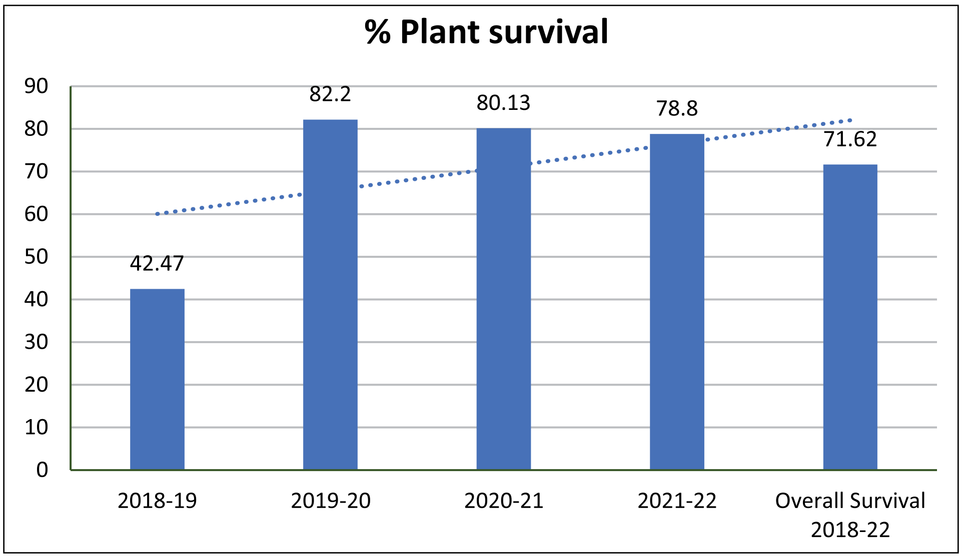


Figure 12. Plant survival by year and overall, 2018–19 to 2021–22

Examining Table 4 and Figure 12, it is evident that the survival of saplings was adversely affected (42.47% survival) during the first year of planting (2018–19). This was mainly due to stray animals destroying the newly planted saplings and lack of moisture during dry spells. In both districts, stray animals are a major problem after the harvest of Kharif season paddy because generally farmers grow only one crop a year owing to non-availability of irrigation during Rabi.

In the project design, there was no provision for protection of plants from stray animal damage and availability of water during dry spells. Besides this, stress migration of farmers in search of employment to other States after the Kharif paddy harvest was another problem because during their absence no-one was available to care for their planted saplings.

The decision of the second Steering Committee Meeting in April 2019 was a landmark, providing tree guards to farmers and assisting them with watering during dry spells, especially, for farmers who migrated, by hiring water tankers and labourers on daily wages (preferably from among the migratory farmers). Providing sub-surface irrigation through pipes was a major intervention making moisture available for one week to plants with a one-time application. This resulted in higher survival rates every year after 2018–19. Even during the COVID-19 pandemic, the plants were maintained.

5.4 Income from backyard fruit species

The prevalence of malnutrition in the Nuapada and Belpada blocks cannot be mitigated only solving food security. Nutritional security is only possible if a nutrient-rich diet is available to the population. Fruit and vegetables are two of the most important sources of vitamins and minerals and can help solve the malnutrition problem, which is the primary objective of the project. But this is only possible if small-scale and marginalised farmers have the fruit and vegetables growing in their backyards and do not need to buy them from the market.

Therefore, the project focussed on increasing year-round availability of these sources in backyard gardens. Beneficiaries were encouraged to consume fruit and vegetables regularly in their diet.

Figure 13. Backyard fruit tree planting

In addition to vegetables, fruit species, such as guava (*Psidium guajava* var. VNR), lemon (*Citrus aurantiifolia* var. Konkan lemon), moringa (*Moringa oleifera* var. PKM 1), papaya (*Carica papaya* var. Red lady), mango (*Mangifera indica* var. Amrapali), and apple ber (*Ziziphus mauritania* Green) were planted. Farmers accepted the material as per available space in their backyard.

The total cost of planting and transportation during the four years (2018–22) was Rs. 1,13,920. The actual value of fruit produced from saplings planted from 2018–19 to 2021–22 was Rs. 3,38,910, which, projected for the next three years, increases to Rs. 8,98,560 (Table 6).

The actual cost–benefit ratio realised up to 2021–22 from the backyard fruit species was 1:2.97 while the projection for the next three years (2022–23 to 2024–25) was 1:7.89.

Figure 14. Production of papaya var. Red lady in a backyard

Table 6. Value of fruit produced from saplings planted in backyards, actual and projected

Species	Actual (Rs. Lakh)				Projected (Rs. Lakh)			2025–26 Projected (Rs. Lakh)	Total Projected (Rs. Lakh)
	2019–20	2020–21	2021–22	Total	2022–23	2023–24	2024–25		
Apple ber (Green)	7.79	16.84	30.75	55.38	29.42	24.41	11.38	11.38	65.21
Papaya (Red lady)	8.40	28.00	56.74	93.14	81.46	78.30	51.39	51.39	211.15
Drumstick (PKM 1)	11.10	34.91	75.86	121.87	111.10	103.34	73.98	73.98	288.42
Guava (L 49/VNR)		6.86	17.77	24.63	34.00	34.55	34.03	19.86	102.58
Lemon (K. lime)		7.70	18.17	25.87	40.05	38.86	30.11	10.32	109.02
Mango (Amrapali)		4.92	13.10	18.02	31.32	41.10	49.74	47.96	122.16
Totals	27.29	99.23	212.39	338.91	327.35	320.56	250.63	214.89	898.56

Note: In Rs. Lakhs: 2019–20 to 2021–22 actual and 2022–23 to 2024–25 projected.
INR 1 lakh = 1333.33333 USD (2023)

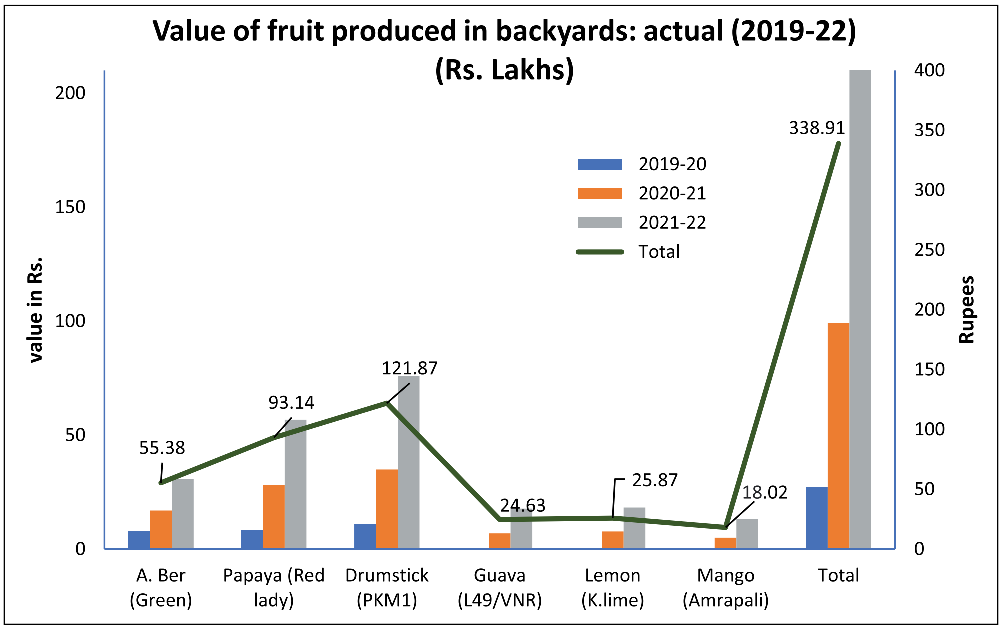


Figure 15. Actual value of fruit produced from saplings planted in different years

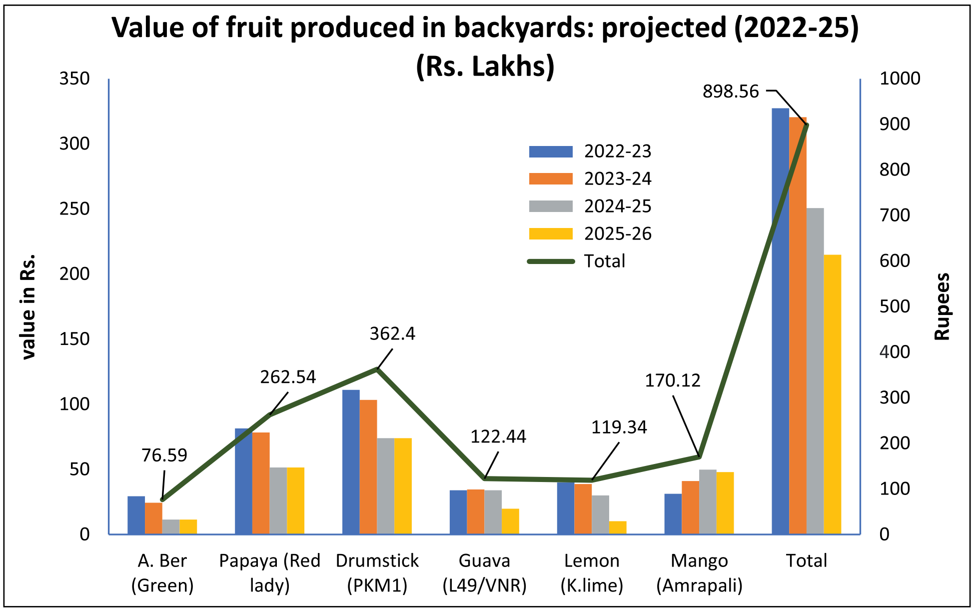


Figure 16. Projected value of fruit produced from saplings planted in different years

Note: Actual (top) and projected (below); in Rs. Lakhs (2019–20 to 2021–22 actual and 2022–23 to 2024–25 projected). Projected income for 2025–26 has not been included in this estimation.

Source: ICRAF

Backyard plantings of vegetables

The prevalent malnutrition in the Nuapada and Belpada blocks cannot be mitigated by solving food security alone. The solution must include augmentation and diversification of the diets of the population. Fruit and vegetables are among the most important natural sources of vitamins and minerals. Therefore, the project focussed on increasing the year-round availability of these in backyard gardens.

A total of 13,400 households were supported by the project through provision of seeds of tomato (*Solanum lycopersicum* var. VNR-3357 F_1), brinjal (*Solanum melongena* var. VNR-Utkal), okra (*Abelmoscus esculentus* var. VNR-Apoorva), cowpea (*Vigna unguiculata* var. Kashi kanchan), bitter gourd (*Momordica charantia* var. VNR-22) and chilli (*Capsicum annum* var. VNR-Sunidhi) and fruit species — guava (*Psidium guajava* var. VNR), lemon (*Citrus aurantiifolia* var. Konkan lemon), moringa (*Moringa oleifera* var. PKM-1), papaya (*Carica papaya* var. Red lady), mango (*Mangifera indica* var. Amrapali), and apple ber (*Ziziphus mauritania* Green) — along with fertilizer and other inputs.

Figure 17. Backyard production of vegetables

Table 7. Income from backyard vegetable production and sale of 70% of produce (30% produce kept for family consumption), 2018–19 to 2021–22

Vegetable grown in backyard	Income 2018–19	Income 2019–20	Income 2020–21	Income 2021–22	Total (Rs. in Lakh)
Okra	10.58	20.13	30.14	52.46	113.31
Brinjal	12.16	22.25	36.65	65.68	136.74
Tomato	14.40	25.66	41.20	71.23	152.49
Cowpea	21.82	18.01	28.95	48.87	117.65
Bitter gourd	-	57.14	92.13	160.33	309.60
Chili	9.34	-	-		9.34
Totals	68.30	143.19	229.07	398.57	839.13
No. of households (HH)	2860	4775	7691	13,400	
Income / HH	Rs. 2388.11	Rs. 2998.74	Rs. 2978.42	Rs. 2974.40	

Note: Rs. in Lakh.
INR 1 lakh = 1333.33333 USD (2023)

The provision of seeds helped farmers by providing access to vegetables and fruit to meet their daily nutritional needs and generate additional income through sale of any extra in local markets. It has been estimated that after consuming 30% of the vegetables, the participating farmers (each household) earned an average of Rs 2388 in the first year, Rs 2998 during the second year, Rs. 2978.42 in the third year and Rs. 2974.40 in the third year of the project (Table 6 and Figure 18).

The total income from sale of 70% of vegetable produce grown in backyards during the four years was Rs. 839.13 Lakh (Table 6).

The total expenditure for vegetable seeds (Rs. 46.73 Lakh) plus Rs. 41.6 Lakh (VNR-CSR) and transportation and distribution (Rs. 4.28 Lakhs) was Rs. 92.61 Lakh. Therefore, the cost–benefit ratio (vegetable production and sale of 70% produce) was estimated at 1:13.40 during the four years (2018–22). The average income from backyard vegetable production per household during the four years is shown in Figure 18.

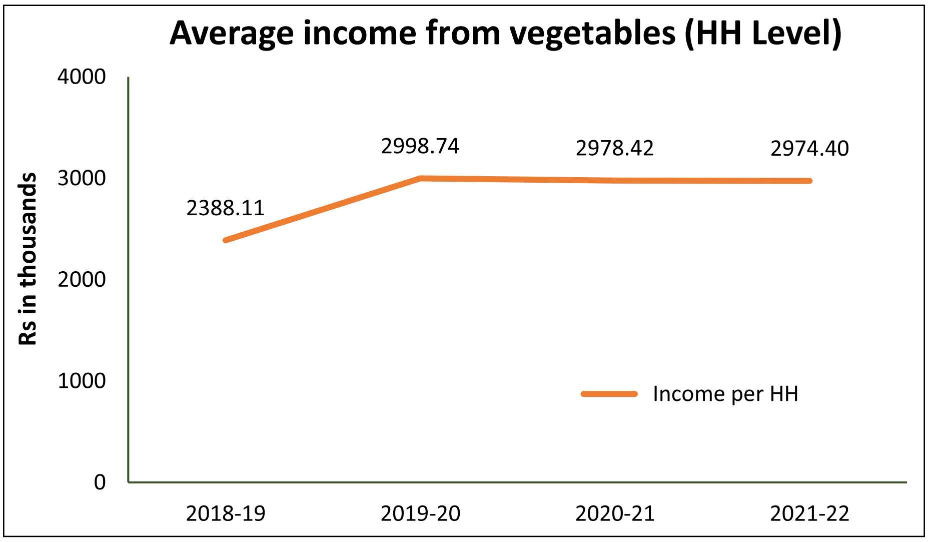


Figure 18. Average income from backyard vegetable production per household, 2018–19 to 2021–22

The actual cost–benefit ratio realised up to 2021–22 from the backyard fruit species was 1:2.97 while the projection for the next three years (2022–23 to 2024–25) was 1:7.89.

The estimated availability of vitamins and minerals to each household through the backyard garden activity is presented in Table 8. The table illustrates how the enhanced availability of vegetables and fruit has increased the access of participating communities to much required vitamins and minerals. Fruit production will increase over time, which will further improve the nutritional security of the population.

Table 8. Estimated availability of vitamins, minerals, and other nutritive components to each household through backyard gardens

			Vegetables				Fruit			Vegetables + fruit
Nutritive component		**Unit**	**2018–19**	**2019–20**	**2020–21**	**2021–22**	**2019–20**	**2020–21**	**2021–22**	**Grand total**
1	Fibre	gm	445.38	576.49	588.93	736.79	190	1989	8542	13069
2	Folate	mcg	7527.45	10508	11272.69	13814.88	4144	6474	30327	84068
3	Niacin	mg	118.56	124.07	115.61	125.77	37.85	130.84	618.17	1270
4	Pantothenic acid	mg	59.6	66.49	56.11	64.90	17.44	37.57	79.88	382
5	Riboflavin	mg	9.06	10.95	9.93	10.71	3.02	7.88	36.13	88
6	Thiamine	mg	13.86	16.57	16.22	17.38	257.6	398.07	1794.3	2514
7	Vitamin A	IU	60562.94	93053.78	108300	106598	106400	166981	752823	1394719
8	Vitamin C	mg	3639.36	8225.78	9204	8141.63	6821	16062	71990	124084
9	Ca	mg	6266.99	6231	5984	6352	2240	5142	23495	55710.99
10	Fe	mg	128.56	107.13	104.48	109.31	28	82	377	936
11	Zn	mg	44	98	107	99.18	8.96	17.8	89	464

5.5 Plants as insurance against adverse weather effects on crop income

Field-crop cultivation depends on weather parameters. In years when rainfall is adequate and distributed during the growing period, yields are good and so is income. Comparing different years' crop yields, it was observed that despite technological interventions, the yield of paddy and grass pea in rice fallow were adversely affected by weather fluctuations.

During 2019–20, rainfall in both districts was good during Kharif so the yields of paddy in Kharif and grass pea in rice fallow were better than 2018–19 but during 2020–21 and 2021–22 inadequate rainfall resulted in lower yields of both paddy and grass pea, which adversely affected farmers' incomes. This resulted in fluctuating additional income from paddy and grass pea over the district average yields for 2018–19 in all years.

However, during the same period, fruit and vegetables grown in backyards under the project survived better under weather fluctuations and yields were not so adversely affected. Farmers consumed 30% of their backyard produce and sold 70% in the market.

As mentioned above, it was estimated that after consuming 30% of the vegetables and 50% of fruit, the participating farmers (each household) earned an average of Rs 2388 in the first year, Rs 3953 during the second year, Rs. 5056 in the third year and Rs. 5735 in the fourth year of the project (Table 7 and Figure 18).

The graph below shows that the total additional income from crops per household over and above the district average yield of 2018–19 fluctuated depending on weather parameters while income from backyard fruit and vegetables per household increased year on year as per the growth of the plants (planted during 2018–19) under the same fluctuating weather conditions (Figure 19).

This clearly shows that growing fruit species may serve as insurance against the adverse effects of weather.

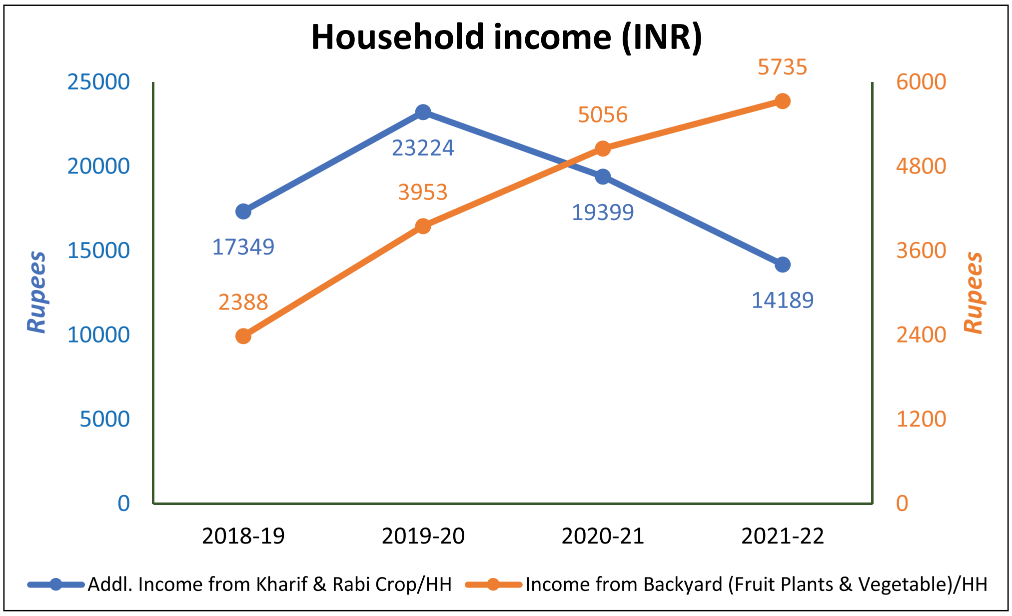


Figure 19. Household income from fruit, vegetables and Kharif and Rabi crops, 2018–22

Agroforestry saplings planted as intercropping.

In addition to planting in backyards, a total of 173,073 saplings of mango, guava, apple ber, custard apple, lemon (Konkan), aonla, jackfruit, drumstick, papaya, and other species, that is, teak and bamboo, were planted with paddy, maize, vegetables, pulses and cotton mixed with crops/intercrops and on bunds (Table 8).

The projected value of these species reveals the additional benefits from agroforestry systems with increases in crop yields over district averages.

Table 9. Total saplings planted and survival during the project period under intercropping

Species	Year 2018–19		Year 2019–20		Year 2020–21		Year 2021–22		Total	
	Saplings planted	Saplings survived	Saplings planted	Saplings survived	Saplings planted	Saplings survived	Saplings planted	Saplings survived	Saplings planted	Saplings survived
Mango (Amrapali)	15113	5189	23485	19553	8070	6573	5782	4378	52450	35693
Apple ber Green	12145	3526	17285	13689	4870	3602	5630	3946	39930	24763
Guava L 49	11739	3128	18831	15792	5912	4675	3239	2802	39721	26397
Custard apple (Balangir)	3658	556	2954	2463	608	512	500	337	7720	3868
Lemon (Konkan)	-	-	2000	1765	-	-	1899	1456	3899	3221
Aonla (NA-7)	1200	228	1500	1170	700	452	1950	1373	5350	3223
Jackfruit (Thailand baromese)	-	-	1900	1508	1200	964	-	-	3100	2472
Drumstick PKM 1	-	-	500	402	2000	1360	50	42	2550	1804
Papaya (Red lady)	-	-	-	-	1500	1179	50	45	1550	1224
Teak	500	344	650	585	2500	1652	3777	3300	7427	5881
Bamboo (Bambusa vulgaris / nutan	200	168	400	360	8000	7140	776	711	9376	8379
Totals	44555	13139	69505	57287	35360	28109	23653	18390	173073	116925

6. Livelihood Improvement through Enhanced Income

6.1. Entry points of interventions

Figure 20. Entry point intervention: vegetable seed packets to farmers

When conducting scientist–farmer interaction meetings for selection of beneficiaries, as our entry point interventions we provided vegetable seed packets (one packet with five types of vegetable seeds: brinjal, chilly, okra, onion, cowpea) (Figure 20), one each to a total of 7925 households: 5301 households (farmers) @ 57 farmers in each village (93 villages) in Belpada and to 2624 households @ 64 farmers in each village (41 villages) in Nuapada, out of which migratory farmers were 385 in Belpada and 134 in Nuapada, initially. A total of 23,000 farmers were supported through the entry point interventions.

Improved varieties of seasonal vegetables were given to all farmers: onion (AFDR), cowpea (Kashi Kanchan), okra (Arka Anamika), chilli (PSB), brinjal (PPL).

After the entry point interventions and selection of beneficiaries through scientist–farmer interactions, as mentioned above small-scale and marginalised farmers from all he villages were selected to introduce agroforestry in a system mode with various crops.

Bund plantings with fruit and MPTs

For bund planting, saplings of fruit species were provided, with a total 4534 ha covered. Species were selected through a participatory approach considering farmers' preferences and agroecological conditions.

A portfolio of eight fruit and/or MPT species per acre was provided for boundary planting (minimum 1 acre and maximum 5 acres). Species like mango, guava, apple ber, custard apple, aonla, jack fruit, teak, bamboo and gambhar were included. Moringa and papaya were also provided as per requirements and suitability. Papaya and apple ber started bearing from the second year with an average yield of 20 kg/plant and 15 kg/plant, respectively. Guava fruiting started in the third year with an average of 8 kg/plant, and lemon with 10 kg/plant. Aonla, jackfruit and custard apple are expected to start fruiting from the fifth year, during 2023–24. Thus, the fruit trees introduced under the project started providing an average income of Rs. 1450/plant from the third year. The project planted 2,61,445 plants with a 71.62% survival rate by the third year (tables 3, 4 and 9).

Figure 21. Bund/boundary planting based in agroforestry system mode

6.2. Nurseries for quality planting material

The project area was dominated by small-scale and marginalized farmers who did not have access to QPM for growing various types of fruit and MPTs.

To help the farming communities and develop a business model, two QPM nurseries were established in the project area. The nursery growers were provided with a 15-day training course on QPM at the Horticultural Institute, Khordha, Government of Odisha.

The nurseries helped in storing planting material procured from other areas for distribution to farmers and grew planting material from the mother stock of various species provided by the project.

The nurseries played a crucial role in maintaining about 200,000 seedlings procured from other far-flung areas, producing root stocks of mango, and are expected to start grafting using the mother plants established at these nurseries.

Figure 22. QPM nurseries at Belpada and Nuapada

Figure 23. Storing QPM in a nursery

Women's self-help groups

In collaboration with Odisha Livelihood Mission, the project established 36 women's self-help groups (WSHGs) and trained the members in producing QPM.

The training was organised at both the district level and at specialized institutions, such as the Horticulture Training Institute, Khordha.

Figure 24. Women's self-help group training

The WSHGs were provided with basic toolkits to etablish and manage nurseries for quality seeds of papaya and moringa. A buy-back system was also established through the project. Production and sale of moringa, papaya, tomato and chilli seedlings enabled the WSHGs to earn Rs. 1,04,920 during 2019 and Rs. 1,69,180 during 2020. Based on interviews with members of the WSHGs, it was estimated that the average income of each member of each group during the four years of the project was Rs. 28,000.

Figure 25. Visit of the Additional Secretary of Agriculture, Government of Odisha to a WSHG nursery

7. Introduction of Innovative Technologies

7.1 Agrivoltaic system: a potential option for food and renewable energy production for smallholders

An agroforestry-agrivoltaic system (Figure 26) was piloted as a potential option to grow crops, fruit and fodder while generating renewable energy from a single land unit. The system is best suited for those areas where sunlight is available in plenty and land productivity is comparatively low.

ICRAF in partnership with ICAR CAZRI Jodhpur (Lal 2019) installed a 5 KW agrivoltaic unit in the field of a migratory farmer in Salandi village of Belpada Block, Balangir District. The unit generates about 1250 KW per month, valued at Rs 3488. In addition, the farmer is growing shade-loving vegetables under the panels.

Considering savings on electricity costs and the additional income from sale of vegetables and enhanced yields of rice owing to assured irrigation, the participating farmer earns an average of Rs 85,000 per year, which was not available without the agrivoltaic system.

A detailed success story can be read at *A Road Less Travelled by Migratory Farmers of Odisha: Innovative Agroforestry Practices*.

Figure 26. Agrivoltaic system installed at a migratory farmer's site

Photo: ICRAF

7.2 Hydrogel technology proves effective in improving survival and yields

Survival of saplings in the absence of sufficient moisture was one the biggest challenges during the peak summer season when temperatures reached beyond 40 ^{0}C. To tackle this, two types of hydrogels, Pusa Vaaridhar and SNF, were introduced. Results indicated the effectiveness of hydrogels by delaying wilting for at least 4–5 days in comparison with the control without using hydrogel (tables 10, 11).

Similarly, hydrogel application to the Ankit variety of paddy yielded 14% higher than control under similar conditions of input, moisture etc. The average yield of paddy variety CR 101 (Ankit) with use of hydrogel was 5.02 ton/ha whereas without hydrogel it was 4.40 ton/ha.

The technology will benefit the survival and growth of plants in areas where water scarcity is high.

Table 10. Crop-cutting yield data for Ankit (CR 101) variety using hydrogel at Nuapada during 2020–21

	Farmer's Name	Village	Crop-cutting date	Yield in 5x5 m	Yield Q/ha
1	Dhani Ram Sabar	Dhanora	12.10.2020	13.50	54.00
2	Basanta Rana	Dhanora	12.10.2020	15.69	62.76
3	Lambodar Sabar	Kuliabandha	21.10.2020	12.5	50.0
4	Lakhan Majhi	Kuliabandha	21.10.2020	15.6	62.4
5	Nadeba Pandey	Boirbhadi	17.10.2020	9.58	38.32
6	Anand Ram Harijan	Kukrimundi	20.10.2021	8.35	33.4
Average				12.54	50.15

Table 11. Crop-cutting yield data for Ankit (CR 101) variety without hydrogel

	Farmer's name	Village	Crop-cutting date	Yield in 5x5 m	Yield Q/ha
1	Shyam Kumar Rana	Dhanora	27.10.2020	6.9	27.6
2	Jhanak Naik	Boirbhadi	17.10.2020	8.5	34.0
3	Kanhiya Raut	Magurpani	28.10.2020	14.00	56
4	Laltu Rout	Magurpani	28.10.2020	16.01	64.04
5	Bhusan Harijan	Kukrimundi	24.10.2020	11.5	46.0
Average				11.38	45.5

Note: Average yield of paddy var. CR 101 (Ankit) with use of hydrogel: 50.15 Q/ha; average yield of paddy var. CR 101 (Ankit) without use of hydrogel: 45.5 Q/ha; % increase owing to use of hydrogel: 10.2%.

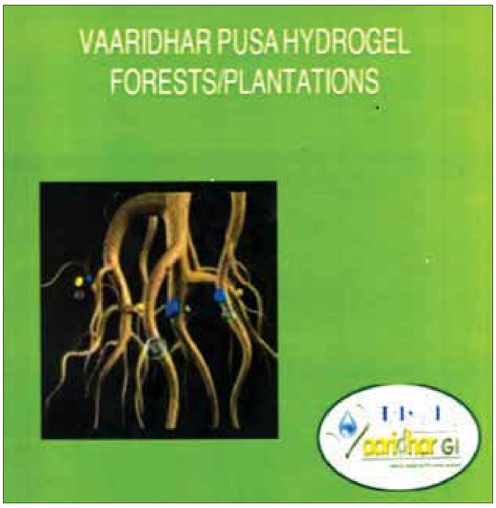


Figure 27. Hydrogel use during sapling planting

7.3 Modified sub-surface irrigation for ensuring better survival and growth of plants

Sub-surface irrigation, also known as sub-irrigation, involves irrigation of crops by applying water from beneath the soil surface either by constructing trenches or installing underground perforated pipes or tile lines. The method, which was intitially used with tuber crops, is now gaining popularity for other crops, and tree plantations as well, where water scarcity is common.

Figure 28. Fixing of sub-surface irrigation and tree guard

Figure 29. The District Collector of Nuapada observing the procedure

ICRAF introduced a modified sub-surface irrigation method wherein a polyvinylchloride (PVC) pipe of approximately 85 cm length, 10 cm inside diameter, and a working pressure of minimum 2.5 kg/cm^2 was installed near the root zone of tree saplings. The bottom of the pipe was permanently closed using a cap, and a hole of 2.5 mm was made just above the cap, facing the sapling. Each pipe was filled with 10 litres of water and the mouth of the pipe covered using a plastic sheet to avoid evaporation. The water in the pipes successfully maintained enough moisture in the root zones of saplings for an average of 5–6 days, reducing the need of watering on a daily basis. Thus, the method has the capacity to save significant amounts of labour and water and increase the survival rate of the plants by 71.62%.

7.4 Biofortified seed production of paddy (CR Dhan 310)

Procuring the seed of appropriate varieties at the right time is one of the biggest challenges faced by small-scale and marginalized farmers yet their livelihoods depend on seasonal incomes from crops.

Biofortified paddy varieties CR Dhan 310 and 311 (with 10.30% protein) introduced under the project in the two districts have proved to be promising in improving yields and adding nutrients to farmers' food baskets.

The average yields of CR-310 and CR-311 were 3.28 ton/ha and 12.33% higher compared to the traditionally grown variety MTU 1010/MTU 1001 of the same maturity duration, which is evident from crop-cutting experiments (Figure 30).

The project encouraged 29 progressive farmers to form five Farmers Producer Organizations (FPOs) in four GPs (Annex 1) who were trained to produce and market certified seeds of the newly introduced biofortified varieties. The FPOs together produced 44 tons of certified seed of CR 310 during 2020–21. The majority of this was procured by the Odisha State Seed Corporation (OSSC) to mainstream the new varieties in the seed cycle of the State. Seed-producing farmers and their FPOs are now registered with OSSC as seed producers.

Figure 30. Crop-cutting experiment for rice var. CR 310

7.5 Geotagging activities through spatial technology

All the project's activities were geotagged and uploaded on the BHUVAN platform. Geotagging is the process of adding geographic information as digital content within 'metadata' tags, including latitude and longitude coordinates, place names and/or other positional data. It can help people find the activity information based on location on satellite images. Every collected piece of GPS datum has LAT/LONG value of the plants and crops with the unique ID of the farmer's name. All the project activities — input distributions, crop demonstrations, agroforestry plantations, natural resource management interventions and others — were geotagged.

The technology helped in monitoring the survival of plants. In the first year of the project in 2018–19, the survival rate was about 50%, however, the introduction of tree guards, hydrogel and sub-surface irrigation, raising farmers' awareness and providing training resulted in improvement of the survival rate to 60% in 2019–20 and 75% in 2020–21.

About 9000 farmers' activities (4700 in Belpada and 4300 in Nuapada) have been geotagged and uploaded on the BHUVAN portal.

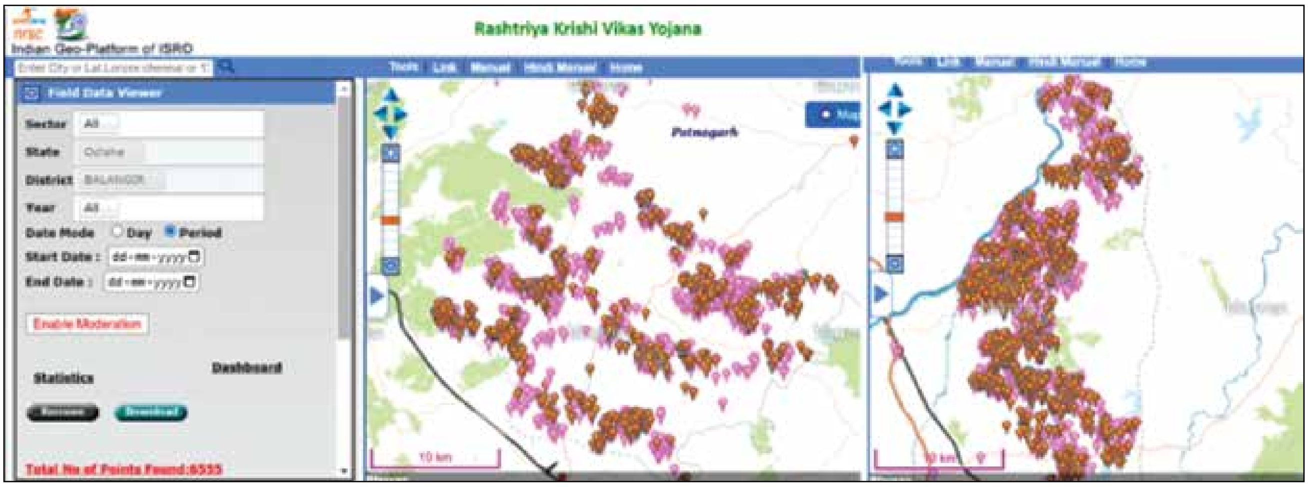
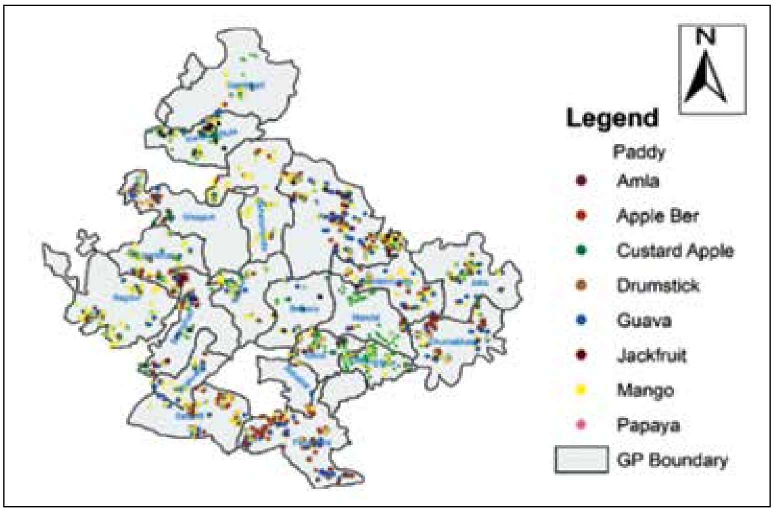


Figure 31. Sample screen of project activities geotagged and uploaded on the BHUVAN platform in Belpada and Nuapada

Source: BHUVAN

The survival rate has been calculated for each species and we found that mango had highest and drumstick the lowest survival rate in 2018–2019 in both blocks. Other species were found to fall in between. In descending order: guava, papaya, custard apple, apple ber and jackfruit.



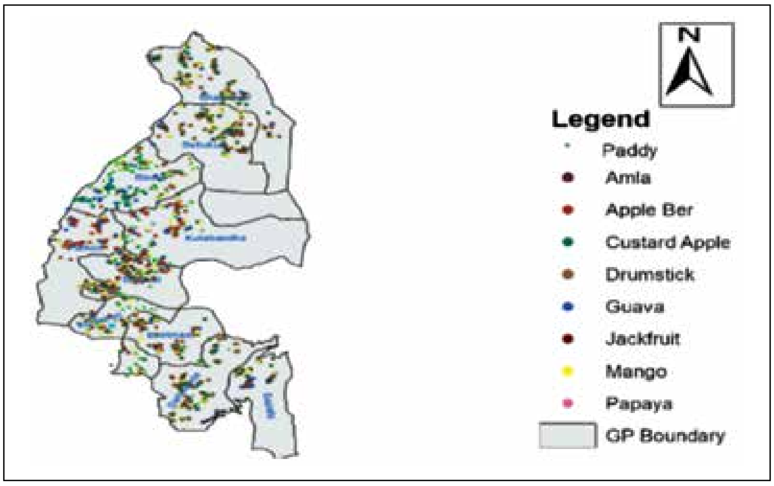


Figure 32. Spatial distribution (geotagging) of agroforestry interventions in Balangir and Nuapada

Figure 33. Geotagging in action

7.6 Geo-tagging of project assets on Bhuvan-RKVY Geo-Portal using Bhuvan-RKVY

Rashtriya Krishi Vikas Yojana (RKVY) is a State Plan Scheme that seeks to provide the States and Territories of India with the autonomy to draw up plans for increased public investment in agriculture by incorporating information on local requirements, geographical/climatic conditions, available natural resources/technology and cropping patterns so as to significantly increase the productivity of agriculture and its allied sectors. Apart from providing autonomy and flexibility to the States, the scheme also aims to maximize returns to farmers in the Agriculture and allied sectors. The Scheme covers various sectors of agriculture, horticulture, animal husbandry, dairy, fisheries, soils and nutrient management etc.

ICRAF uploaded most of the project's activities onto the RKVY-Bhuvan portal using the Bhuvan geotagging mobile app. Up to the time of writing, ICRAF had uploaded approximately 9000 farmers' data, moderated at district and State levels.

Figure 34. Bhuvan-RKVY portal (Bhuvan-RKVY-https://bhuvan-app1.nrsc.gov.in/rkvy/)

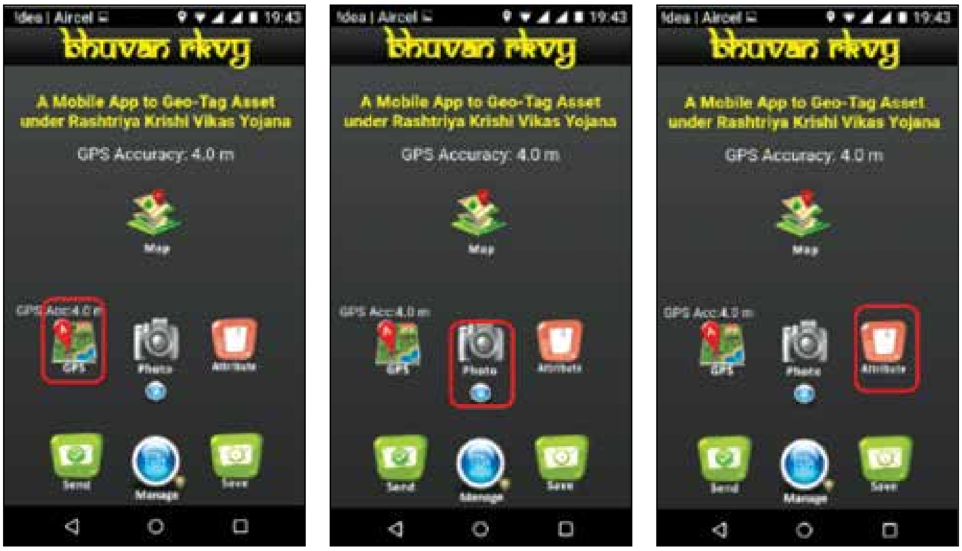


Figure 35. Screenshots of the Bhuvan-RKVY mobile app

Figure 36. Screenshots of uploaded information on Bhuvan-RKVY

7.7 Agroforestry Assistant smartphone application

To provide a strong extension support mechanism, an Agroforestry Assistant Application (AFA) was jointly developed by ICRAF and the Government of Odisha.

AFA is a smartphone-based digital platform to accelerate sustainable agroforestry intensification for site-specific interventions. AFA helps extension agents, development partners and progressive farmers to select the right agroforestry system and package of associated practices (including tree species, accompanying crops, and nearest nursery to procure QPM). Farmers are able to choose the right kinds of trees to produce timber, fruit, fuel wood, fodder, and medicinal products.

Figure 37. Sample screens of the smartphone Agroforestry Assistant application

Before the project, farmers were not able to easily obtain correct information in time owing to an shortage of strong extension services. With AFA, a farmer can select suitable tree species based on desired products and environmental services, drawing on research conducted by ICRAF and partners, including spatial databases of both naturally occurring and exotic agroforestry tree species. The app can also suggest appropriate tree and crop combinations. AFA helps farmers to manage both components, improving productivity by timely and precise dissemination of appropriate information. AFA offers easy and wider access to information for profitable agroforestry systems: farmers save time and money since they don't need to travel to obtain information and documents. Through AFA, extension agencies and others related to agriculture reduce their administrative costs for dissemination of information. The crops and agroforestry species' suitability was estimated using optimum parameters of climate, topography, soil and socioeconomic factors and a multicriteria decision analysis and analytical hierarchy process was used for final suitability.

AFA comprises six specific modules, excluding registration that facilitates farmers to register and use the app (Figure 39).

1. Introduction: Information on the agroforestry systems and benefits.
2. Crops: A full package of practices related to selected tree species.
3. Trees: A full package of practice related to selected crop species.
4. Agroforestry System.
5. Nursery.
6. Agroforestry Planner: the farmer can add their farm resources, which are used for interacting and for providing recommendations and services on crops and agroforestry species, including QPM.

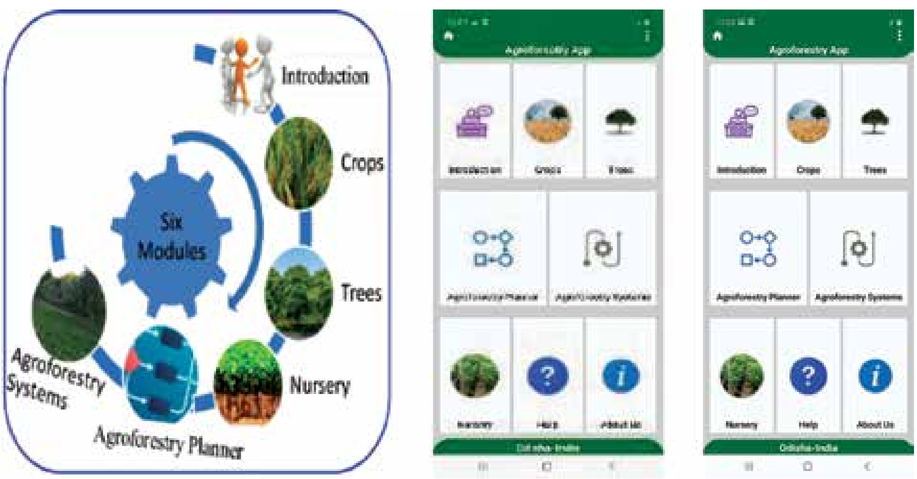


Figure 38. Modules of AFA

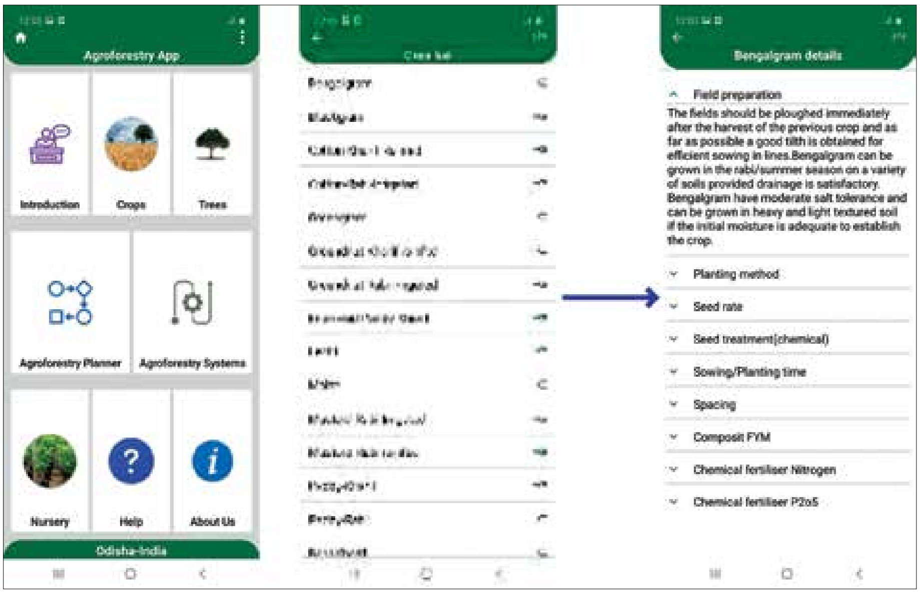


Figure 39. Agroforestry species (Crop) module

Figure 40. Agroforestry species (Tree) module

Figure 41. Screenshots of Nursery module

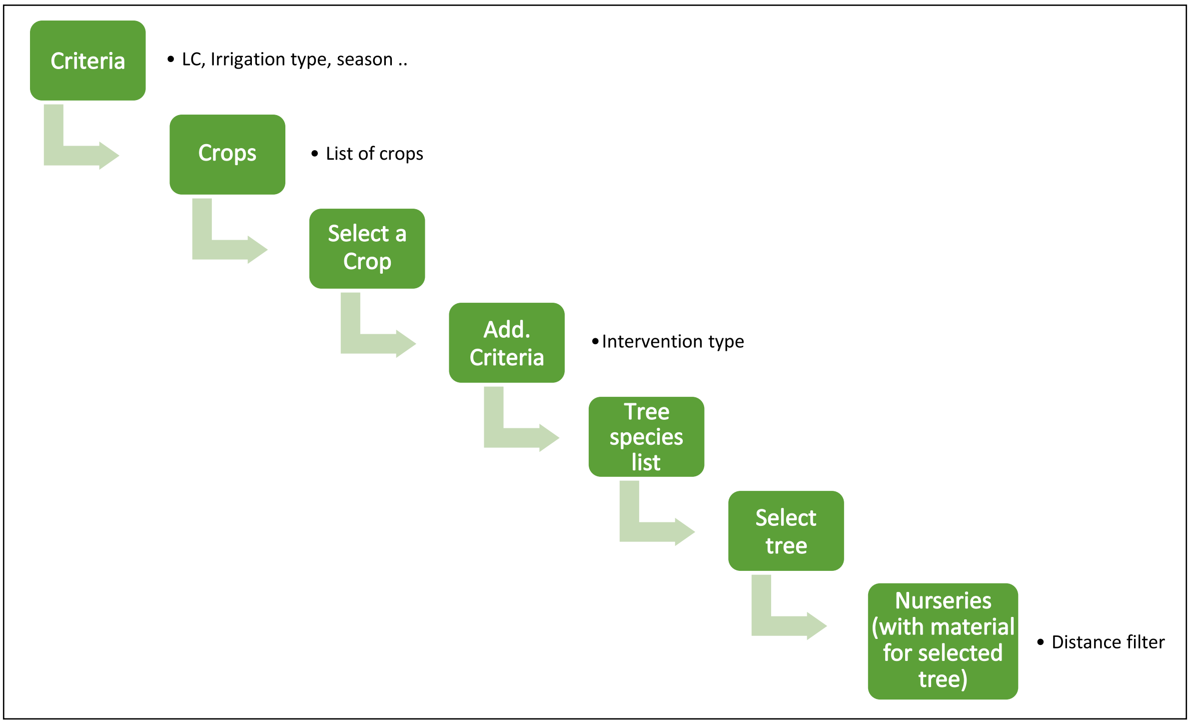


Figure 42. Agroforestry Planner workflow

AFA also provides suggestions about processing, value addition and marketing for tree products to assist the farmer produce high value, marketable products.

AFA was officially launched by Shri Suresh Kumar Vashishth, Commissioner and Secretary, DAFE, Government of Odisha, on 24 December 2021 in Bhubaneswar, Odisha.

Figure 43. The Agroforestry App being launched by Shri Suresh Kumar Vashishth, Commissioner and Secretary, Government of Odisha

AFA is available on Google Play: https://play.google.com/store/apps/details?id=org.icraf.agroforestryappindia&hl=hi&gl=US. It had been downloaded 5000+ times as of March 2024.

8. Building System Resilience through Agroforestry-based Natural Resource Management

The project area is typically rainfed, degraded, undulating and highly vulnerable to various types of topographic and climatic vagaries and socio-economic pressures. The soil featured a poor waterholding capacity owing to severe erosion, requiring frequent irrigation. Climatic events, including high incidence of extremes — such as increased frequency of heavy downpours, longer duration of dry spells, shifting length of growing periods, and greater temperature stresses — are common in both the project's districts.

During the rainy season, a significant amount of surface runoff is generated, ranging 350–700 mm/ year. Even capturing 10–20% of the runoff offers great opportunities through small-scale, decentralised, rainwater-harvesting structures. Much of the area is left fallow during the Rabi season owing to water scarcity, which can be successfully changed through physical and biological interventions. Improvement of vegetal cover through agroforestry along with natural resource management can help in sustainable agriculture and resource conservation.

8.1 Intervention and impact

ICRAF with ICAR CAFRI initiated a series of agroforestry-based natural resource management (NRM) interventions. With strong support from the Government's line departments, led by the Directorate of Soil Conservation and Watershed Development, and from communities, an agreement was signed with community members regarding a common understanding and sharing of benefits of NRM initiatives.

Diversion drainage channels (3–5 m wide and 1–3 m deep) with nala plugs at suitable intervals, deepening and widening of drainage networks, construction of farm ponds along with masonry inlets and outlets with gauging facility, and earthen field bunding with masonry surplus arrangements were implemented at Tara and Dhumbabhata in Belpada Block in Balangir District and at Boirbhadi and Darlinuapada sites in Nuapada District. The interventions have shown positive impacts at each site.

Tara, Belpada Block, Balangir District

- Bunding of 112 ha facilitated an estimated harvesting of rainwater of 112,000 cm^3, equivalent to about 140 mm rain/ year.
- Part of this harvested rainwater was used for recharging greenwater and the rest used to improve groundwater.
- Four ponds with capacities of 16,000, 5400 and 6000 cm^3 in Tara and 2600 cm^3 in Dhumbabhata (total 30,000 cm^3) harvested about 90,000 cm^3 of rainwater.
- Of this, an estimated 40,000 cm^3 was used to irrigate Rabi crops and 50,000 cm^3 facilitated groundwater recharge. In turn, more than 135,000 cm^3 water infiltrated into the ground.
- Groundwater improved by 2–3 metres.

Reduction in soil erosion owing to bunding

- Bunding significantly reduced soil erosion by 75% from the pre-intervention phase (12–15 tons soil/ ha). Soil loss from the Boirbhadi sites was lower (65%) than Tara owing to lower field slopes; but at Darlinuapada soil erosion was 75%. The interventions saved 168 tons of soil from erosion.

Boirbhadi and Darlinuapada, Nuapada Block, Nuapada District

- Bunding of 21 ha facilitated rainwater harvesting of 21,000 cm^3 equivalent to 26.25 mm in a year.
- Two ponds with 6300 and 6000 cm3 capacity harvested 36,900 cm^3 rainwater.
- 9000 cm^3 were used to irrigate Rabi crops and the remainder helped with groundwater recharge.

Fisheries in ponds

- Farmers were supported to undertake fish farming. Hands-on training along with inputs were provided. Planting of papaya and drumstick on the embankments of ponds was also encouraged. This resulted in the adoption of an integrated farming system by six farmers in Nuapada and three farmers in Belpada. Besides providing nutrition from fruit trees, the additional income from fish farming has been a major benefit (Table 12) for farmers.

Table 12. Results of fish farming in Nuapada and Belpada

Farmer	Field location	Total fish produced (kg)	Fish consumed (kg)	Fish sold (kg)	Fish sold (Rs.)	Input cost (Rs.)	Net income after household consumption (Rs.)	Income (%)
Nuapada								
Dayalu Majhi	NRM pond, Darlinuapada	120	10	110	16800	11314	5486	48.49
Hiralal Majhi	Darlinuapada	38	10	28	5320	4643	677	14.58
Dayalal Sahu	Chuhuri	52	7	45	7800	4943	2857	57.80
Dasrath Majhi	NRM pond, Boirbhadi	90	35	55	12600	6706	5894	87.89
Narottam Majhi	Boirbhadi	40	5	35	6000	2278	3722	163.39
Lakhan Majhi	Kuliabandha	60	15	45	8400	5308	3092	58.25
Belpada								
Judisthir Dharua	Big pond, Tara	?	20*	95*	14300	24480.00	No harvesting, left for egg laying	No harvesting, left for egg laying
Tankadhar Naik	Naik Pada pond, Tara	?	25*	13*0	18850	8966.20	No harvesting, left for egg laying	No harvesting, left for egg laying
Annirudha Chhatria	Kasakhunta pond, Kasakhunta	?	20*	40*	7800	5223.00	No harvesting, left for egg laying	No harvesting, to for egg laying

*Only first harvest
INR 1 lakh = 1333.33333 USD (2023)

8.2 NRM activities ensured availability of lifesaving irrigation during Rabi season

The availability of water for lifesaving irrigation was made possible through water tanks and groundwater recharge, which encouraged farmers to grow a Rabi crop where only Kharif crops used to be produced.

In 2019, for the first time in the history of the target villages in Nuapada, farmers grew a crop of green gram var. IPM 2-14 on approximately 35 ha.

Farmers did not use any input like rhizobium culture, and use of recommended doses of fertilizer, yet the provision of only one lifesaving irrigation resulted in an average yield of 425 kg/ha. Observing this success, in the following years farmers grew a second crop (green gram) on about 133 ha. This is expected to further enhance the adoption of agroforestry-based NRM.

Besides this, the project developed seven dug wells of about 2.5 m diameter and 6–7.5 m depth in seven villages to create the facility of lifesaving irrigation for trees and vegetables.

Figure 44. NRM-based agroforestry at project sites

Figure 45. More agroforestry-based NRM interventions at project sites

8.3 Monitoring soil health

To observe the current health status of the soils and create a baseline to measure the impact of agroforestry interventions, soil samples from the project's farms as well as non-project farms were collected during November–December 2020, following a uniform protocol.

Based on soil variability, 4–12 soil samples were collected from each GP. The distribution of soil samples by GP is shown in Figure 46.

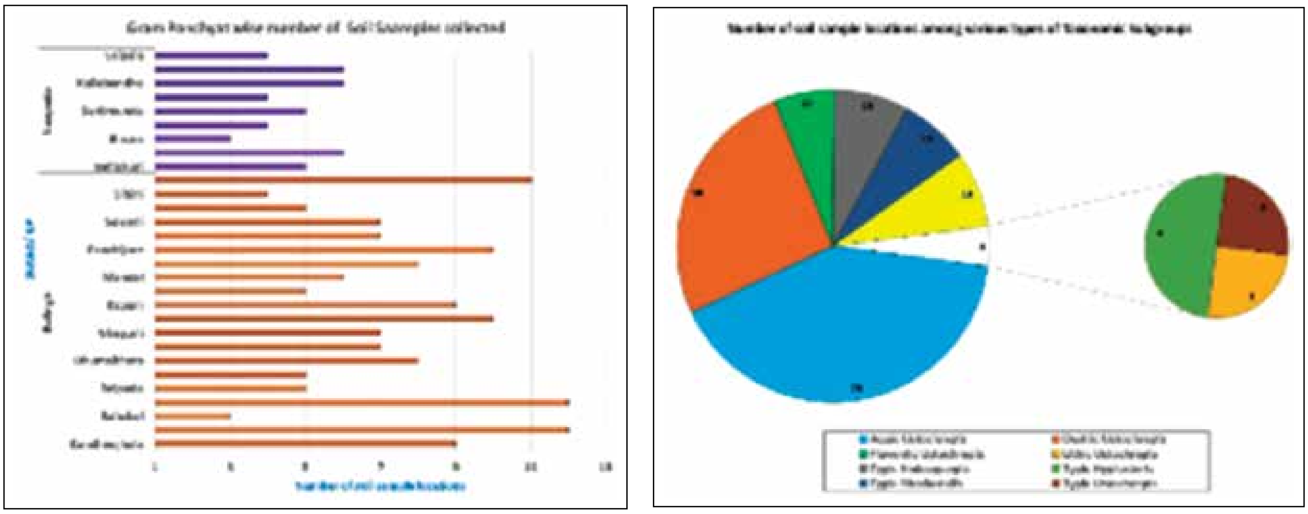


Figure 46. Soil sampling and distribution in each taxonomic subgroup in Belpada and Nuapada blocks

In general, Belpada Block is dominated by Inceptisols whereas Nuapada features a mix of Inceptisols, Vertisols and Alfisols. In these two blocks, the soils are strongly acidic to slightly alkaline, low in organic C and available N, and medium in available P and K. Among the three soil groups, Vertisols has a higher status of available nutrients and enzyme activities, followed by Inceptisols and Alfisols. The soil samples were also analysed for various physical and chemical properties using mid-infrared soil spectroscopy and near-infrared handheld soil analysers at ICAR IISS Bhopal, which confirmed the above results.

9. Capacity Development

Creating awareness of the benefits of producing and consuming diverse, nutritious farm produce and building the capacity of all stakeholders were key elements of the project. Therefore, various types of formal and informal TOT and village-level training activities were undertaken.

The project organised 38 TOT sessions through which 1865 trainers were trained during 2018–23 (including the period of no-cost extension). These included progressive farmers, KS and village workers of the Agriculture department and progressive farmers (ASHA and Aanganwadi Workers), who in turn acted as resource persons for the village-level training.

The village-level training benefitted 21,114 farmers (36.22% women) in different aspects of production of nutritive food and agroforestry practices and maintenance of fruit plants, value-addition packaging and vegetable seedlings' transportation during 2018–2023 (including the no-cost extension period 2021–23)

As an exit strategy, the project successfully trained 58 youth from the project area as KVMs to ensure extended 'hand holding' of farmers within communities at village level after the project's completion.

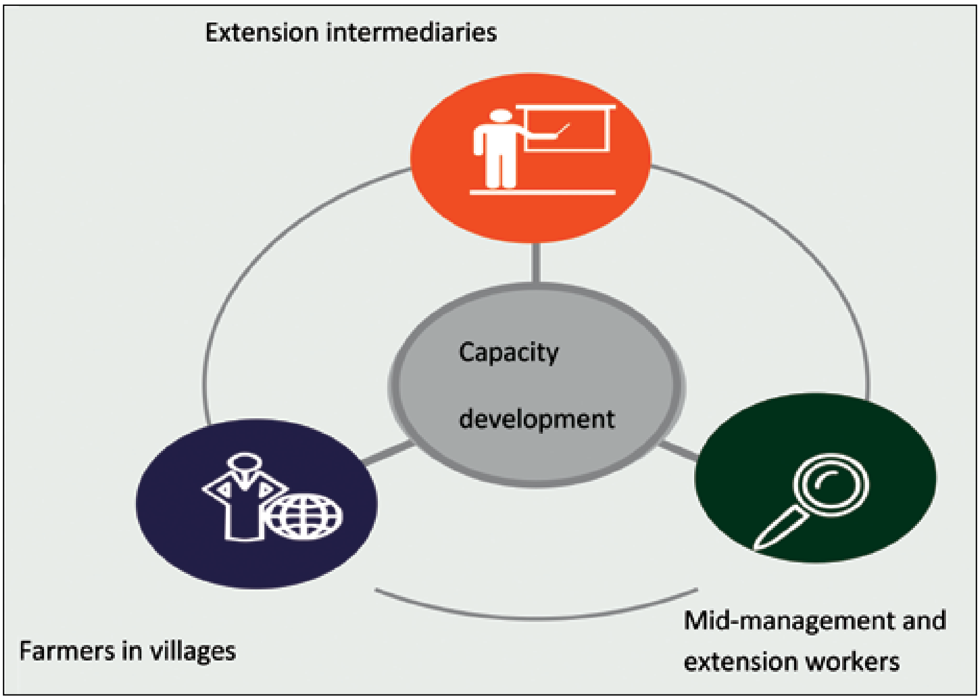


Figure 47. Relationship between capacity development, farmers, extensionists and management

Besides the training at district and village levels, exposure visits of farmers within and outside the State were conducted, which helped farmers interact with other farmers and research scientists and exchange their views, which helped farmers adopt new techniques learned during exposure.

Similarly, visits of State Government officials from related line departments were conducted to ICAR CAFRI to see the successful agroforestry-based NRM model in Bundelkhand and Jhansi regions, which may help them implement in the State.

Table 13. Capacity development of trainers and farmers during 2018–2021 and no-cost extension during 2021–23

Topic	No. of trainees (male)	No. of trainees (female)	Total no. of trainees
Trainers training at district level			
Integrated Crop Management and seed Production in Paddy (CR Dhan 310 and 311)	49	2	51
Production of Agroforestry Quality Planting Materials & Development of Nursery	512	130	642
Awareness Creation on Balanced & Nutritious Food, Health & Hygiene	26	228	254
Agroforestry Interventions: Diversification for enhanced Income & Climate Resilience	563	108	671
Management of Fruit Plants (pruning/training), Value Addition (fruit covering in plants, grading packaging) & Market Links (during no-cost extension 2021–23)	211	36	247
Total	1361	504	1865
Farmers' training at village level			
Agroforestry Interventions	2594	596	3190
Package and Practices of Paddy, Grass Pea and Fruit Crops	4878	542	5420
Quality Planting Material and Nursery Raising	2868	1312	4180
Awareness on Balanced & Nutrition Food, Health and Hygiene	968	4854	5822
Management of Fruit Plants (pruning/training), Value Addition (fruit covering in plants, grading packaging) & Market Links (during no-cost extension 2021–23)	2160	342	2502
Total	13468	7646	21114
Grand Total	14829	8150	22,979

Figure 48. ASHA, Aanganwadi workers and WSG training in Diversified Food for Nutrition at KVK, Nuapada

Figure 49. Gender-balanced capacity development of extension workers, farmers and policymakers

Figure 50. Participation of Odisha Govenment Officials in village-level training

Figure 51. Village-level farmers' training

Figure 52. Intra-State farmers' exposure visit to KVK, Nuapada

Figure 53. Exposure visit of staff and farmers to ICAR CAFRI, Jhansi

10. Adjusting Project Activities to COVID-19 Challenges

At the onset of the COVID-19 pandemic, the project management team developed a Standard Operational Protocol based on the guidelines of the Government of Odisha and ICRAF.

Regular virtual meetings were organized to assess the risks posed by the pandemic and to reorganize activities to adapt to prevailing conditions. Activities that required gatherings of large groups of farmers, such as capacity building at district and village levels, were the most impacted by the pandemic. The project teams restructured these activities by reducing the number of participants while observing COVID-19 protocols, such as social distancing measures, wearing facemasks, handwashing with soap, and the use of sanitizers.

The project provided COVID-19-related support to local communities to the extent possible within budget limits and, as a result, ensured that activities continued to maximum possible limits.

The pandemic posed the challenge of farmers losing their livelihoods and, thus, the project in consultation with the Government of Odisha's Directorate of Soil Conservation and Watershed Development, met this challenge and supported a greater number of migratory farmers. In total, around 7000 migratory farmers benefitted from project activities.

Figure 54. Project staff ensured appropriate social distancing and behaviour against COVID-19 during gatherings and distributing seedlings and other inputs

11. Agroforestry Project: Carbon Sequestration, Ecosystem Services and Biodiversity Conservation

Large-scale diversification of rainfed agriculture, including agroforestry-based NRM interventions in the two districts, are contributing to the improvement of the environment, quality of life, and biodiversity. These interventions, moreover, are expected to improve greenwater use efficiency, groundwater recharge, incomes and livelihoods in the long term. Preliminary results have already indicated such positive trends in terms of increases in groundwater tables and improved crop yields, incomes, and biodiversity. The interventions facilitated a rainwater harvest of an estimated 112,000 cm^3, equivalent to about 140 mm rain/year; part of this harvested rainwater was used as greenwater supplemental irrigation and storage and the rest percolated as groundwater recharge. Four farm ponds harvested about 90,000 cm^3 of rainwater, of which an estimated 40,000 cm^3 was used to irrigate Rabi crops and 50,000 cm^3 contributed to groundwater recharge. In turn, more than 135,000 cm^3 of water infiltrated into the ground and groundwater improved by 2–3 m. Bunding significantly reduced soil erosion by 75% from the pre-intervention phase (12–15 tons soil/ha) and saved 714 tons of soil from erosion.

Over the course of four years, a total of 3071 ha was used for crop intensification by growing grass pea as a second crop, which was introduced for the first time in a paddy–pulse, double-cropping sequence in lands otherwise unutilized. The interventions helped in enriching and strengthening biodiversity by way of the introduction of 13 MPT species and bamboos and maintaining more than 35 existing tree species, and new and improved crop varieties — including nine for paddy, 22 for vegetables, eight for pulses, and one for grass — in the agricultural landscape.

Since the plantings are only 3–4 years-old at the time of writing, the accumulated aboveground biomass is in a lower range below 30 tons/ha. The planting on agricultural land is estimated to sequester about 12,695 tons of carbon valued at USD 63,475 in the third year, which is projected to increase to 21,160 tons of carbon valued at USD 105,800 by the fifth year and 42,320 tons of carbon valued at USD 211,600 by the tenth year.

Overall, the projected estimation of carbon sequestration from these interventions is 2,20,062 tons (Dombro 2011), valued at USD 1.10 million at an average carbon price of USD 5/ton.

Interestingly, the plantings in the third year are estimated to emit through evapotranspiration 17,439 kilolitres of water, which improves micro-climates. The estimated figures for years 8 and 12 are 46,860 and 69,757 kilolitres, respectively (Carbon Offset Tree Planting Calculator: Find How Many Trees to Plant; https://8billiontrees.com/).

Thus, the project's activities have had a positive impact on ecosystem restoration, with quantifiable economic returns as well as biodiversity enrichment.

12. Documentary Video of the Implementation and Impact of the Project

A documentary video produced by the project team covers activities from start to end, showcasing the impact on the landscapes where the project was implemented. The video also highlights the impact on the lives of the participants and their NRM practices. Viewers can hear statements from senior policymakers of the Government of Odisha, who took the time to visit and monitor the project's activities. The project team sincerely thanks community members for allowing the use of their photos and videos for the documentary.

Full documentary video (25:26): Enabling smallholders in Odisha to produce and consume nutritious food through agroforestry systems (https://www.youtube.com/watch?v=DDTpnY16NYs).

Summary documentary video (7:00): Enabling smallholders in Odisha to produce and consume nutritious food through agroforestry systems (https://youtu.be/jAqEtHgYvrQ).

13. Impact Evaluation

The nodal department, Directorate of Soil Conservation and Watershed Development, DAFE, Government of Odisha identified and facilitated engaging with the Nabakrushna Choudhury Centre for Development Studies (NCDS), which is registered under the Societies Registration Act, 1860. NCDS has been jointly funded by the Indian Council of Social Science Research (ICSSR), the Ministry of Human Resource Development of the Government of India, and the Higher Education Department, Government of Odisha. The NCDS agreed to undertake an impact assessment and submit a final report, which is a requirement for closing the project.

NCDS used both qualitative and quantitative methods, collecting necessary data and information from the project area both from primary and secondary sources using various tools and techniques, including household surveys, key informant interviews, group discussions, field observations, and a literature review. NCDS submitted a report on the impact evaluation to the Directorate of Soil Conservation and Watershed Development, DAFE, Government of Odisha.

The report concluded that, "Overall, the project has made a positive impact on the ground and given hope to project farmers, including migratory farmers, by agroforestry demonstrations to sustain their livelihoods. There is strong demand for such intervention and projects from farmers, local panchayat offices, and district officials. The project has successfully demonstrated agroforestry models, which have been adopted by the farmers, and if resources permit such interventions can be taken up in other areas of Odisha".

The assessment report can be found here: Impact Evaluation Study of the RKVY Funded Project "Enabling Small Holders in Odisha to Produce and Consume More Nutritious Food through Agro-forestry Systems" in Nuapada and Bolangir Districts of Odisha | World Agroforestry | Transforming Lives and Landscapes with Trees.

A financial assessment found that from an investment of USD 2.7 million, the total return was USD 6.7 million (a rate of return of 2.48). This was composed of an ecological return of USD 1.5 million (and impact on Sustainable Development Goals 6, 12, 13 and 15); a social return of USD 2 million (SDGs 1, 2, 3, 5 and 10); and an economic return of USD 3.2 million (SDG 8) (Figure 55).

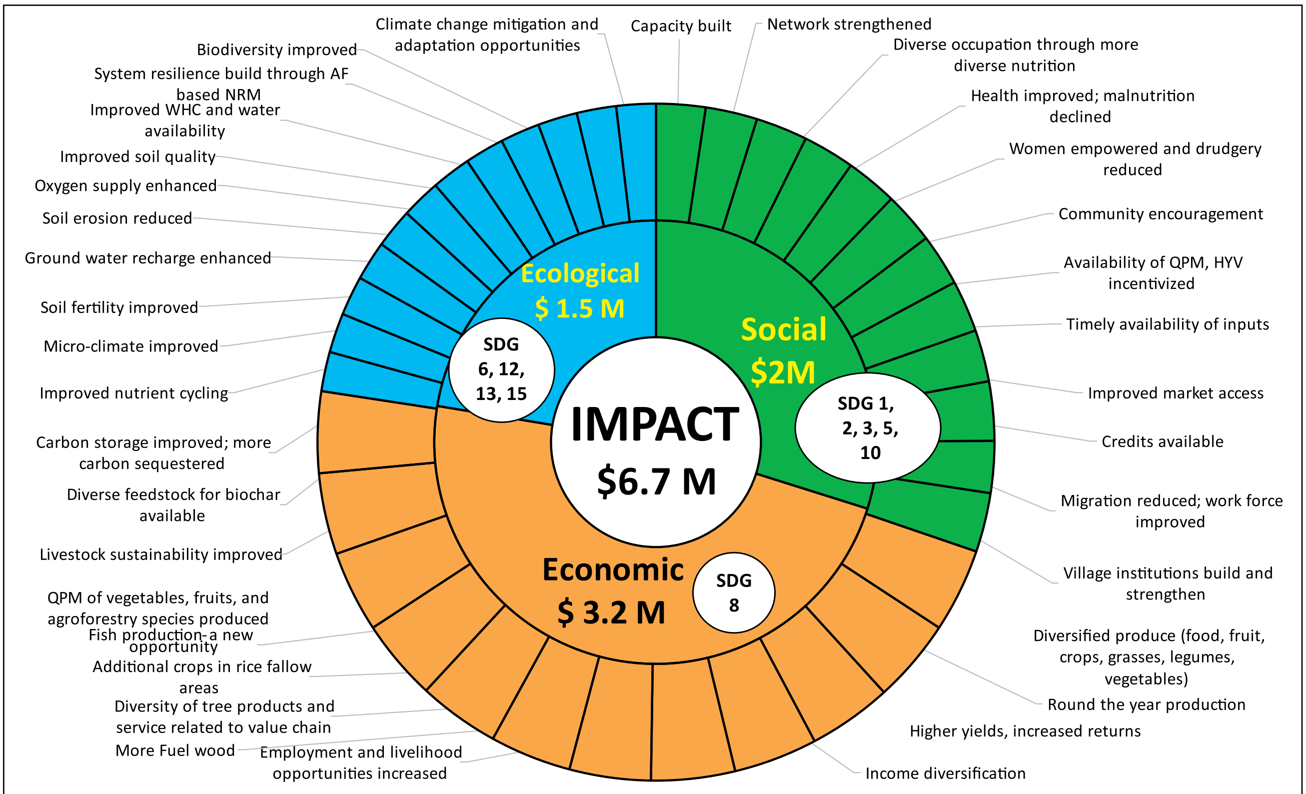


Figure 55. Quantification of ecological, social and economic impact

14. References and Research Publications

Ahmad F, Talukdar NR, Biradar CM and Dhyani SK. 2022. Harnessing the potentiality of farm landscape for trees based on satellite evaluation: a GIS Modeling perspective. *Anthropocene Science* 1:278–294. https://link.springer.com/article/10.1007/s44177-022-00025-1#citeas

Dombro D. 2011. *How much carbon does a tropical tree sequester?* Bruxelles, Belgium: Tree-nation. http://www.truevaluemetrics.org/DBpdfs/Forests/Tree-Nation-Tropical-tree-sequestration-of-CO2.pdf

Government of Odisha and ICRAF. 2021. *Agroforestry app Odisha (India)*. Mobile application. Bhubaneswar, India: Government of Odisha; New Delhi, India: World Agroforestry (ICRAF). https://play.google.com/store/apps/details?id=org.icraf.agroforestryappindia&hl=hi&gl=US

Government of Odisha and ICRAF. 2021. *A road less travelled by migratory farmers of Odisha: innovative agroforestry practices*. Bhubaneswar, India: Department of Soil Conservation and Watershed Development, Government of Odisha; New Delhi, India: World Agroforestry (ICRAF). https://www.worldagroforestry.org/publication/road-less-travelled-migratory-farmers-odisha-innovative-agroforestry-practices

Haddad L, Nisbett N, Barnett I, Valli E. 2014. *Maharashtra's child stunting declines: what is driving them? Findings of a multidisciplinary analysis*. Brighton, UK: Institute of Development Studies. https://core.ac.uk/download/pdf/29135131.pdf

Hoddinott J and Yohannes Y. 2002. *Dietary diversity as a food security indicator*. FCND Discussion Paper 136. Washington DC, USA: Food Consumption and Nutrition Division, International Food Policy Research Institute. https://www.ifpri.org/publication/dietary-diversity-food-security-indicator-0

[IFAD] International Fund for Agricultural Development. 2015. *Annual report*. Rome, Italy: International Fund for Agricultural Development. https://www.ifad.org/en/web/knowledge/-/publication/ifad-annual-report-2015

Kennedy G, Ballard T and Dop MC. 2013. *Guidelines for measuring household and individual dietary diversity*. Rome, Italy: Nutrition and Consumer Protection Division, Food and Agriculture Organization of the United Nations. https://www.fao.org/3/i1983e/i1983e.pdf

Kilgore G. 2022. *Carbon offset tree planting calculator: find how many trees to plant*. Las Vegas, USA: 8 Billion Trees. https://8billiontrees.com/carbon-offsets-credits/carbon-offset-tree-planting-calculator-find-how-many-trees-to-plant/

Lal PV. 2019. Jodhpur agrivoltaic pilot project replicated. *pv magazine* 30 September 2019. https://www.pv-magazine-india.com/2019/09/30/jodhpur-agrivoltaic-pilot-project-replicated/

National Rice Research Institute. 2020. *National Rice Research Institute annual report 2020*. Cuttack, India: National Rice Research Institute. icar-nrri.in/wp-content/uploads/2021/01/Annual-Report-2020.pdf

Prabhu R, Dhyani SK, Nayak D and Rizvi J. 2022. Transformative agroecology-based alternatives for a sustainable and biodiverse future. In: Chand R, Joshi P, Khadka S, eds. *Indian agriculture towards 2030*. India Studies in Business and Economics. Singapore: Springer. https://doi.org/10.1007/978-981-19-0763-0_7

Ram A, Dogra A, Dev I, Kumar N, Gautam K, Londhe S, Handa AK, Singh R, Arunachalam A and Dhyani SK. 2022. Agroforestry for sustainable cereal based cropping systems in Indo-Gangetic Plain Region. In: Kashyap PM, Gupta V, Gupta OP, Sendhil R, Gopalareddy K, Jasrotia P, Singh GP, eds. *New horizons in wheat and barley research*. Singapore: Springer. https://link.springer.com/chapter/10.1007/978-981-16-4134-3_21

Sarkar SK, Hazra SK, Sen HS, Karmakar PG, Tripathi MK. 2015. *Sunnhemp in India*. Barrackpore, India: ICAR Central Research Institute for Jute and Allied Fibres. https://www.feedipedia.org/node/24265

Singh R, Behera MD, Das P, Rizvi J, Dhyani SK and Biradar CM. 2022. Agroforestry suitability for planning site-specific interventions using machine learning approaches. *Sustainability* 2022 14(9):5189. https://doi.org/10.3390/su14095189

Singha RK, Rizvi J, Behera MD and Chandrashekhar B. 2021. Automated crop type mapping using time-weighted dynamic time warping: a basis to derive inputs for enhanced food and nutritional security. *Current Research in Environmental Sustainability* 3(2021):100032. https://www.sciencedirect.com/science/article/pii/S2666049021000086

Swindale A and Bilinsky P. 2006. *Household Dietary Diversity Score (HDDS) for measurement of household food access: indicator guide* (v.2). Washington DC, USA: FHI 360/Food and Nutrition Technical Assistance III Project.

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16. Project Team

ODISHA

Bhubaneswar

Prof. M. M. Hossain (from 16.10.2018 to 30.08.2020)
Nimai Charan Swain (from 16.10.2020 to 31.03.2023)

Belpada Block, Balangir District

Somnath Sahoo	District Project Coordinator
Kapil Kumar	Agril. Engineer
Badri Narayan Sahu	Project Officer
Narsingh Behera	Project Officer
Ishwar Padan	Project Officer
Kapileshwar Mahapatra	Project Officer
Soumya Ranjan Mahakund	Technical Assistant to March 2021
Raghab Padan	Office Assistant

Nuapada Block, Nuapada District

Bibhu Prasad Mishra	District Project Coordinator
Pithan Bhoi	Project Officer
Manoj Kumar Meher	Project Officer
Soumya Ranajan Mahakund	Project Officer w.e.f April 2021
Prem Raj Nial	Technical Assistant

Krishi Vaniki Mitra (Friends of Agroforestry):

Belpada Block

	Name of KVM	Gram Panchayat	Village
1.	Rohita Bagarti	Kapani	Tara
2.	Bhojaraj Bhoi	Kapani	Chhuinara
3.	Jitendra Behera	Kapani	Kapani
4.	Dharani Bhoi	Tentulimunda	Mundodarha
5.	Harihara Bhoi	Tentulimunda	Bagudar
6.	Chenturam Biswal	Tentulimunda	Tentulimunda
7.	Dambarudhar Budek	Juba	Bhuliabandha
8.	Naresh Putel	Juba	Juba
9.	Shiba Bariha	Juba	Bileimara
10.	Krushna Chandra Mallik	Dhumabhata	Dhumabhata
11.	Pramod Budek	Dhumabhata	Jalia
12	Pramod Barge	Dhumabhata	Ainlapali
13.	Sartika Nag	Madhyapur	Katapal
14.	Akshya Sahoo	Sihini	Sihini
15.	Pradeep Nial	Sihini	Semelpali
16.	Subash Parabhue	Bahabal	Khairmal
17.	Hara prasad Majhi	Pandrijore	Bichhubahali
18.	Birendra Majhi	Pandrijore	Bichhubahali
19.	Gaura Dharua	Pandrijore	Pandrijore
20.	Himanshu Puta	Salandi	Salandi
21.	Baishnaba Bag	Salandi	lathakenda
22.	Debaraj Kand	Bharuapali	Phulkani
23	Durjan Bag	Bharuapali	Kharbahali
24	Lohit Sahu	Sarmuhan	Bhalukhai
25.	Bichitrananda Majhi	Sarmuhan	Ainlabhata
26.	Mohan Bag	Sarmuhan	Budhabhata
27.	Jayaram Patra	Bagdor	Dudkamal
28.	Kshyamanidhi Biswal	Bagdor	Banmal
29.	Rajkishore Bhue	Bagdor	Thodibahal
30.	Pradyumna Kheti	Parlimal	Munapali
31.	Raju Majhi	Parlimal	Rengali
32.	Bipin Luha	Ghagurli	Chikili
33.	Rohita Bhue	Ghagurli	Ghagra
34.	Susil Rana	Ghagurli	Khaliapali
35.	Gadan Putel	Beheramunda	Dhingiamunda
36.	Kesaba Dharua	Kandhenjhola	Kandhenjhola
37.	Thabira Naik	Kandhenjhola	Bahabal
38.	Gunanidhi Padhan	Gambhari	Gambhari
39.	Tejabanta Sahu	Gambhari	Baijal sagar
40.	Mrutyunjaya Bhoi	Mandal	Jamkhari

41.	Hemanta Meher	Belpada	Belpada
42.	Bhishma Dharua	Nunhad	Nunhad

Nuapada Block

1.	Bhaskar Naik	Bhaleswar	Amodi
2.	Tushar Chandrakar	Bhaleswar	Saraipali
3.	Gopal Ahir	Beltukri	Pandrupani
4.	Lokchand Chandrakar	Biromal	Biromal
5.	Yogendra Kr. Majhi	Biromal	Darlinuapada
6.	Binod Kr. Sahu	Bishora	Chingrasarar
7.	Prakash Pandey	Bishora	Bishora
8.	Parikshit Kharsel	Darlimunda	Darlimunda
9.	Rameswar Pandey	Parkod	Parkod
10.	Deolal Pandey	Parkod	Semeria
11.	Hemanta Kr. Satnami	Kodomeri	Kodomeri
12.	Santosh Naik	Boirbhadi	Boirbhadi
13.	Amarchand Goud	Kuliabandha	Kuliabandha
14.	Nilakantha Sabar	Kuliabandha	Dhanora
15.	Tijesh Kr. Sahu	Sahipala	Sahipala
16.	Sanjay Chandrakar	Beltukri	Beltukri

Other ICRAF staff in Delhi, Nairobi or elsewhere who contributed to the project

1. Javed Rizvi, Principal Investigator & Director, Asia
2. Shiv Kumar Dhyani, Country Coordinator, India & Co-Principal Investigator
3. Rajendra Choudhary, Project Manager
4. Atul Dogra, Co-Project Manager
5. Devashree Nayak, Gender Specialist
6. Sunil Londhe, Soil Scientist
7. Raj Kumar Singh, Geoinformatics Scientist
8. Aqeel Hasan Rizvi, IFS Scientist
9. Archna Singh, Research Scientist
10. Sakshi Gaur, Communication Coordinator
11. Muhammad Ahmad, Spatial Platforms Technical Lead, Geoscience
12. Onkware Benard Geospatial Programmer and Mobile App Developer
13. Robert Fredrick Finlayson, Senior Strategic Communication and Liaison
14. Jamal Noor, Finance and Administrative Officer
15. Neeti Sablok, Finance Assistant
16. Preeti Bhalla, Administrative Assistant
17. Rini Prabhakar, Finance Assistant
18. Vinod Kumar Singh, Driver
19. Santosh
20. Sukhbir
21. Amit Chauhan

Annex 1. Certified Seed Producers

Members FPO: Certified Seed Production, Nuapada

FPO No.1: Bhaleswar, G.P. Bhaleswar

	Farmer's name	Village	G.P.	Quantity of certified seed (in qtl)
1	Jishu Krishna Pradhan	Beltukri	Beltukri	30.60
2	Pabitra Mohan Pradhan	Bhaleswar	Bhaleswar	20.40
3	Puskar Majhi	Bhaleswar	Bhaleswar	8.00
4	Umakanta Bhoi	Bhaleswar	Bhaleswar	16.60
5	Ramakanta Chandrakar	Bhaleswar	Bhaleswar	21.00
6	Kundan Chandrakar	Bhaleswar	Bhaleswar	24.20
7	Bailochan Pradhan	Bhaleswar	Bhaleswar	13.60
1	Jishu Krishna Pradhan	Beltukri	Beltukri	134.40
Total				134.40

FPO No.2: Darlinuapada, G.P. Biromal

	Farmer's name	Village	G.P.	Quantity of certified seed (in qtl)
1	Hiralal Majhi	Darlinuapada	Biromal	25.4
2	Kanak Ram Sahu	Darlinuapada	Biromal	39.2
3	Raj Kr. Sahu	Darlinuapada	Biromal	8.2
4	Puranjaya Sahu	Darlinuapada	Biromal	12.8
Total				85.6

FPO No.3: Biromal, G.P. Biromal

	Farmer's name	Village	G.P.	Quantity of certified seed (in qtl)
1	Gaindram Majhi	Darlinuapada	Biromal	20.2
2	Shyamlal Durga	Darlinuapada	Biromal	4.8
3	Ballu Durga	Darlinuapada	Biromal	4.8
4	Durjan Majhi	Darlinuapada	Biromal	28.2
5	Thanuar Majhi	Biromal	Biromal	7
Total				65.00

FPO No.4: Beltukri, G.P. Beltukri

	Farmer's name	Village	G.P.	Quantity of certified seed (in qtl)
1	Rakesh Baishnab	Beltukri	Beltukri	7.2
2	Ratanlal Chandrakar	Beltukri	Beltukri	37
3	Gaindlal Sahu	Beltukri	Beltukri	4.6
4	Sudhir Chandrakar	Beltukri	Beltukri	3
5	Tikelal Majhi	Beltukri	Beltukri	5.2
6	Tushar Chandrakar	Bhaleswar	Bhaleswar	19.4
Total				76.40

FPO No.5: Lukupali, G.P. Bisora

	Farmer's name	Village	G.P	Quantity of certified seed (in qtl)
1	Omkar Singh Majhi	Lukupali	Bishora	22.60
2	Kesho Ram Majhi	Lukupali	Bishora	15.80
3	Tarachand Majhi	Lukupali	Bishora	9.00
4	Maniram Majhi	Lukupali	Bishora	8.80
5	Manrakhan Majhi	Lukupali	Bishora	8.80
6	Iswar Das Baisanav	Lukupali	Bishora	10.60
Total				75.60