RESEARCH BULLETIN NO. 41

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National Innovations in Climate Resilient Agriculture

ICAR-NATIONAL RICE RESEARCH INSTITUTE

Cuttack-753006, Odisha, India

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PREFACE

In the eastern India, rice-green gram cropping system is considered as one of the most profitable cropping systems. The CSA technologies such as application of bio fertilizers in green gram (nutrient-smart), furrow irrigated raised bed planting (water-smart), zero tillage (carbon- and energy-smart), crop-intensification (knowledge-smart) are able to reduce the risk and vulnerability; financially rewarding for farmers who invest in these methods over a short period of time. Intensifying the cultivation of green gram with maize, cowpea, bhindi, and bitter gourd is a successful investment decision for smallholder farmers in rural areas with limited financial resources.

The objective of this research bulletin is to assess the impact of different climate-smart agricultural practices on the crop and water productivity and energy budget of the rice-green gram cropping system. This research bulletin describes and applies a participatory assessment method for farmers' preferences and their willingness to adopt for climate-smart technologies. The study uses socioeconomic data and climate information of the study areas to assess farmers' preferences for CSA technologies that are highly vulnerable to climate change and climate variability.

The authors believe that the results will be of interest to scientists, students, researchers, academics, donors, and funding agencies. The authors gratefully acknowledge financial support from the National Innovations in Climate Resilient Agriculture (NICRA) project funded by the Indian Council of Agricultural Research (ICAR) for conducting experiments on climate-smart agricultural practices in participatory mode.

Authors

CONTENT

1. INTRODUCTION

The world's population is growing at a rapid pace, further agriculture is threatened by the destruction of natural resources and climate change. Climate change is adversely affecting agricultural production, production stability, income, food security and the livelihoods of millions of people around the world (Hossain and Majumder, 2018). Agriculture must adapt to current conditions in order to meet future food security needs while coping with seasonal climatic variability. According to projection estimates based on food consumption pattern and population growth, agricultural production would need to increase by 65% by 2050 to meet the needs of growing population in India (Siegel et al., 2014). Agriculture contributes to and is also impacted by climate change phenomenon. To address these issues, climate smart agricultural (CSA) practises must be developed to address the climate resilient productivity issue, adaptation as well as mitigation goals. Consequently, the adoption of climate-smart agriculture (CSA) is critical to achieving agricultural sustainability and climate change goals.

Several studies have found that increase in temperature (Lobell et al., 2012; Vermeulen et al., 2012), altered precipitation pattern (Prasanna, 2014; Mall et al., 2006) and differences in the frequency and severity of extreme climatic conditions *viz.* droughts and floods could have major impacts on agricultural production (Brida and Owiyo, 2013; Singh et al., 2013).CSA is a novel strategy for creating the technological, political, and financial conditions for achieving long-term development goals (FAO, 2015). CSA is a three-pillared approach to food and nutrition security that focuses on (i) increasing farmer income and productivity, (ii) improving the adaptive capacity of communities, and (iii) reducing and laminating greenhouse gas emissions from the environment. Multiple cropping, crop rotation and intercropping to address climate change as well as system of rice intensification (SRI), conservation agriculture, integrated nutrient management (INM), agroforestry, integrated pest management (IPM), water management and harvesting, crop and post-harvest management are some of the CSA techniques need to be adopted in different agro-ecological zones. Technologies facilitating conjunctive use of water (e.g., weather-prediction-based irrigation, direct-seeded rice, and alternate wetting and drying), nutrients (e.g., slow-release nitrogen fertiliser and site-specific nutrient management), carbon neutral (e.g., residue incorporation and retention), weather proof (e.g., index-based crop insurance), energy efficient (e.g., zero tillage or minimum tillage, direct-seeded rice, and laser soil levelling), and information and knowledge based precision farming practices are among the climate smart agriculture practises **(Fig. 1)** (Ajani, 2014; Amin et al., 2016; 2010; Jat et al., 2016, Nayak et al., 2020). In general, CSA decisions combine conventional and advanced methods, technologies, and services appropriate for a particular location to adapt to climate change and unpredictability (Barasa et al., 2021).

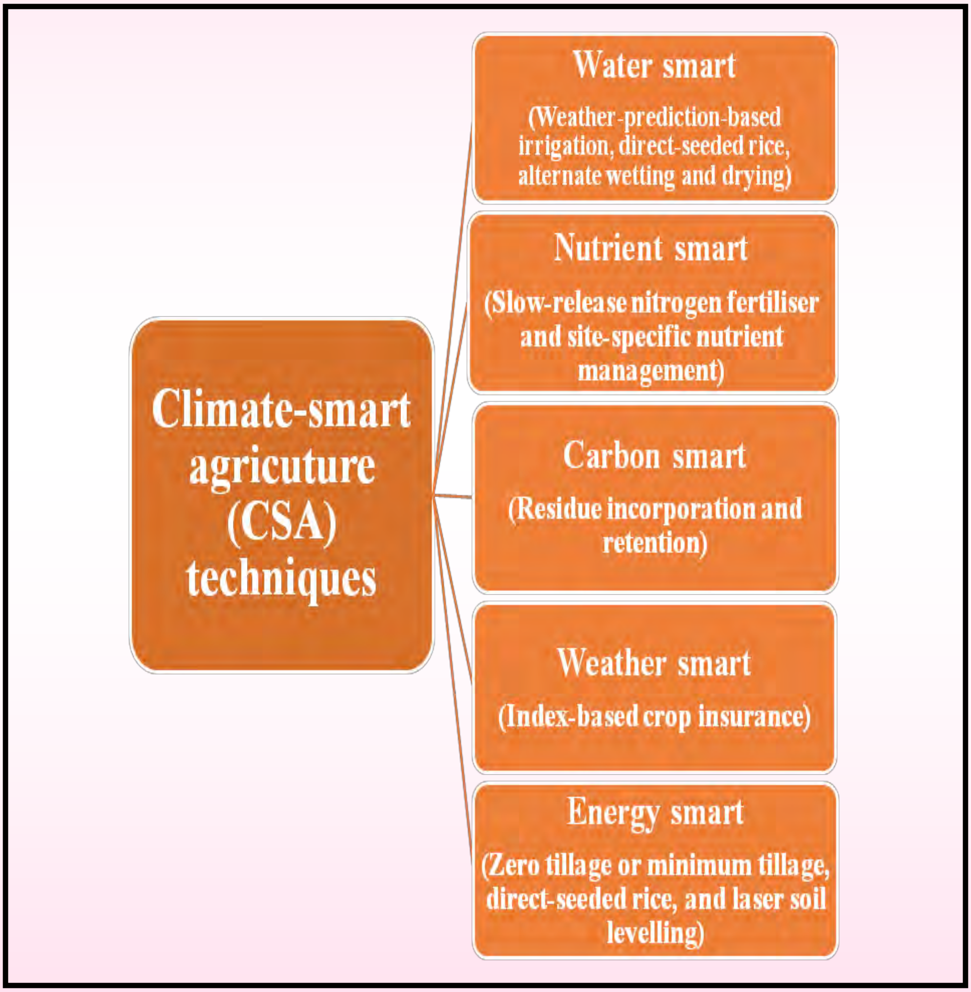

Fig.1. Different approaches of climate smart agriculture (CSA) (Nayak et al., 2020)

2. DRIVERS FOR ADOPTION OFCSA PRACTICES

- Drought, heavy rainfall, and floods are examples of extreme events that are becoming more frequent and intense. Up to 84% of all economic impacts of droughts are found on agriculture (Brida et al., 2013).
- Agriculture faced 22% of the economic impact of large or medium natural hazards and disasters in developing nations. It is critical to integrate adaptation efforts and financing into these sectors (Reckien et al., 2017).
- Between 1990 and 2015, global emissions from deforestation decreased, but emissions from forest degradation (cutting, burning, etc.) increased from 0.4 to 1.0 Gt CO_2 per year (Le Quéré et al., 2018).
- The global loss of soil carbon is due to the long-term conversion of grassland and forest land to cropland and livestock grazing.
- Himalayan ice and snow, which provide huge amounts of water for agriculture in Asia, are expected to decrease by 20% by 2030 (Wang et al., 2017).
- Adaptation through changes in food production planning, particularly in seeding, variety selection, and drainage, will improve yields by 7-15% on average (Pathak et al., 2011).

3. KEY PILLARS OF CSA

Productivity: CSA seeks to increase agricultural production and yields from crops, livestock, and fisheries while minimising environmental impacts **(Fig. 2)** and improving result, food and nutritional security.

Adaptation: CSA practices reduce farmer's vulnerability to short-term threats, while strengthening their resilience by enhancing their ability to adapt and thrive well in short-term as well as long-term challenges. Additionally, this also protects the ecosystem services necessary to sustain crop production and facilitate climate change adaptation.

Mitigation: CSA practices help to reduce and/or to restrict greenhouse gas (GHG) emissions whenever and wherever possible. This means reducing emissions for every calorie of food, fibre or fuel produced by agro ecosystem. The mitigation can be achieved by employing suitable fertilizer and manure management in agricultural systems.

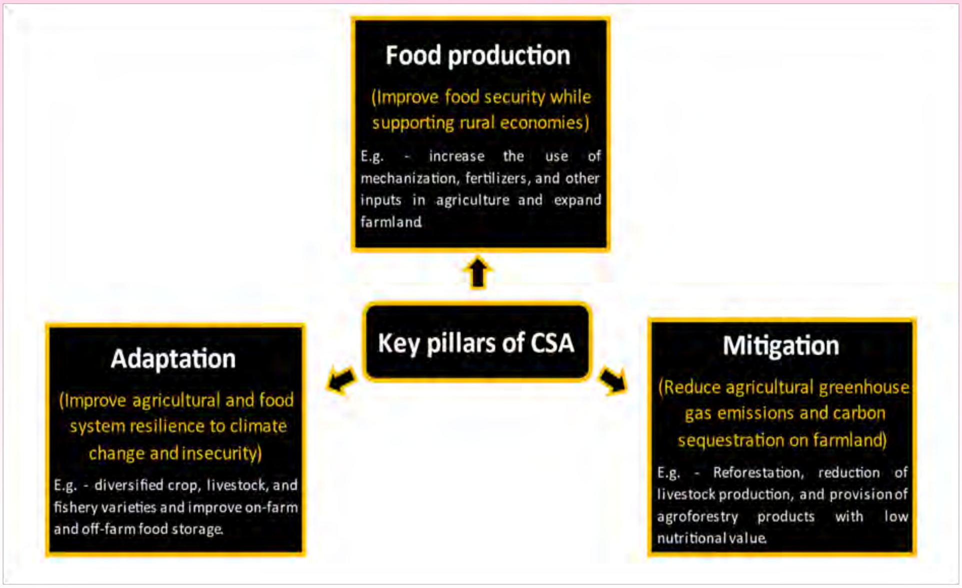

Fig.2. Activities that contribute to the adoption of CSA methods

4. RICE-GREEN GRAM CROPPING SYSTEM: CSA PRACTICES

Cropping systems have gained importance in India's intensified agriculture to address the inadequacies of monoculture farming and to use the land more intensively for higher food production. Cropping system are the essential of human nutritional security which will become increasingly important alongside food security in near future. Incorporation of leguminous-crops in the farming system is an input-saving resource-conserving technology (fix atmospheric nitrogen), helps in the reduction of nitrogenous-fertilizer use, reduces nitrous oxide (GHG) emission and also inhibits harmful soil pathogen infestation is one of the best examples of CSA (Nagargade et al. 2017).

Rice-based cropping systems are a combination of cropping methods with rice as the primary crop, followed by the cultivation of other crops. In many places, upland rice is also grown as a mixed crop with other suitable crops. Rice-based cropping systems are widespread in India and include alternate crops such as rice, pulses, oilseeds, cotton, sugarcane, green vegetables after *kharif* rice. Both lowland and upland crops can be used in rice-based cropping systems (Tiwari et al., 2013). Most farmers have focused on single crops, ignoring the fact that a single crop is only one part of a larger cropping system.

In eastern India, rice-pulse cropping systems are considered the most profitable cropping system because legumes can both store atmospheric nitrogen and consume mineral nitrogen (Magrini et al., 2016). In addition to fixing atmospheric nitrogen through biological nitrogen fixation, legumes in rotation with cereals improve soil fertility, recycle nutrients from deeper layers, reduce soil compaction, increase organic matter, reduce and disease and pest attack, focus on promoting mycorrhizal colonization, and maintain the productivity of cereal-based cropping systems (Rani et al., 2019). The addition of short-maturing and uniformly maturing summer legumes (green gram and cowpea) to the rice-based cropping system has increased production and farmers' income that enabled the entire crop production system to achieve food security.

Rice-green gram is the predominant cropping system of major rice growing areas of Odisha (Swain et al., 2020).Paddy is the most important cereal crop in Odisha in terms of area under cultivation, production and yield with 39.41 lakh ha, 14.78 lakh MT and 37.51 q ha^{-1} (Kumar et al., 2020). Paddy is predominantly grown in wetland areas during the *kharif* season using the traditional manual random planting method. Green gram (*Vigna radiata L.*) is the most important pulse crop in Odisha with an area under cultivation of 8.26 lakh ha and an average production of 495 kg ha^{-1}, which accounts for nearly 40% of the total area under pulses in the state (Kumar et al., 2020). The cropping sequence of rice-green gram is practically feasible, effective, affordable, eco-friendly, water saving technology for sustaining soil fertility and rice yield. (Alagappan and Venkitaswamy, 2016).

A climate-smart rice-green gram cropping system is ecologically sound and economically viable for this region. Rice-green gram cropping system acts as nutrient smart, as green gram fixes atmospheric nitrogen and improves soil health by adding residues through root exudation. In addition, green gram acts as a cover crop, reduces weed population and ensures efficient utilization of soil moisture. Therefore, cropping systems with rice-green gram sequence are very suitable for irrigated or rainfed rice-growing areas with limited water supply, where they prove to be particularly water

In addition, rice-green gram cropping under zero tillage saves energy (energy smart), conserves water (water smart) as it preferentially flows through soil cracks, mitigates seasonal abrupt soil temperature fluctuations, reduces weed emergence, and adds organic matter and nutrients to the soil. In addition, the maturity of green gram is 20 days earlier with zero tillage saves it from terminal heat stress exposure (Nayak et al., 2020). Intensification of green gram with other crops in the rice-green gram system aims to achieve better system productivity through efficient use of available resources and beneficial interactions among different components with reduced environmental impact. Incorporation of cereals (maize) and vegetables (okra, cowpea, and bitter gourd) can increase the net system productivity. Care must be taken when selecting vegetables, as they are susceptible to waterlogging. Therefore, a furrow-irrigated raised bed is sometimes recommended. This system increases water use efficiency and saves up to 25-30% of irrigation water. It saves 70-80% in time, labour, cost, diesel and energy, gives higher yield (4-5%) and energy efficiency (20-25%) compared to conventional sowing (Nayak et al., 2020). The use of biofertilizer to increase the productivity of green gram is a nutrient smart technology. *Rhizobium* is a symbiotic nitrogen fixer that fixes about 100-300 kg N ha^{-1}. Green gram seeds are treated with Rhizobium at a rate of 20-50 g kg^{-1}. It can also be added to the soil. Sometimes a 10% solution of jaggery (Gur) is used for better binding. The application of *Rhizobium* increased the yield of green gram by 5-14% (Hettiarachchi et al. 2021). Similarly, phosphorus solubilizing bacteria (PSB) at a rate of 5 kg ha^{-1} is also recommended to improve phosphorus availability to green gram plants.

5. EXPERIMENTAL SITE

The climate-smart technologies are tested and validated in farmers' fields. A participatory research experiment was conducted in two consecutive cropping seasons (2018-19 and 2019-20) at Bateswar village in Salipur Block, Cuttack, to assess the impact of different climate-smart agricultural practices on the productivity and energy budget of the rice-green gram cropping system **(Fig. 3)**. The experiment was conducted in a randomized block design in the fields of four farmers, with each farmer serving as a replication. The climate at the sites is characterized by hot and humid summers and cold winters with 1686 mm average annual rainfall. The average annual maximum and minimum temperatures are 32.8˚C and 26.8˚C, respectively, with relative humidity of 60-95% throughout the year (**Fig. 4a** and **4b**).

The cultivated area is a riverine area where rice is grown in the *kharif* season. The village is located in the flood-prone zones of the state, being part of the agro-climatic zone of the eastern coastal plain. During the rainy season, most low-lying regions of the region remain flooded. The climate smart rice-green gram agriculture was compared with farmers' practices that include traditional transplanting of rice in *kharif,* tillage after rice harvest, and traditional broadcasting of green gram. Farmers' comments on the technology were recorded and it was found that farmers considered the technology suitable for them and that it improved production. To get the most out of the technology, it must be applied and operated in a timely manner.

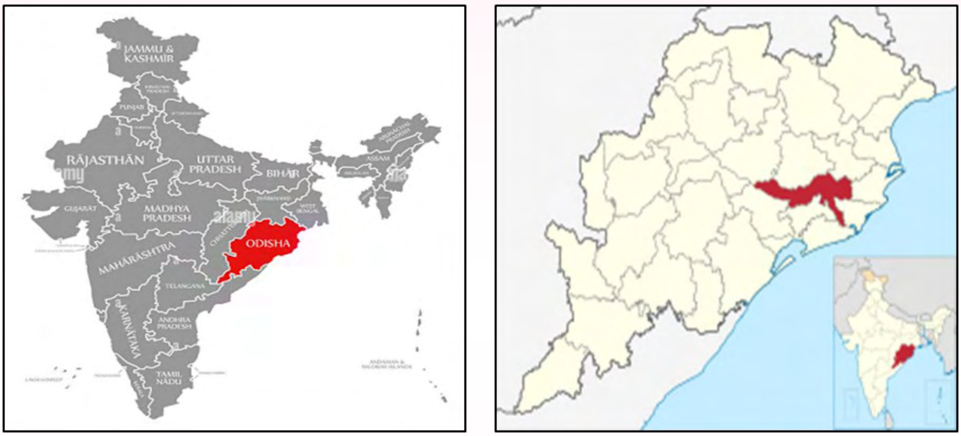

Fig.3. Experimental site: Bateswar village in Salipur Block, Cuttack

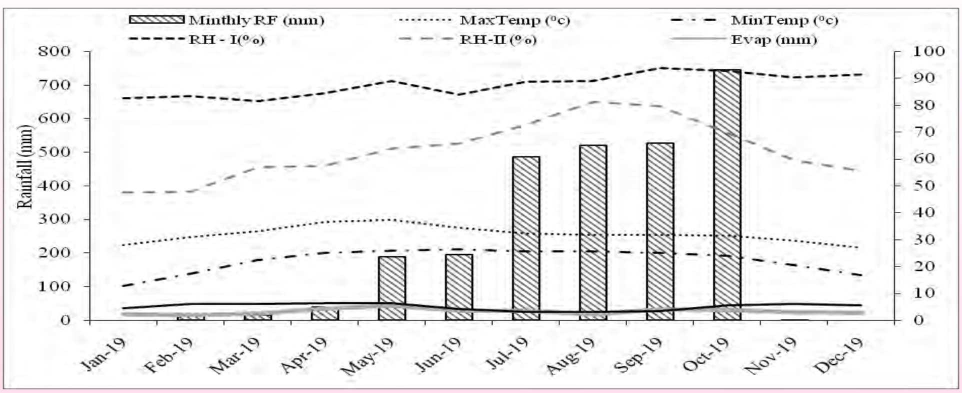

Fig.4a. Weather data of nearby IMD station during 2019

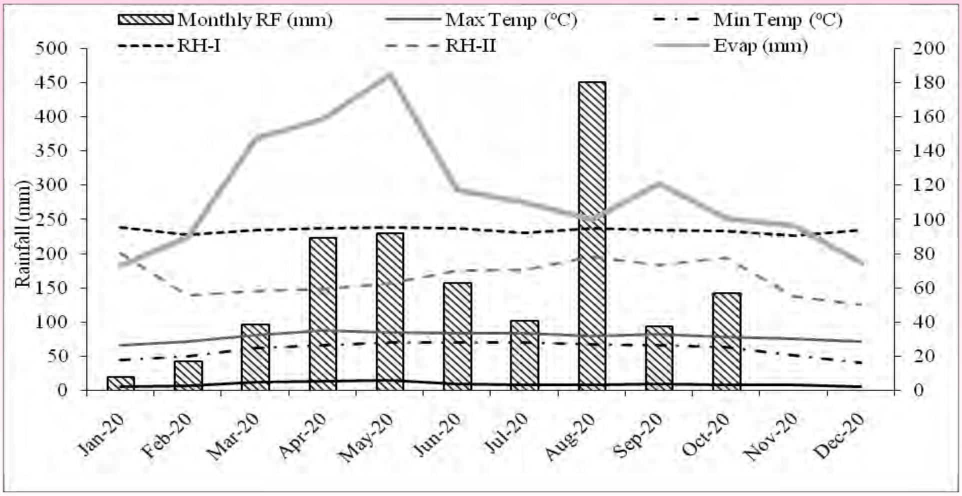

Fig.4b. Weather data of nearby IMD station during 2020

6. DESCRIPTION OF CSA TECHNOLOGY FOR RICE-GREEN GRAM CROPPING SYSTEM

In the present context of climate change, agricultural production is going to decrease due to various vagaries of adverse weather aberrations. The major objectives of this study are:(i) reducing vulnerabilities and increasing productivity of rice-green gram cropping system, (ii) identification of the drivers controlling the adoption of CSA technologies in climate vulnerable area. A climate smart agriculture technology was developed by ICAR-NRRI involving rice-green gram cropping system and was also validated in farmer's field.

6.1 *Kharif* season

As an intervention, the rice variety Pradhan Dhan (submergence tolerant) was grown by the farmers during *kharif* season with the recommended packages of practices (**Table 1**). This area experiences flooding in the initial phase and drought in the later phase (terminal drought). To tackle both flood and drought, a rice variety CR Dhan 801 (both drought and submerge tolerant) was grown with an additional application of 20% phosphate fertilizer for better root development to overcome the effect of flooding over the recommended packages of practices (**Fig. 5**).

Pradhan Dhan with RFD

CR Dhan 801 with RFD+20% additional P

Fig.5. Treatments demonstration during *kharif* season

Table 1. Intervention of technology over farmers' practice during *kharif*

Treatment	Type of technology	Description of technology
T1	Farmers' practice	Pradhan Dhan with recommended dose of fertilizer (RDF)
T2	Improved practice	CR Dhan 801 (Flood + Drought tolerant) with recommended dose of fertilizer with 20% additional P

6.2 *Rabi* season Climate-smart technologies for better nutrient, carbon and energy management in green gram were applied during the *rabi* season. The treatments are mentioned in **Table 2**:

Table 2. Intervention of CSA technologies over farmers' practice during *rabi*

Treatment	Type of technology	Description of technology
T1	Farmer's practice	Local variety of green gram was sown broadcasting after conventional tillage of the land
T2	Zero tillage (ZT)	Improved variety of green gram (IPM 2-3, tolerant to yellow mosaic virus) was line sown under conservation agriculture (30% of the rice residue retention, zero tillage) Recommended dose of fertilizer for green gram was applied (20:40:20kgha^{-1})
T3	Nutrient management (NM)	Improved variety of green gram (IPM 2-3, tolerant to yellow mosaic virus) was line sown after seed treatment with Rhizobium at the rate of 20-50 gkg^{-1}seed and phosphorus solubilizing bacteria (PSB) at the rate of5 kgha^{-1} (OUAT). Recommended dose of fertilizer for green gram was applied (20:40:20kgha^{-1})
T4	Agro-intensification I	Improved variety of green gram (IPM 2-3, tolerant to yellow mosaic virus) was line sown on furrow irrigated raised bed along with maize and cowpea. Recommended dose of fertilizer for maize was applied(120:60:40 kgha^{-1})
T5	Agro-intensification II	Improved variety of green gram (IPM 2-3, tolerant to yellow mosaic virus) was intercropped with Okra in line and bitter gourd was sown on border. Recommended dose of fertilizer for bitter gourd was applied(100:60:60 kgha^{-1})

The details of each treatment along with schematic diagram (**Fig. 6-10**) and photographs (**Fig. 11-13**) are explained hereunder.

a. Farmers' practice

- The broadcasting of the local variety of green gram (*desi-mung*) seed was carried out with conventional tillage.

- The RDF of 20:40:20 kg ha^{-1} was applied as a basal dose at the time of sowing.

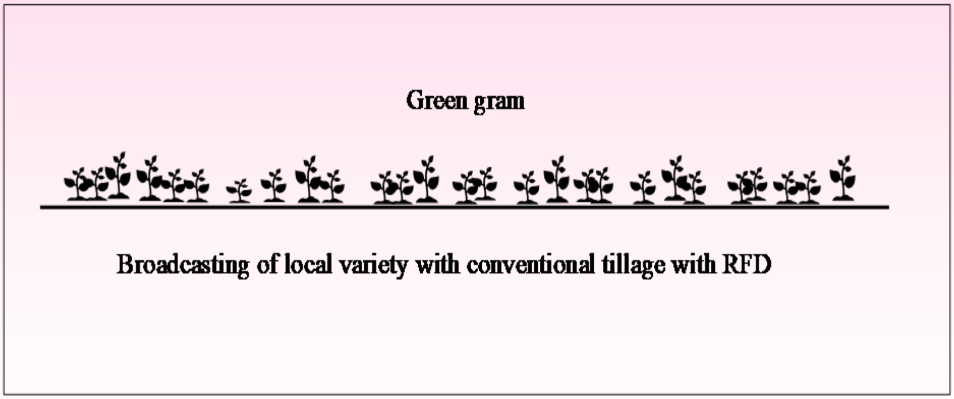

Fig.6. Schematic diagram of planting pattern of farmers' practice

b. Zero tillage (ZT)

- Zero Tillage (ZT) is a component of conservation agriculture in which soil organic carbon content is maintained under the ZT. The residue is also utilized in the process.
- In this treatment, seeds ofa high-yielding variety (HYV) of green gram (IPM 2-3) were planted by line sowing in zero tillage, leaving 30% of rice residues from the previous *kharif* season on the soil, along with RDF (20:40:20 kg ha^{-1}).

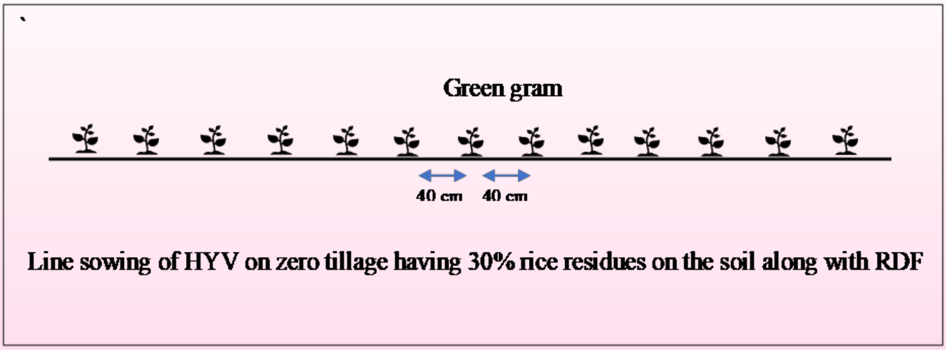

Fig.7. Schematic diagram of planting pattern of zero tillage

c. Nutrient management (NM)

- Treating the seed with a suitable *Rhizobium* culture before sowing helps in better germination, emergence and nodulation, thus increasing the availability of more biologically fixed nitrogen.
- Line sowing of HYV (IPM 2-3) with RDF (20:40:20 kg ha^{-1}) along with *Rhizobium* seed treatment and PSB application to soil before sowing for better plant growth.

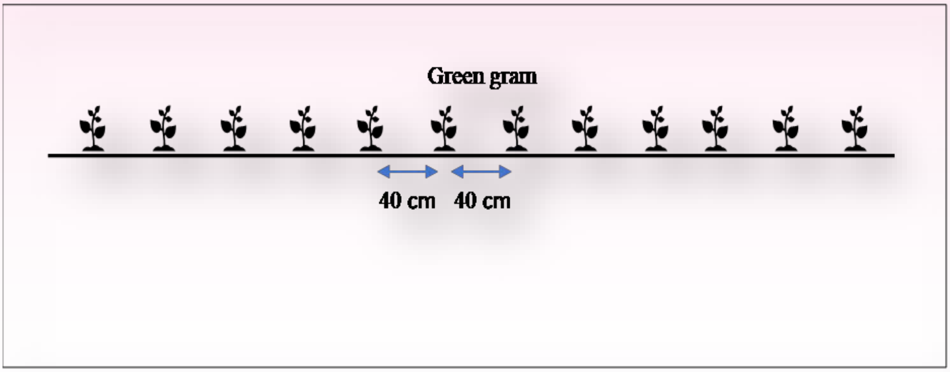

Fig.8. Schematic diagram of planting pattern of nutrient management

d. Agro-intensification I

- In the furrow-irrigated raised bed system, plants are planted on the raised beds.
- This system is often considered more suitable for growing high-value crops that are more sensitive to temporary waterlogging stress.
- Intercropping of maize with green gram and cowpea was done with 1:1:2:1:1 (maize: cow pea: green gram: cow pea: maize) ratio in a 120 cm wide furrow-irrigated raised bed, leaving 30 cm for the furrow, which served as an irrigation channel.
- The recommended fertiliser dose for maize of 120:60:40 kg ha^{-1} NPK was applied in the field which was the recommended dose for maize as it is the largest fertiliser consumer in this system.

e. Agro-intensification II

- Intercropping of green gram in okra with 2:1 (green gram: okra) ratio was adapted with bitter gourd as a border crop.

- Since bitter gourd is a heavy consumer of nutrient, the fertiliser dose of 100:60:60 kg ha^{-1} NPK recommended for bitter gourd was applied in the system.

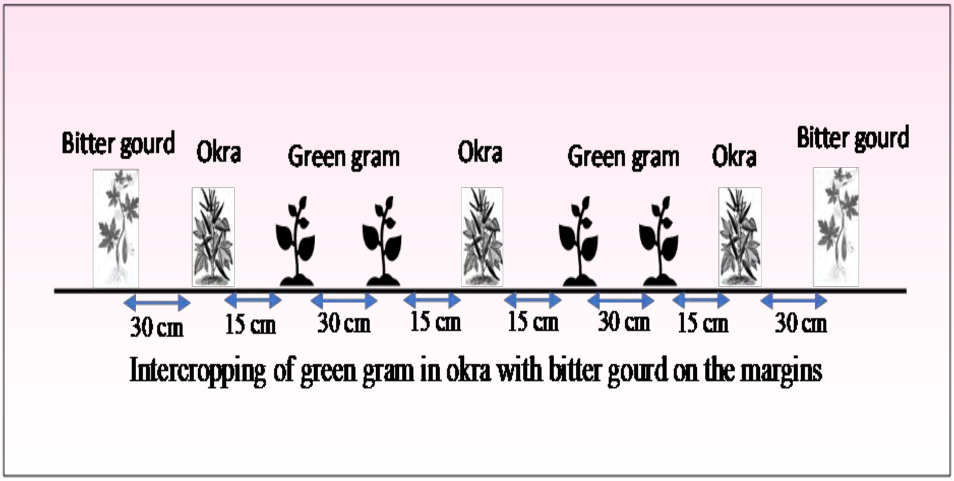

Fig.9. Schematic diagram of planting pattern of agro-intensification I

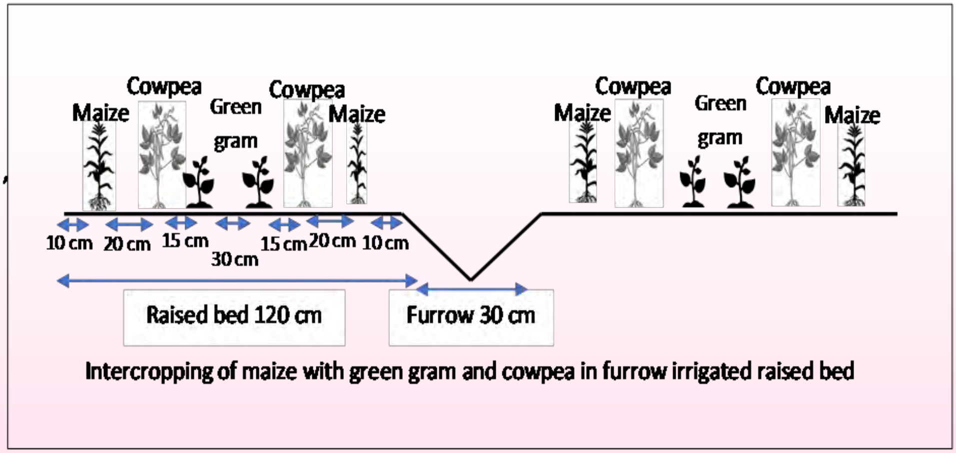

Fig.10. Schematic diagram of planting pattern of agro-intensification II

The spacing, seeding rate and variety of these crops were maintained according to the recommendations in **Table 3**.

Table 3. Spacing, seed rate, variety and plant population of different treatments during *rabi*

Crops	Spacing	Seed rate (kg ha^{-1})	Variety	Population (plants ha^{-1})
Farmers' practice				
Green gram	Broadcasting	40	Local variety	333300
Zero tillage				
Green gram	40cm × 10cm	25-30	IPM 2-3	266640
Nutrient management				
Green gram	40cm × 10cm	25-30	IPM 2-3	266640
Agro-intensification I				
Green gram	30cm × 10cm	10	IPM 2-3	133320
Maize	60cm × 20cm	14	Asha-3501	55000
Cowpea	45cm × 15cm	16	YB-7	97777
Agro-intensification II				
Green gram	30cm × 10cm	16	IPM 2-3	219978
Okra	30cm × 15cm	5	NS-862	48888
Bitter gourd	2m × 1.5m	0.18	DEB-510	6666

Demonstration of CSA technologies in rice-green gram cropping

Fig. 11. CSA implemented at Bateswar village in Salipur Block, Cuttack

Local variety (*desi mung*) with conventional tillage with RDF

Local variety (*desi mung*) with conventional tillage with RDF

Line sowing of IPM 2-3 with RFD together with *Rhizobium* seed treatment and soil application of PSB

Intercropping of maize with green gram and cowpea in furrow irrigated raised bed

Intercropping of green gram in okra with bitter gourd as border crop

Demonstration of climate-smart technologies in rice-green gram cropping system in farmer's field

Fig.12. Field view of *rabi* crop under different intervention

7. COMPLETE PACKAGE OF PRACTICES FORRICE UNDER RICE-GREEN GRAM CROPPING SYSTEM

I. FARMER'S PRACTICE

Seeds and varietal selection

- Pradhan Dhan suitable for shallow lowland ecology was grown by farmers with recommended package of practices.

Seed treatment

- Seeds were treated with Bavistin @ 2 g kg^{-1} seed to control fungal diseases before sowing in the nursery.

Nursery management

- Nursery was raised during first week of June with water from canals/river for planting during early July.
- Raising of seedlings with sufficient farm yard manure@ 1 t ha^{-1}.

Land preparation

- Land was cultivated after harvest of the previous crop preferably with a power tiller.
- Summer ploughing was done after summer showers.
- Final land preparation was done with pre-monsoon showers for sowing. Adequate amount of compost or FYM was applied at the rate of 5 tha^{-1} during final land preparation for improving soil structure and water holding capacity.
- The soil was ploughed at about 20-25 cm deep. Ploughing was done by rotavator initially followed by the standard ploughs.
- Ploughing was followed by harrowing and land was levelled properly so as to avoid water stagnation.
- Field was submerged in water at 3-5 cm and land was puddled well.

Time of Transplanting:

- Transplanting should be completed soon after receipt of monsoon showers during the third-fourth week of June.
- Broadcasting of seeds were carried out under suitable field condition in nursery bed.
- In case of early flood, the aged seedlings (45-60 days) can be transplanted up to third week of July. In case of already transplanted condition, after receding of flood water the plant population can be maintained by transplanting clonal tillers.

Nutrient management

- Well decomposed FYM was applied @ 5tha^{-1}along with chemical fertilizers.

- The N: P_2O_5: K_2O @ 80:40:40 kgha^{-1}was applied depending upon the initial fertility of soil and yield potential of variety.
- Full P & K was applied as basal by broadcasting during final land preparation. For nitrogen management, 50% of N was applied as basal for early vigour of seedlings, 25% N during tillering stage (third week after sowing) and rest 25% at panicle initiation (PI) stage (18-20 days before panicle emergence).

Weed management

- Timely weed control is very important. Pre-plant weedicide glyphosate was applied @ 1 kg *a.i.* ha^{-1}during 6-7 days before planting to eliminate weeds.
- Pulling by hand or using tools like hoe, spade or sickle, take up two hand weeding's at 20 and 40 days after transplanting was carried out.

Water management

- The crop was most sensitive to water deficit stress in the reproductive stage.
- Wherever water was available, irrigate the crop at tillering, panicle initiation (PI), flowering, milking and dough stage.
- Maximum rain water was collected by strengthening field bunds.
- Maintained saturation to 5-7 cm standing water till 25-30 days after transplanting and thereafter low depth of 3-5 cm water till 15 days after flowering.
- Drained out water at yellow ripe stage (10-15 days before harvesting) for uniform maturity.

Harvesting

- Harvesting was done when the grains in the panicle were yellowing colour.

II. IMPROVED PRACTICE

Selection of variety:

- A rice variety CR Dhan 801 which was both flood and drought tolerant was grown during *kharif*.

Seed treatment:

- Seeds were treated with Bavistin @ 2 g kg^{-1} seed to control fungal diseases and Imidacloprid @ 5 g kg^{-1} seed to control sucking pests and mites before sowing in the nursery.

Nursery raising and its management:

- A nursery was selected location that was adequately irrigated and drained.
- The nursery field was prepared one month before transplanting.
- The field for the nursery was prepared by ploughing it two-three times.
- For transplanting to 1 hectare of land, a nursery area of 800-1000 square metres was sufficient.
- The germinated seeds were sown at the rate of 15-20 kg per acre in the nursery bed, which was enough for one hectare of main field.
- The seedlings were line sowed evenly in the seedbeds with a thin film of water and removed the water the next morning to ensure proper aeration.

Field preparation:

- Puddling is the realignment of soil particles due to cultivation at high moisture content. This causes soil particles to become compact and oriented to each other resulted in an increase in bulk density and a significant decrease in non-capillary porosity.
- The soil was ploughed once or twice in July before beginning primary field preparation; this helps control weeds by exposing weed root systems.
- The field was bunded properly to conserve and retain 5 cm water depth.
- The field was watered at least a week before transplanting to give the weeds a chance to thrive and then ploughed before transplanting by filling it with water stagnation and puddling.
- The field after final puddling was levelled and let it rest for 2-3 days before transplanting in heavy soils for better water and weed control.

Fertilizer management:

- Adequate amount of compost was applied at the rate of 5 tha^{-1} during final land preparation.
- N, P_2O_5, and K_2O at a ratio of 80:40:40 $kgha^{-1}$ during *kharif* was applied with additional application of 20% (8 kgP_2O_5 ha^{-1}) of phosphorus to ensure better root development during the early season flood.
- The field was allowed to drain before N fertilisation and did not irrigate the field until two days later.
- Apply half of the nitrogen and full doses of phosphate and

potassium as a basal fertiliser dose before transplanting. The remaining nitrogen was applied in two stages, the first during tillage and the second at ear emergence as top dressing in equal split.

Time of Transplanting:

- It was transplanted from the third week of June to mid-July, while long-lasting duration and aromatic varieties can be transplanted until the last week of July.
- During the *kharif* period, 30-day-old rice seedlings were generally considered to be most suitable for transplanting.
- In case of early flood, the aged seedlings (45-60 days) can be transplanted up to third week of July. In case of already transplanted condition, after receding of flood water the plant population can be maintained by transplanting clonal tillers.

Weed Management:

- The field should be kept weed-free until 45 days after transplanting to avoid critical crop weed competition.
- Hand weeding were carried out at 20 and 40 days after transplanting.
- Pre-plant weedicide glyphosate was applied at the rate of 1 kg *a. i.* ha^{-1} at 6-7 days before planting to eliminate weeds.
- If the weed infestation is severe, it can be applied two or three times.
- The soil should be saturated each time before spraying the herbicide to effectively kill the weeds.

Water Management:

- Maintained submergence to 5-7 cm standing water till 25-30 days after transplanting and thereafter low depth of 3-5 cm water till 15 days after flowering.
- Drained out water at yellow ripe stage (10-15 days before harvesting) for uniform maturity.
- Irrigate crops at ear emergence and flowering stages when there is no rain.
- When the plant was reached physiological maturity, which was usually 7-10 days before harvest, water must be removed.

Harvesting:

- The most important sign of maturity was the change in the colour of the grain from green to yellow. At this time, the grain was began to ripen from the top to the bottom of the panicle.

- Harvesting was begun when grain attains physiological maturity.
- The crop should be dried in the field for 2-3 days.

Table.4. Package of practices of rice under rice-green gram cropping system

Crop	**Rice**	
Type of technology	Farmers' practice	Improved practice
Cultivars	Pradhan Dhan (submergence tolerant)	CR Dhan 801 (both drought and flood tolerant)
Seed treatment	Bavistin @ 2 g kg^{-1} seed	Bavistin @ 2 g kg^{-1} seed
Weed management	One applications of Glyphosate @ 1 kg *a.i.* ha^{-1} (6-7 days before transplanting)	One applications of Glyphosate @ 1 kg *a.i.* ha^{-1} (6-7 days before transplanting)
Planting method	Transplanted	Transplanted
Nutrient management	Farmer's fertilizer practice (RDF 80-40 -40 kg ha^{-1})	RDF (80-40-40 kg ha^{-1}) + 20% additional P (8 kg ha^{-1})
Water management	Fully depends on *kharif* rain	One irrigation was provided before transplanting and fully depends on *kharif* rain

Fig.13. Demonstration of CSA technologies in rice-green gram cropping system during *kharif*

8. PACKAGE OF PRACTICES FOR GREEN GRAM UNDER RICE-GREEN GRAM CROPPING SYSTEM

I. FARMER'S PRACTICE

Selection of variety:

- Green gram (local/ *desi-mung*) was grown during *rabi* season after *kharif* rice harvest.
- This crop can also be grown on heavy textured soil if the initial soil moisture was sufficient for the plant development and adequate drainage facility is available.

Field preparation:

- Soon after soil preparation, seeds were broadcasted.
- Seeds could be soaked for 1 hour in water if the soil had low moisture content to speed germination.

Fertilizer Management:

- No fertilizer was applied as the soil is from a river command area enriched with plant available nutrients.

Weed Management:

- Depending upon the weed infestation, one manual weeding was done during the cropping period.
- Weeding within 2 to 3 weeks not only prevented weeds from using up nutrients in the soil, but also conserved moisture and promotes plant growth and development.

Water Management:

- Only one irrigation was given before flowering.

Harvesting:

- The green gram was harvested when at least 85% of the pods are fully grown.
- Harvesting should be avoided during inclement weather, such as rain showers and cloudy skies. This type of weather favours the spread of fungal infection.
- The harvested stacks were cubed for drying on the threshing floor in a dry, clean room to allow air circulation.

II. ZERO TILLAGE

Selection of variety

- A high yielding improved variety of green gram (IPM 2-3) was selected for the planting.

Field preparation

- The land was left with 30% of rice residue from previous *kharif* season and sowing was done in presence of adequate moisture.
- IPM 2-3 seeds were planted in between two rows of rice stubbles with the help of a tyne in untilled soil.

Fertilizer Management

- RFD was applied at the rate of 20:40:40 kg ha^{-1}N: P_2O_5: K_2O and applied as basal dose at the time of sowing.

Water Management

- Two irrigations were applied depending on the soil moisture for better crop development.
- First irrigation was given after 20-25 days after sowing (DAS) and repeated after 10-15 days.

Weed management

- Pre-planting herbicide Glyphosate was applied at the rate of 6 ml l^{-1}, about 7 days before planting for controlling escaped weed population under zero tillage.
- Although pre-planting herbicide was applied, weeds were hand-picked after 20-25 days after sowing (DAS).

Cropping system

- Green gram was cultivated solely with the help of residue management.

Harvesting

- The green gram pods were harvested at least 85% maturity consisting of two to five handpicks at weekly interval.

III. NUTRIENT MANAGEMENT

Selection of variety

- A high yielding improved variety of green gram (IPM 2-3) was selected for the planting.

Seed treatment

- *Rhizobium* inoculations considerably minimize the need for nitrogen fertilizer application and also improve yield of green gram.
- *Rhizobium* culture at the rate of 20-50 g $kg^{-1}$of seed was applied and mixed thoroughly and left for overnight after treatment.
- Phosphobacteria at the rate of 5 kg $ha^{-1}$of soil were applied.

Field preparation

- There was no additional field preparation effort for growing green gram.

- One ploughing followed harrowing was enough for crop establishment.
- Seeds were planted by line sowing with the help of tyne.

Fertilizer Management

- Recommended chemical fertiliser was applied at the rate of 20:40:40 kg ha^{-1}N: P_2O_5: K_2O as basal dose at the time of sowing.

Water Management

- One irrigation was applied after 35-40 DAS for healthy and better seedling growth.

Weed management

- Pre-planting herbicide was not applied; weeds were handpicked 20-25 days after sowing (DAS) and 40-45 DAS as per need.

Cropping system

- Green gram was solely cultivated with RDF along with *Rhizobium* seed treatment and soil application of PSB for better nutrient management.

Harvesting

- The green gram was harvested at least 85% pod maturity, consisting of two to five handpicks at weekly intervals.

IV. AGRO-INTENSIFICATION I

Selection of variety

- A high-yielding improved variety of green gram (IPM 2-3), maize (Asha-3501), and cowpea (YB-7) were selected for cultivation.

Field preparation

- Ploughed the field twice or more with country plough followed by harrowing to obtain good tilth.
- The seeds were planted on raised bed by line sowing with the help of tyne.

Fertilizer Management

- The recommended chemical fertiliser for maize was applied @ 120:40:60 kg ha^{-1} N: P_2O_5: K_2O.
- Half dose of N and full dose of P and K were applied as basal dose at the time of sowing and remaining amount of N was applied into two split doses.
- Maize was the highest fertilizer consumer so that recommend dose of maize was applied in this system.

Water Management

- 6-7 irrigations (10-15 days interval) was applied for healthy and better seedling growth.
- Irrigation was applied immediately after sowing and a light irrigation was applied on the 3rd day. Thereafter, depending on the climate and soil type, irrigated at intervals of 10-15 days.

Weed management

- Pre-planting herbicide was not applied, the first weeding was done when the crop was 20-25cm height and a second weeding was carried out at 60cm crop height.

Cropping system

- Intensification of maize with green gram and cowpea was carried out in a 120 cm wide furrow irrigated raised bed, leaving 30 cm for the furrow which served as an irrigation channel.
- In this system, 2 rows of maize, 2 rows of green gram and 2 rows of cowpea were planted per unit area.

Harvesting

- The maize was harvested without leaving residues in the field. Green gram was harvested at least 85% crop maturity with two to five handpicks at weekly intervals and cowpea was harvested in 60-75 DAS or at 50% flowering to pod formation.

V. AGRO-INTENSIFICATION II

Selection of variety

- A high-yielding improved variety of green gram (IPM 2-3), okra (NS -862), and bitter gourd (DEB-510) were selected for cultivation.

Field preparation

- Ploughed the field twice or more with the country plough followed harrowing was enough to obtain good tilth.
- The seeds were planted on the field by line sowing with tyne.

Fertilizer Management

- The recommended chemical fertiliser for bitter gourd was applied @ 120:60:60 kg ha^{-1} N: P_2O_5: K_2O.
- Half dose of N and full dose of P and K were applied as basal dose at the time of sowing and the remaining amount of N was applied into two equal split doses.
- Bitter gourd is heavy feeder so that recommend dose of bitter gourd was applied in this system.

Water Management

- 4-5 irrigations (15-20 days interval) was applied for healthy and better seedling growth.
- Irrigation was applied immediately after sowing thereafter, depending on the weather and soil type, irrigation was applied at 15-20 days interval.

Weed management

- Pre-planting weedicide was not applied, the first weeding was given when the crop was 20-25 cm height and a second weeding was carried out when it was about 60 cm high.

Cropping system

- Intensification of green gram in okra was planted in combination with bitter gourd as border crop.
- In this system, 2 rows of green gram, 2 rows of okra and 2 row of bitter gourd were planted per unit area.

Harvesting

- The green gram was harvested at 85% maturity and fully grown consisting of two to five handpicks at weekly intervals. Bitter gourd was handpicked at an interval of 2-3 days as bitter gourd fruits mature very fast and turn red and okra harvesting was carried out by simple handpicking above their caps.

Table.5. Package of practices of green gram under rice-green gram cropping system

Crop			**Green Gram**		
Type of technology	Farmers' practice	Zero tillage (ZT)	Nutrient management (NM)	Agro-intensification I	Agro-intensification II
Cultivars	Local variety	IPM 2-3	IPM 2-3	IPM 2-3	IPM 2-3
Inter-cropping	Sole green gram	Sole green gram	Sole green gram	Green gram + Maize + Cowpea intercropping	Inter-cropping of green gram with Okra + bitter gourd on border

Seed treatment	No	No	Rhizobium @ 20-50 g kg^{-1} seed + PSB @ 5 kg ha^{-1}	No	No
Pre-planting Weed management	No	Glyphosate @ 6 ml l^{-1}	No	No	No
Planting method	Broadcasting	Line sowing	Line sowing	Furrow irrigated raised bed with line sowing	Line sowing
Nutrient management	No	RDF (20-40-40 kg ha^{-1})	RDF (20-40-40 kg ha^{-1})	RDF (120-60-40 kg ha^{-1}) (Maize)	RDF (100-60-60 kg ha^{-1}) (Bitter gourd)
Water management	One irrigation (Just before flowering)	2 irrigations (first irrigation after 20-25 DAS and repeat after 10-15 days)	One irrigation (Just before flowering)	6-7 irrigations (10-15 days interval)	4-5 irrigations (15-20 days interval)
Tillage	Conventional Tillage	Zero Tillage	Conventional Tillage	Conventional Tillage	Conventional Tillage

9. IMPACT OF CLIMATE SMART AGRICULTURAL PRACTICES IN RICE-GREEN GRAM CROPPING SYSTEM

9.1 YIELD

Yield is the result of coordinated interplay of growth characters and yield attributes. Grain yield of paddy were influenced significantly by different planting methods during 2019 and 2020 (**Table-2**). In two consecutive seasons, the yield of rice in farmers' fields were recorded under two different varieties **(Fig.14)**, whereas the yield of green gram in farmers' fields during *rabi* season were recorded under five climate smart technologies **(Table 6)**. Although there were no significant differences in rice yields in the *kharif* season. The different CSA management approaches resulted in significant differences in grain yields in the two successive cropping seasons during the *rabi* season. The experimental studies revealed that CR Dhan 801 gave higher grain yield (4.95-4.96 t ha^{-1}), followed by Pradhan Dhan (4.88-4.9 t ha^{-1}). In both years, there was a flash flood in the early season before transplanting of rice and the crop received normal monsoon rains throughout the growing season. In two consecutive *rabi* seasons, Agro-intensification I had the highest system yield, while ZT had the lowest system yield. System yield with CSA practices was higher (2-year average) in 2019 than in 2020. Overall, climate smart agriculture practices improved productivity compared to farmer practices.

Table 6. Yield of the various treatments grown in both season

Treatments		**Yield**		
		2019	2020	Average
Rice (t ha^{-1})	FP	4.87	4.91	4.89
	IP	4.95	4.97	4.96
Green gram (GEY) (q ha^{-1})	FP	4.22	3.98	4.10
	ZT	2.78	2.81	2.80
	NM	5.00	4.87	4.93
	AI I	18.06	18.01	18.03
	AI II	13.19	12.67	12.93

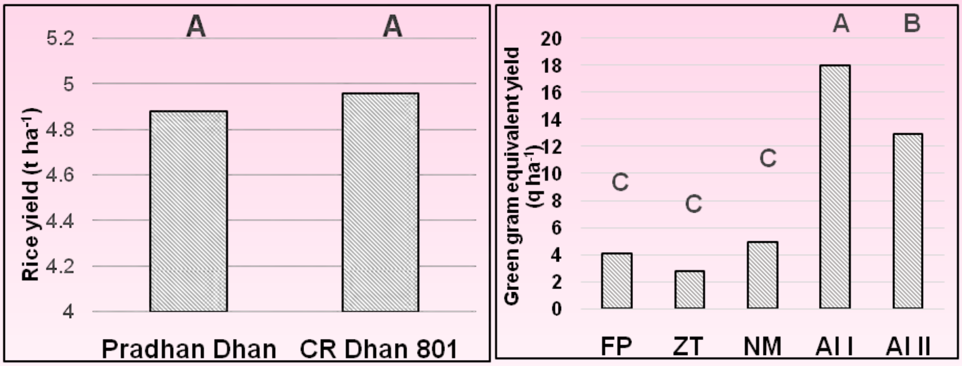

Fig.14. Yield comparison between two different varieties in both season

9.2 YIELD ATTRIBUTES:

The dry matter accumulation and its conversion into yield components lead to yield-determining characteristics. These yield parameters are directly related to the physiological grain yield of the plant. In both years of the study, the alternative cropping methods had a significant effect on yield variables such as number of effective shoots m^{-2}, panicle length (cm), number of grains per panicle, and 1000-grain weight. At maturity, plants were harvested from each plot and the number of effective shoots and panicles, as well as panicle weight and length, were recorded; all grains were then threshed or separated from the panicles.

In the 2019 and 2020 crop years, plant height varied significantly (**Table 7**). The tallest rice plant was found in improved practice and CR Dhan 801 variety in 2020, while the shortest was found in farmer practice and Pradhan Dhan variety in 2019. In 2019, the maximum number of panicles m^{-2} was counted under the farmers' practice, while the minimum number was in the improved practice. However, the different treatments did not show significant differences. The highest test weight was recorded in the improved practice in both the years of study.

During *rabi,* plant height did not change significantly in the 2019 and 2020 crop years (**Table 8**). However, the average height of green gram plant was better in nutrient management followed by agro-intensification I. The reason could be due to genetic variability and varietal differences and environmental adaptability. The number of nodules varies significantly. The highest number of nodules per plant was observed in nutrient management with 50.33 in 2019 and 48.67 in 2020. The nodule count was better under nutrient management, probably due to the application of *Rhizobium*. The different treatments did not show significant differences in numbers of pods. Nutrient management had the highest number of seeds per pod in both years, which is 17.9% better than farmers' practice. Genetic diversity, large grain size, and seed treatment with *Rhizobium* and application of phosphate solubilizing bacteria could all be contributing factors.

Table 7. Yield attributes of the green gram under various treatments

Type of technology	Plant height (cm)		No. of nodules plant^{-1}		No. of pods plant^{-1}		No. of seeds pod^{-1}	
	2019	2020	2019	2020	2019	2020	2019	2020
Farmers’	30.95	30.42	35.33^{B}	36.33^{CD}	37.00^{C}	36.67^{B}	9.40	9.17
ZT	31.85	30.18	38.00^{B}	38.67^{D}	41.00^{B}	38.00^{B}	10.84	10.25
NM	31.93	30.22	50.33^{A}	48.67^{A}	44.67^{A}	43.00^{A}	11.17	10.75
Agro-intensification	31.23	30.15	42.67^{AB}	41.67^{B}	40.00^{A}	39.33^{B}	10.86	10.42
Agro-intensification	30.97	30.05	42.67^{AB}	41.00^{BC}	43.00^{A}	41.67^{A}	10.34	9.50
General Mean	31.39	30.20	41.80	41.27	41.13	39.73	10.52	10.02
p-Value	0.121	0.051	0.027	0.025	0.0002	0.0071	0.398	0.184
CV (%)	2.01	0.50	10.48	8.64	2.57	4.43	12.50	9.69

Table 8. Yield attributes of the rice under various treatments

	Plant height(cm)				No. of tiller m^{-2}				No of panicle m^{-2}				Panicle length(cm)				1000 grain weight(g)			
Year	2019		2020		2019		2020		2019		2020		2019		2020		2019		2020	
Technology	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP	FP	IP
Mean	90.05	102.2	95.4	109.9	267.0	241.5	277.5	248.0	250.0	209.5	272.0	235.5	23.7	23.3	24.7	25.4	20.0	19.5	19.7	22.1
SD	1.31	0.60	3.46	3.42	8.49	6.36	10.61	11.31	4.24	2.12	8.49	10.61	0.61	0.62	1.36	1.30	1.42	0.69	0.67	0.06
SEM	0.54	0.25	1.41	1.40	6.00	4.50	7.50	8.00	3.00	1.50	6.00	7.50	0.25	0.25	0.56	0.53	1.00	0.49	0.48	0.05
p-Value	<0.0001		< 0.0001		0.08		0.11		0.01		0.06		0.28		0.34		0.70		0.04	
t-test	20.68		7.30		3.40		2.69		12.07		3.80		1.13		0.99		0.45		5.00	
Standard error of difference	0.59		1.99		7.50		10.97		3.35		9.61		0.35		0.77		1.12		0.48	

9.3 ENERGETICS:

Agriculture consumes a lot of energy, both directly and indirectly, due to its many economic activities, inputs, and demands, such as tillage, ploughing, inorganic fertilisers, herbicides and pesticides, irrigation, harvesting, etc., especially since the green revolution and the development of highly mechanised, irrigated, high-input cropping systems. As a result, increasing energy efficiency is a top priority for farmers and policymakers alike. Nevertheless, current initiatives are not sufficient to realise the full economic potential of agricultural energy use.

Energy input-output budgeting in the farmer's field and improved practices were carried out. The different energy sources in crop production were calculated based on the input demand and the corresponding energy coefficients. From the *kharif* energy calculation, the total input energy (MJ ha^{-1}), total output energy (MJ ha^{-1}), net energy gain (MJ ha^{-1}) and energy ratio were highest in the improved method due to higher yield of CR Dhan 801 and additional 20% phosphate fertilizer applied compared to the recommended packages and practices (**Table 9**). However, there were no significant difference in the energy productivity of the two systems.

Table 9. Energetics of the various treatments grown in *kharif* crop

Energy	FP	IP
Total input energy (MJha^{-1})	17539.33	17688.13
Total output energy (MJ ha^{-1})	137147.00	139174.00
Net energy gain (MJ ha^{-1})	119607.68	121485.88
Energy ratio	7.82	7.87
Energy productivity (KgMJ^{-1})	0.28	0.28

Energy calculations in *rabi* showed total input energy (MJ ha^{-1}), total output energy (MJ ha^{-1}), net energy gain (MJ ha^{-1}) and energy ratio were highest in AI I (**Table 10**). Maize requires higher amount of fertilizers (120-60-40 kg ha^{-1}) and water (6-7 irrigations) which resulted in higher input energy. The yield (GEY) was also higher in this system. However, energy productivity was highest in farmers' practice (FP) as it used less input energy (no fertilizer, one pre-sowing irrigation) per unit of produce compared to other treatments.

Table 10. Energetics of the various treatments grown in *rabi*

Energy	FP	ZT	NM	AI I	AI II
Total input energy (MJ ha^{-1})	3062.30	4034.86	5101.00	22774.46	18607.54
Total output energy (MJ ha^{-1})	13331.17	9093.80	15779.20	184612.12	76985.44
Net energy gain (MJ ha^{-1})	10268.87	5058.94	10678.20	161837.66	58377.90
Energy ratio	4.35	2.25	3.09	8.11	4.14
Energy productivity (Kg MJ^{-1})	0.51	0.27	0.37	0.30	0.27

9.4 ECONOMICS:

Any technique in agriculture today must be economically viable before it can be accepted and adopted by farmers. Economic viability is a function of profit and loss, such as gross return, net return, and benefit-cost ratio (B:C), which are necessary to evaluate the effects of various treatments during the trial. Improved practice with additional phosphorus treatment had the highest cost of cultivation (₹78152 ha^{-1}) and gross return (₹97870 ha^{-1}) followed by farmers' practice with RFD due to better grain and straw production of CR Dhan 801, whereas farmers' practice had the highest net return (₹21250 ha^{-1}) and best B:C ratio (**Table 11**).

The economics of the whole system of rice-green gram was calculated for two consecutive years with different climate smart technologies. For two consecutive cropping years, Agro-Intensification I proved to be economically advantageous over alternative treatments. The AI-I had a gross return of ₹142947 ha^{-1}, which was more than 400% higher than the farmer's practice (**Table 11**). AI-I has a higher cost of cultivation per hectare than other methods. The cost of the improved cropping pattern was higher due to the intercropping of maize, the labour-intensive cultural practises, and the cost of fertiliser and other inputs. Based on the calculation, the benefits of the technology were evaluated and it was found that the CSA technology leads to an increase in net return compared to the farmers' practices. The benefit-cost ratio of the cropping system based green gram under CSA practices varied from 1.13 to 1.57 averaged over two years.

Table 11. Effect of rice-green gram cropping system on economics

Treatments	Cost of cultivation (₹ha^{-1})	Gross return (₹ha^{-1})	Net return (₹ha^{-1})	B:C ratio
Kharif				
Farmers' practice	75102.40	96352.71	21250.31	1.28
Improved practice	78152.40	97870.00	19717.60	1.25
Rabi				
Farmer's practice	19693.58	30581.20	10887.62	1.55
Zero tillage	20598.24	27661.58	7063.34	1.34
Nutrient management	23597.58	36004.27	12406.69	1.53
Agro intensification I	90884.36	142947.15	52062.79	1.57
Agro intensification II	83824.98	94396.95	10571.97	1.13

9.5 WATER PRODUCTIVITY:

The relationship between the volume of product (i.e., crop grain yield) and the amount of water consumed, transferred, or lost is called crop water productivity. From a farmer's perspective, this translates into higher productivity per unit of irrigation. The water requirement of the rice and green gram cropping system was estimated by adding the effective rainfall during the entire cropping season to the amount of irrigation water used. The increase in water productivity of rice is highest in the studied area under improved practice with 20% additional phosphorus application, followed by farmers' practice with RDF (**Table 12**). This is due to higher grain production and lower water consumption of CR Dhan 801 compared to Pradhan Dhan averaged over two years.

During the *rabi* season, water productivity of the different treatments varied from 0.088 to 0.324 kg m^{-3}. Intercropping with maize was critical for increasing water productivity during the *rabi* season. Agro-intensification I had the highest water productivity, followed by agro-intensification II. Compared to the other farming practises, zero tillage had slightly lower water productivity.

Table 12. Effect of rice-green gram cropping system on water productivity

Treatments	Grain yield (t ha^{-1})	Water use (mm)	Water productivity (kg m^{-3})
Kharif			
Farmers' practice	4.89	1168.5	0.418
Improved practice	4.96	1092.2	0.454
Rabi			
Farmer's practice	0.41	464.09	0.088
Zero tillage	0.28	464.09	0.060
Nutrient management	0.49	464.09	0.106
Agro intensification I	1.80	555.72	0.324
Agro intensification II	1.29	531.27	0.243

10. OTHER ADVANTAGES

- Climate-smart agricultural strategies such as conservation agriculture seek to conserve soil moisture, preserve crop residues for soil fertility, minimum soil disturbance, and crop diversification through intercropping or crop rotation.
- Climate smart agriculture (CSA) technologies are able to reduce vulnerabilities, increase system productivity, and enhance production sustainability.
- The technology provides a better knowledge of the drivers of CSA technologies in climatically vulnerable areas and should enable policy makers to plan more competent development-oriented interventions.
- The technology increases production and profitability while reducing greenhouse gas emissions and improving soil health.
- Facilitates timely establishment of rice and subsequent *rabi* crop cultivation.
- CSA helps improve food security for the poor and marginalised while reducing global food waste (CCAFS 2013).

11. TARGET AREA FOR THE TECHNOLOGY

The technology is suitable for the eastern coastal plains and hills (Agro climatic zone planning commission). The eastern and south-eastern coastal zone and climatically vulnerable areas (especially flood-prone areas) are suitable for the technology. The technology was validated in Bateswar village in Salipur Block, Cuttack.

12. UPSCALING OF THE TECHNOLOGY

By changing the intensive traditional farming methods, the technology-based farming methods of climate smart agriculture (CSA) are becoming more and more prevalent. The whole package as well as the techniques need to be disseminated to popularise this CSA-based technology. The implementation of CSA also provides opportunities for much needed intensification and diversification of agriculture. Efforts should be made to disseminate CSA-based technologies by combining the efforts of state ICAR institutes and state agricultural universities.

Up scaling CSA will undoubtedly require millions of agricultural producers to change their behaviour, approach, and farming practises to better understand the impacts of climate change and find more climate-friendly solutions. Extension and advisory services (EAS) can help significantly improve CSA. To facilitate outreach and promote the transfer of ideas across a broader range of stakeholders than is currently the case, EAS needs to be supported by extensive expertise and capabilities (Cornell et al., 2013). Eligible stakeholders include those involved in policy development as well as those involved in agriculture. EAS help achieve all three CSA goals (food security, adaptation, and mitigation), although they currently focus on the first, food security through increased production. Climate smart technologies are becoming increasingly popular. This technology can also help prevent floods and droughts in climatically vulnerable areas.

Climate change will negatively impact agricultural productivity in developing countries, especially for smallholder farmers. Many government programmes encourage farmers to use climate-smart agriculture (CSA) strategies to increase their climate resilience and reduce the negative impacts of climate change on agricultural productivity.

13. SUCCESS STORY

Name of farmer: Abhiram Kandi

Address: Village: Bateswar,
Block: Salipur, District: Cuttack, Odisha

Mobile Number: 9090815146

Age: 55

Education: High School

Land holding : 2.5 Acre

1) Before Intervention

Component Description		Benchmark (Baseline period 2018-19)			
Compo-nents	**Names**	**Area (Acre)/ Number**	**Produc-tion(Q litre^{-1} no.$^{-1}$)**	**Gross-Income (Rs.)**	**Net-Income(Rs.)**
Field Crop 1	Rice (local)	1.5 Acre	28q	30800	20800
Hort. Crop2	*Rabi* vegetable (local var.)	1.8	-	55000	40000
Hort. Crop3	Back yard fruit crops (local banana, guava, custard apple)	15 Nos	-	3000	2200
Livestock 1	Cattle	2 Nos	4 litday^{-1} + cow dung	54850	36600
Livestock 2	Goat	2 Nos	25 kg meat	11250	9250
Total					108,850

2) Status in 2020-21

Component Description		Period 2021-22				% Increase over base year
Components	**Names**	**Area (Acre)/ No**	**Production (Q litre^{-1} no.$^{-1}$)**	**Gross Income (Rs.)**	**Net Income (Rs.)**	
Field Crop 1	Rice (HYV with improved cultivation practice)	2.0 Acre	45q	69750	53750	
Field Crop 2	Maize (hybrids)	0.5 Acre	10.6q	18020	12000	
Field Crop 3	Moong (YMV)	0.2 Acre	2.2q	14300	7800	
Hort. Crop 2	Rabi vegetables (HYV and Hybrids with IPM	1.8 Acre	-	90000	62000	
Hort. Crop 4	Improved varieties of fruit crops in backyard garden	30 Nos	-	5000	3500	
Livestock 1	Cattle (balanced feeding)	05	6 litday^{-1} + cow dung	103890	67390	
Livestock 2	Goat (balanced feeding)	04	40kg meat	26000	23000	
Total				**3,26,960**	**2,29,440**	**110.8%**

The farmer was drawing an average monthly income of Rs **9,071/-** in 2018-19. He faced problems like non-availability of improved varieties, quality seeds, pest and disease problems, stray cattle, early floods, terminal drought etc. Through measures such as planting both flood and drought tolerant high yielding rice varieties (CR Dhan 801), YMV resistant varieties (IPM 2-3), seed treatment with Rhizobium and PSB, better irrigation, weed control, intensification of cultivation, etc., he was able to significantly increase his earnings. The increase in vegetable acreage and the use of livestock manure in crop production, as well as the balanced feeding of cattle and goats helped to increase the system productivity of the different components of his farm. The multimodal approach has helped the farm family find employment for most of the year. The average monthly net income is Rs **19,120/-** per month in 2021-22.

Name of farmer: Tukuna Bhoi
Address: Village: Bateswar, Block: Salipur, District: Cuttack, Odisha
Mobile Number: 8337934434
Age: 52
Education: High School (9th Std.)
Land holding : 2 Acre

1) Before Intervention

Component Description		**Benchmark (Baseline period 2018-19)**			
Compo-nents	Names	Area (Acre)/ Number	Production(Q litre^{-1} no.$^{-1}$)	Gross In-come (Rs.)	Net-Incom e(Rs.)
Field Crop 1	Rice (local)	1 Acre	18q	19800	13200
Hort. Crop2	*Rabi* vegeta-ble (local var.)	0.9 Acre	-	35000	27500
Hort. Crop3	Back yard fruit crops (local banana, guava, cus-tard apple)	30 Nos	-	9000	5000
Livestock 1	Cattle	2 Nos	cow dung + 2 lit day^{-1}	35688	23438
Livestock 2	Goat	3 Nos	45 kg meat	20250	17250
Total					86,388

The farmer was drawing an average monthly income of Rs **7,199/-** in 2018-19. He faced problems like non-availability of improved varieties, quality seeds, pest and disease problems, stray cattle, early floods, terminal drought etc. Through measures such as planting both flood and drought tolerant high yielding rice varieties (CR Dhan 801), YMV resistant varieties (IPM 2-3), seed treatment with Rhizobium and PSB, better irrigation, weed control, intensification of cultivation, etc., he was able to significantly increase his income. The increase in vegetable acreage and the use of livestock manure in crop production, as well as the balanced feeding of cattle and goats, help to increase the productivity of the different components of his farm. The multimodal approach has helped the farm family find employment for most of the year. The average monthly net income is Rs **12,997/-** per month in 2021-22.

2) Status in 2020-21

Component Description		Period 2021-22				% Increase over base year
Components	Names	Area (Acre)/ No	Production (Q litre^{-1} no.$^{-1}$)	Gross Income (Rs.)	Net Income (Rs.)	
Field Crop 1	Rice (HYV with improved cultivation practice)	1.6 Acre	35q	54250	41450	
Field Crop 2	Maize (hybrids)	0.5 Acre	7.1q	12070	6870	
Field Crop 3	Moog (YVM)	0.2 Acre	2.4q	15600	8800	
Hort. Crop 2	*Rabi* vegetables (HYV and Hybrids with IPM	1.2 Acre	-	60000	40000	
Hort. Crop 4	Improved varieties of fruit crops in backyard garden	40 Nos	-	8000	6300	
Livestock 1	Cattle (balanced feeding)	05 Nos	cow dung + 4litday^{-1}	71040	34540	
Livestock 2	Goat (balanced feeding)	02 Nos	30kg meat	19500	18000	
Total				2,40,460	1,55,960	80.5%

14. CONCLUSION:

When implemented in combination and on a larger scale, CSAs have the capacity to alleviate food insecurity among smallholder farmers. To increase adoption, land fragmentation should be discouraged through civic education and the availability of alternative income-generating activities that can benefit farmers when implemented on comparatively larger areas. Farmers should be educated on the need to invest in agricultural inputs to mitigate the effects of climate change while increasing the adoption of CSA practises. Research showed that CSA methods such as crop rotation and intercropping green gram with maize and cowpea, are financially rewarding for farmers who invest in these methods over a short period of time. Agro-intensification of green gram with maize, cowpea, bhindi and bitter gourd is a successful investment decision for smallholder farmers in rural areas with limited financial resources, as these investments pay for themselves more quickly.

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