Award Category – Innovation and Discoveries (to be filled by teachers)

Award for - Teachers

Important Note:
a) The work must be available on Institute's website
b) The work must be available for peer review and critique
c) The work must be reproducible and developed further by other scholars.

Duly completed form to be submitted by August 20, 2021.

Email *

anjaniias@gmail.com

Name of the teacher, age, institution name, course name *

ANJANI KUMAR, 42, ICAR - National Rice Research Institute, Agricultural Science

Pls share what Innovation techniques have you implemented in your Teaching and learning process. Pls upload valid documents to justify your claim. *

- Soumya Nayak - ...
- Sumit Parida - A...
- Swarnalisha sah...
- Gitanjali and Rup...
- OUAT external ex...
- BHU thesis exam...
- Dr. Anjani Kumar...

What Research and development initiatives have you undertaken in the last one year? Upload valid documents or provide website links to justify your claim. *

- Color coded tens...
- TechNRRI_MR-V...
- lcc_english - ANJ...
- Rice xpert wid na...
- Product and Tec...

Pls share details of Patents and copyrights filed in the last one year. Upload valid documents or provide website links to justify your claim. *

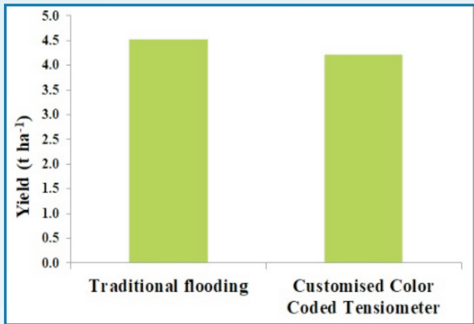
- Application for p...
- Letter to Shri Anj...

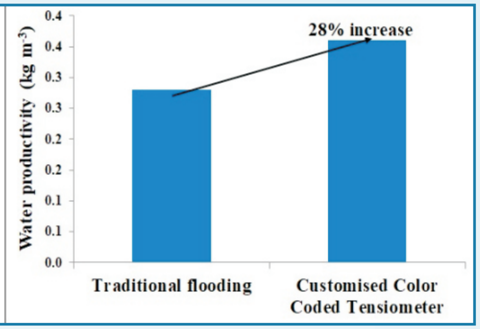
Pls share details of any others work pertaining to innovation and discoveries. Upload valid documents or provide website links to justify your claim. *

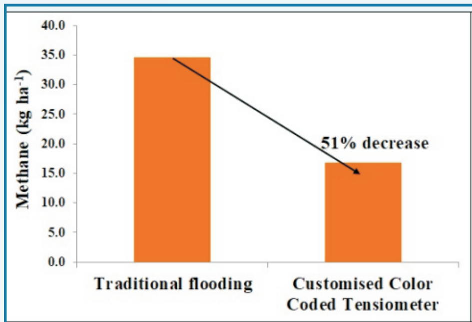
- Research Public...
- Book and Book c...

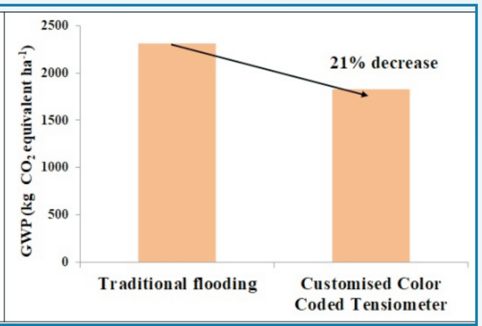
Upscaling

Customized color coded tensiometer can be upscaled by imparting training and demonstration by taking leverage of State and Central Govt. schemes like Pradhan Mantri Krishi Sinchai Yojana, National Food Security Mission, Odisha Integrated Irrigation Project for Climate Resilient Agriculture etc. Policy support and systematic extension will help popularization of this technology among the farmers.









Customized Color Coded Tensiometer for Scheduling Irrigation in Rice

NRRI Technology Bulletin - 154

Editing and layout : GAK Kumar & Sandhyarani Dalal

Photography: Prakash Kar & Bhagaban Behera

Laser typeset at the National Rice Research Institute, Indian Council of Agricultural Research, Cuttack (Odisha) 753 006, India and printed at Printech offset, BBSR. Published by The Director, for the National Rice Research Institute, Cuttack (Odisha) 753 006.

Customized Color Coded Tensiometer for Scheduling Irrigation in Rice

Anjani Kumar, AK Nayak, Rahul Tripathi, Sangita Mohanty and PK Nayak

Rice crop is known to have high water requirement. In traditional rice cultivation, farmers generally keep the field continuously flooded from transplanting to physiological maturity of rice crop. However, it is well established that continuous flooding is not necessary for rice to achieve high yields. After seedling establishment phase, even in the absence of standing water in field, rice plant can extract soil water from the below surface soil around root zone. Over the past few decades, water scarcity has emerged as one of the biggest challenges for sustaining rice production. Development of novel water saving technologies is an important step to help rice farmers cope with water scarcity. It is well proved that soil water potential as measured by tensiometer can be used as an irrigation index for scheduling irrigation in rice.

The tensiometer consists of a rigid and sealed body tube and a porous ceramic cup filled with water. The body tube is transparent so that water within the tube can easily be seen. The tensiometer tube along with the ceramic cup is inserted in the soil preferably at the plant root zone depth to provide a direct measurement of soil water potential- the force by which the soil particles hold the water. The wetter the soil, the lower the soil water potential. The ceramic cup is porous so that water can move through it to equilibrate with the soil water. As the soil dries out, water is sucked out of the tensiometer through the porous ceramic tip. This creates a partial vacuum in the sealed tensiometer tube which is measured by the electronic gauge. When the soil is watered the converse happens.

The core idea behind the use of tensiometer is the identification of threshold soil water potential for optimizing irrigation scheduling. Such irrigation scheduling can maximizing water productivity by reducing irrigation water input, because farmer generally over irrigates the crop irrespective of its requirement.

A simplified and farmer friendly version of tensiometer tube for real time soil water potential based irrigation management has been developed by ICAR National Rice Research Institute, Cuttack. In this tensiometer, the usual measuring gauge has been replaced by the stripes of light blue, deep blue, orange and brown color. While the water level in tensiometer tube at light blue stripe signifies no need for irrigation, there is need to irrigate when the water level enters the deep blue stripe. The entry into the orange and brown stripe may adversely affect the crop yield and hence should be avoided.

Installation and Use

STEP-1

Before installation, fill the tensiometer tube with air free water and cap it. Place the unit into a container of clean water deep enough to cover the ceramic cup and leave overnight. The porous ceramic cup of the tensiometer must be kept dipped overnight to ensure that they get fully water saturated and do not leak.

STEP-2

The instrument is now ready to be installed, but the ceramic cup must be protected from drying out. Cover the ceramic cup with wet paper towels or a plastic bag, while transporting to the site.

STEP-3

- For field installation, make a hole in the soil, using a soil auger up to the desired depth (15 cm). Remove the auger and drop a handful of loose friable soil into the hole.
- Insert the tensiometer into the hole after removing the paper towel. Push the instrument by giving a firm twisting downward motion applied to the connecting tube and place the cup at the desired soil depth. This procedure will ensure the necessary intimate contact between the porous cup and the soil in the vicinity. However, care must be taken that the cup is not broken in this process.

- Backfill the hole with soil slurry so that the tensiometer is firmly held in the soil.

STEP-4

- Check the tensiometer tube for accumulated air. If air bubble is present beneath the service cap, the cap should be removed and the tube should be refilled with de-aerated water.
- Allow the tensiometer to equilibrate for about 24 hours before recording readings.

Precautions

- At regular interval the tensiometer tube should be inspected for accumulated air and if air has accumulated beneath the service cap, the cap should be removed and the tube should be refilled with water.
- In some of the soils viz. cat clay (Shrink-swell clay) which may shrink away from the porous cup during drying, resulting in loss of contact with the soil, very coarse sands which creates capillary barrier at the interface between micro and macropores, saline-sodic soils as their salts might block the pores of the ceramic cup, the response of tensiometer is slow and readings are not reliable.

Interpretation of the color stripes of Customized color coded tensiometer

Color Stripe	Interpretation
Light Blue	No need of Irrigation
Deep Blue	Irrigation should be applied
Orange	Immediate need of irrigation
Brown	Adverse effect on grain yield and hence should be avoided

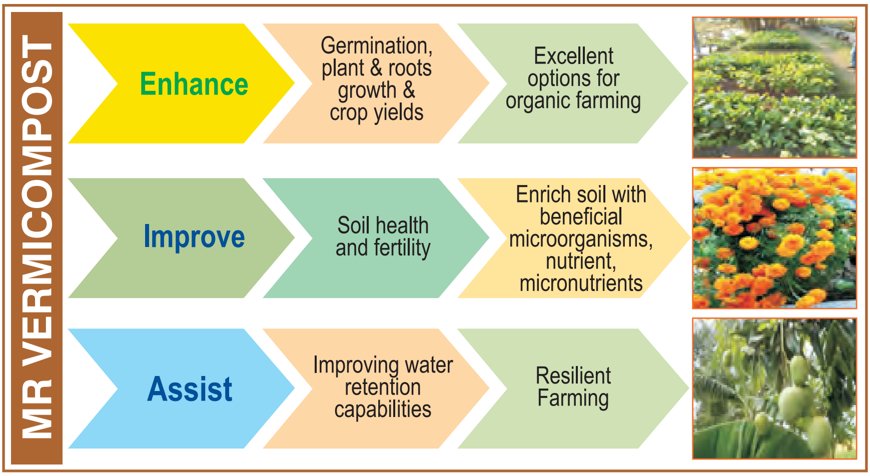
Testing and Validation

Customized color coded tensiometer was tested and evaluated both at research station and farmer's field. Experimental data revealed that irrigation scheduling based on customized color coded tensiometer resulted in similar grain yield with significantly higher water productivity (28%) and it also mitigates methane emission by 51% and global warming potential by 21%. Its cost-benefit ratio varies from 0.4 to 0.5.

MR VERMICOMPOST

A product of integrated farming system

PK Nayak, AK Nayak, M Shahid, R Tripathi, BB Panda,
A Kumar, U Kumar, S Mohanty and SK Das



Integrated farming system (IFS) generates lot of biomass residues round the year. In principle these residues are to be suitably recycled within the farming systems to meet the nutrient and energy requirements of enterprises (IFS) for enhancing productivity. Out of various method of practices of residue recycling, the vermicomposting is one of the most efficient ways to convert farm wastes (agricultural waste and crop residues) to valuable nutrient rich fertilizers for plant growths. The Multi Resource Vermicompost (MRV) is a organic fertilizer product of IFS prepared by utilizing various agricultural, livestock, horticultural and agroforestry wastes generated/available in the rice based integrated farming systems through the bio-oxidative degradations accomplished by the synergistic actions of earthworms and microorganisms. The organic manure prepared from the use of multiple farm resources (Table 1) not only provide higher levels of organic carbons and available plant nutrients, but also bearing several plant growth promoting substances (i.e. enzymes, vitamins and hormones) and beneficial microorganisms which helpful in healthy and better plant growth. Additionally, it has varied inert characteristics potentials of suppression of plant diseases and soil borne pathogens.

Table 1. Agricultural residues available in crop-livestock-agroforestry based integrated farming systems and their characteristics.

Agricultural residues	Nutrient contents*			Absorbency	Bulking potential	C:N ratio
	N %	P_2O_5 %	K_2O %			
Rice straw	0.5 - 0.8	0.18 - 0.20	1.4 - 2.0	Poor	Medium-good	150 - 160
Green gram residues	1.20 - 1.29	0.08 - 0.1	0.34 - 0.39	Good	Medium	18 - 22
Vegetables residues and stubbles (brinjal, tomato, cow peas, radish, okra, pumpkin, bottle gourd, snake gourd, chilly, papaya, turmeric, ginger, Colocasia etc.)	1.85 - 3.18	0.35 - 0.49	1.52 - 2.85	Good	Medium	10 - 17
Banana pseudo stem	0.71	0.22	2.21	Good	Poor-medium	45 - 50
Leaves litters of mango, guava, coconut & acacia plants etc.	1.2 - 1.6	0.15 - 2.0	1.05 - 1.35	Poor-medium	Poor-medium	30 - 70
Horticultural fruits	0.85 - 2.47	0.5 - 0.8	2.6 - 3.1	Good	Medium	20 - 49
Weeds biomass	2.3 - 6.88	-	-	Good	Medium	10 - 30
Fodder grass	2.3 - 6.1	-	-	Good	Medium	15 - 20
Poultry droppings	2.5 - 3.0	1.0 - 1.13	0.7 - 1.2	-	-	5 - 7
Duck droppings	0.95	0.54	0.37	-	-	25 - 30
Goat droppings	2.5 - 3.0	0.3 - 0.4	1.5 - 1.7	-	-	30 - 36
Cow dung	0.8 - 1.2	0.2 - 0.4	0.3 - 0.6	-	-	20 - 25
Farm yard manure	0.4 - 1.5	0.3 - 0.9	0.3 - 1.9	-	-	20 - 25

*Nutrient values expressed in dry wt. basis.

Methods of preparations

Organic farm wastes, suitable earthworms and water are the three basic requirements for production of MR vermicompost.

- An area under shade of tree or thatched house, having high humidity and cool places with provisioning of suitable protections from direct sun, extreme temperature (i.e. freezing or high temperature) and close to the fish pond was selected.
- The plastic containers or bag of height of 2½ feet and a breadth of 3 feet were used for preparation of compost, however, length may depend on the size of the room.
- Vermicompost can also be prepared either in pits (dug below the ground) or in raised heap (above ground), or circular/rectangular cemented structure or containers like wooden boxes, plastic buckets or vermiculture bags having provision of water draining hole at the bottom for draining excess waters.
- On the floor of the bed one layers of broken bricks, mixed soil and sand are spread uniformly (2-3 inch thickness).
- After this a layer of neem or pangamia (karanj) leaves are applied for preventing and discouraging the ants and termites infestations.
- Agricultural wastes materials generated from IFS, i.e.crops and livestock's including horticulture, agroforestry, vegetables and fodder etc. were collected, sun dried and chopped into suitable size (bedding materials).

Fig. 1. Some of the crop residues of IFS

Fig. 2. Picture depicting cemented structure vermibed (A), Plastic vermibags for vermi composting (B), Earthworm species *Eisenia foetida* (C), Vermicompost final product (D).

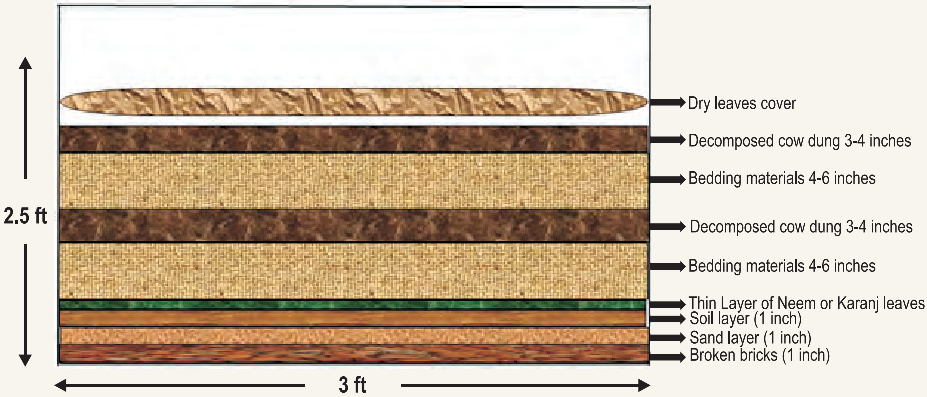


Fig. 3. Cross sectional view of Vermicomposting bed with different spreading layers.

- The bedding materials of 4-6 inches are sprayed with a layer of cow dung slurry (bulky substrate). This is followed by a 2^{nd} layer of decomposed cow dung (3-4 inches thickness) spread uniformly over the bedding materials. This process layering of organic waste and dry cow dung are repeated until the container is filled up or desired level.
- After 15-20 days of pre-conditioning (spraying of water for moisture and turning of heap 2-3 times at 4-5 days intervals), the earthworms are released at the rate of 1 kg earthworms /m^2 of heap.
- Adequate water spraying is essential for maintenance of moisture levels in the compost heap.
- Efficient debris consuming, non-borrowing earthworms (*Eisenia foetida*, *Eudrilus eugeniae*, *Eisenia andrei*, *Perionyx excavates* are ideal for vermicomposting)
- Once in every 15-20 days, the heap of organic wastes are turned upside down for efficient conversion and covered with gunny bags for moisture retention and protect from predators like birds and other animals.
- For complete conversion of organic wastes to vermicompost needs 2-3 months and also depends on favorable conditions (moisture, temperature, aeration, pH value, ammonia and salt contents) and density of worms etc.
- The approximate turnover of the compost is 50 - 75% of the organic residues loaded (i.e. if one tons of organic materials loaded expected vermicompost will be 500-750 kg). The harvesting of vermicompost can be done by using manual, or making pyramidal heap, screening or sieving methods or inducing the migration of worms.
- The vermicompost are stored in dark and cool places and packed in a laminated sac/bag prior to selling. Vermicompost can be store for longer period (1 year) without compromising qualities (nutrients and beneficial microbial population) with maintenance adequate moisture (40% of levels) and aerations.
- The physical and chemical composition of the compost is determined by following standard laboratory methods.

Fig. 4. MR Vermicompost

Nutrient values of MR Vermicompost

The MR Vermicompost are rich in nutrient contents along with diversified beneficial micro-organisms and other growth promoting substances (Table 2 and 3).

Table 2. Nutritional composition of MR Vermicompost.

Nutrient contents in MR Vermicompost*	
pH	6.12 - 7.5
EC dSm^{-1}	3.1 - 3.9
Total Organic carbon, %	9.10 - 18.83
Total Nitrogen, %	1.9 - 3.3
Total Phosphorus, %	0.5 - 1.9
Total Potash, %	0.9 - 2.1
Calcium, %	0.5 - 1.5
Magnesium, %	0.2 - 0.4
Sulphur, ppm**	100 - 550
Iron, %	0.9 - 1.7
Copper,ppm	2.1 - 9.4
Zinc, ppm	5.2 - 10.7
Manganese, ppm	1000 - 2000

* Values may vary depending upon the type of organic waste used.
**ppm parts per million

Table 3. Total microbial count in MR vermicompost using *Eisenia foetida*.

Groups	Total microbial count (CFU/gm)
Bacteria (10^7)	3.3 - 4.1
Fungi (10^6)	1.2 - 1.6
Nitrogen fixer (10^7)	3.3 - 3.9
Phosphate solubilizer (10^4)	2.1 - 2.7
Actinomycete (10^4)	1.6 - 2.2

CFU- colony-forming units

MR Vermicompost uses and its beneficial effects

Vermicompost can be used for any crops, however, its use is most profitable in the case of commercial crops like horticultural and fruit crops, ornamental plants, & vegetables and flower cultivations including kitchen gardening etc.

Table 4. Dose, time of application and yield advantage of different crops applied with MR vermicompost.

Crops	Quantity to apply	Time to apply	% increase in yields
Rice	1.0 - 2.0 tons/Acre	After transplanting	5 - 8
Sunflower	0.4 kg m^{-2}	Last ploughing	5 - 8
Chilli	0.25 kg m^{-2}	Last ploughing	8 - 10
Maize	0.25 kg m^{-2}	Last ploughing	5 - 8
Turmeric	0.25 kg m^{-2}	Last ploughing	10
Flowers	0.075 - 0.1 kg m^{-2}	Applied around the plant and covered with soil before irrigation	10 - 12
Fruits trees (guava, mango, banana)	0.075 - 0.1 kg m^{-2}	Every year depending on age of trees	5 - 10
Vegetables onion, tomato, cow pea, bhendi, radish, brinjal, cabbage etc.	5.0 - 10.0 kg $tree^{-1}$	Last ploughing and during vegetative growth	12 - 15
Banana	0.25 - 0.375 kg m^{-2}	At the time of planting	15
Teak, acacia magnesium	0.5 - 0.75 kg $plant^{-}$	At time of planting and once every year	10 - 15 higher growth

Economics

- Agricultural waste generated from the IFS can be suitably utilized through vermicomposting for production of quality fertilizers MR vermicompost for use in agriculture and horticulture. The protein rich worms become pro-biotic food for fish culture and livestock production (dairy, goatry, duckery and poultry etc.). In crop-livestock-agro forestry based integrated farming systems (1 hectare area), a vermicompost unit consisting of 5 vermi bags (size 12' x 3' x 2.5') can be operated from a thatched house (25' x 15'). The duration of one cycle of MR vermicompost is approximately 110 days. Maximum of three cycle can taken in one year periods, however, depending on availability of organic residues two cycle of vermicomposting will be beneficial with annual targeted production capacity /year of 8 tonnes (800 kg x 5 units x 2 cycle = 8000 kg). The cost benefit ratio of MR vermicompost is 1:3.4 (Table 5).

Table 5. Estimated capital investment and profits of vermicompost unit under IFS.

Input materials	Quantity	Rate (Rs.)	Amount (Rs.)
Depreciation cost of thatched house using bamboo and rice straw	1 Nos.	2000	2000
Depreciation cost of Vermi bed (5 yrs life span)		550	2750
Organic residues (available in crop-livestock agroforestry IFS system)	–	–	–
Cow dung and droppings of other livestocks available in crop-livestock agroforestry IFS	–	–	–
Labour requirements (material processing and filling, 1 MDY/bag, watering, 1 MDY/bag, harvesting and packing and sale etc., 2 MDY/bag. Total = 4 x 5 x 2 cycle = 40 nos.	40 Nos.	300	12000
Procurement of Vermi worm (initial)	10 kg	400	4000
Total production cost	–	–	20,750
Output			
Vermicompost production	8000 kg	10	80000
Sale of vermin worm	40 kg	300	12000
Total returns	–	–	92000
Net profit			**71,250/-**
Benefit cost ratio			**3.4**

Benefits

- Reduces quantity of organic wastes, converted to high quality organic fertilizers and providing safe ecological environments.
- MR Vermicompost is prepared from multi resource organic wastes, hence, it is qualitatively better fertilizers for plant growth.
- Application of MR Vermicompost improves the soil quality (i.e.physico-chemical constituents and biological properties with soil enrichment of micro-organisms).
- Reduces the needs for synthetic store purchased product.

- MR Vermicompost increases the crop yield and reduces the dependence on application chemical fertilizers.
- Suppresses the varied plant diseases and soil borne pathogens.
- Freshly harvested MR vermicompost having higher concentration of diversified beneficial microorganisms helps in enhancing crops growth and productivity.
- Reduces GHG emissions.

Up scaling

The IFS farmers can go for production of such type of vermicompost from their system by taking leverage of state Govt. scheme under National Food Security Mission (NFSM) and National Horticulture Mission (NHM) through availing the subsidies to beneficiaries. The vermicompost produce can be utilized in the system and surplus can be marketed giving additional return/benefits to farmers.

TechNRRI

MR VERMICOMPOST

A product of integrated farming system

NRRI Technology Bulletin - 153

Editing and layout : GAK Kumar & Sandhyarani Dalal

Photography: Prakash Kar & Bhagaban Behera

Laser typeset at the National Rice Research Institute, Indian Council of Agricultural Research, Cuttack (Odisha) 753 006, India and printed at Printech offset, BBSR. Published by The Director, for the National Rice Research Institute, Cuttack (Odisha) 753 006.

2. Products, Patents and Technologies on rice

A. Products:

1. **Developed and popularized five panel Customized Leaf Colour Chart (CLCC) for real time Nitrogen Management in Rice for Different Ecologies *(Co - Developer)***

A five panel customized leaf colour chart (CLCC) for N management in rice for different ecologies was developed by on the basis of spectral evaluation of leaves of hundreds of HYVs and local cultivars grown in eastern India under different levels of N applications. By using this, N application schedule for different rice ecology was developed. It is a cheap and easy to use handy tool provided with N application schedule in terms of kg urea per acre for rainfed favorable low land, submerged and flood prone low land, rainfed upland, and irrigated rice. By using this, farmers can adjust the N application to actual crop demand. In addition to this it also contains cultivar specific recommendations for Hybrids and HYVs (Swarna etc). The CLCC contains instructions in English, Hindi and Odia in simple language which can be easily followed by the farmers.*[**Published as** Nayak A.K., Mohanty S., Raja R., Shahid Md., Lal B., Tripathi Rahul., Bhattacharyya P., Panda B.B., Gautam P., Thilagam VK., **Anjani Kumar.,** Meher J. and Rao K.S. (2013). Customized leaf color chart for nitrogen management in rice for different ecologies. Central Rice Research Institute, Cuttack (India)].*

This CLCC is published in three languages English, Hindi and Odiya for its wider adaptability and reach.

Technology commercialized

The CLCC is commercialized through MoU with the following farms for manufacturing and distributing the CLCC.

1. M/S Nitrogen Parameters, Chennai and
2. Fine trap limited, Maharashtra.

Impact

Yield enhancement

- Customized leaf colour chart (CLCC) based N application enhanced yield by 10.3-13.3 % and 9.9-10.9 % over conventionally applied urea (RDF urea) in direct seeded (DSR) and transplanted rice (PTR), respectively. Yield enhancement with neem coated urea (NCU) when applied conventionally was 7.1-13.4 % and 6.8-10.0 % respectively. Whereas NCU when applied on the basis of CLCC, the yield enhancement over conventionally applied urea was 21.2-22.9 % and 14.6-15.9 % respectively for DSR and PTR.

Increase in Use efficiency

- As compared to RDF urea, CLCC based urea enhanced N recover efficiency (REN) by 10.7-12.4% and 9.1-12.2% in DSR and PTR, respectively. The increase of REN with NCU applied conventionally was 6.6-8.9% and 6.2-6.7%, respectively. Whereas NCU when applied on the basis of CLCC, the increase in REN over conventionally applied urea was 16.3-18.0% and 11.6-14.6%, respectively for DSR and PTR

Saving of fertilizer

- Since CLCC based N recommendation could increase N recovery efficiency from applied urea by 9.1-12.2 % as compared to conventional practice in transplanted rice it has the potential to save 18.5-27.3 % urea to produce same level of yield. Field trials also demonstrated application of 75% of recommended N on the basis of CLCC reading produced similar yield as that of 100% RDF, thereby saving 25% of fertilizer.

Monetary Benefit

- Results of on station and farmers' field experiment showed that at same level of N application yield advantages of 0.5-0.7 t ha-1 and 0.5-1.0 t ha-1 could be achieved following CLCC recommendation over RDF application and farmer's practice, respectively. That can lead to monetary benefits of Rs. 6,680-10,080/- and Rs. 7,776-14,544/- respectively per hectare. In addition to this, use of CLCC has a potential of cutting down approximately 25% total fertilizer consumption in low land rice that can save upto Rs. 1,514/- crores from the total urea subsidy bill of Govt. of India.

Media coverage

- Krishi Darshan DD Odiya on 16.09.2013: Integrated fertilizer management in paddy

- Krishi Darshan DD Odiya on 27.09.2013: Phone in Live programme on Nitrogen management in paddy by using CLCC

- Dharitri News Paper on 25.12.2013: Development of CLCC was included as one of the **important technology in the field of agriculture** developed in Odisha during 2013

- Krishi Sansar Programme, All India Radio, Cuttack at 7.30 pm on 28.11.2016. Radio Talk on "Mati parikshya aadhara ra dhana ra susama sara prayoga"

Published as:

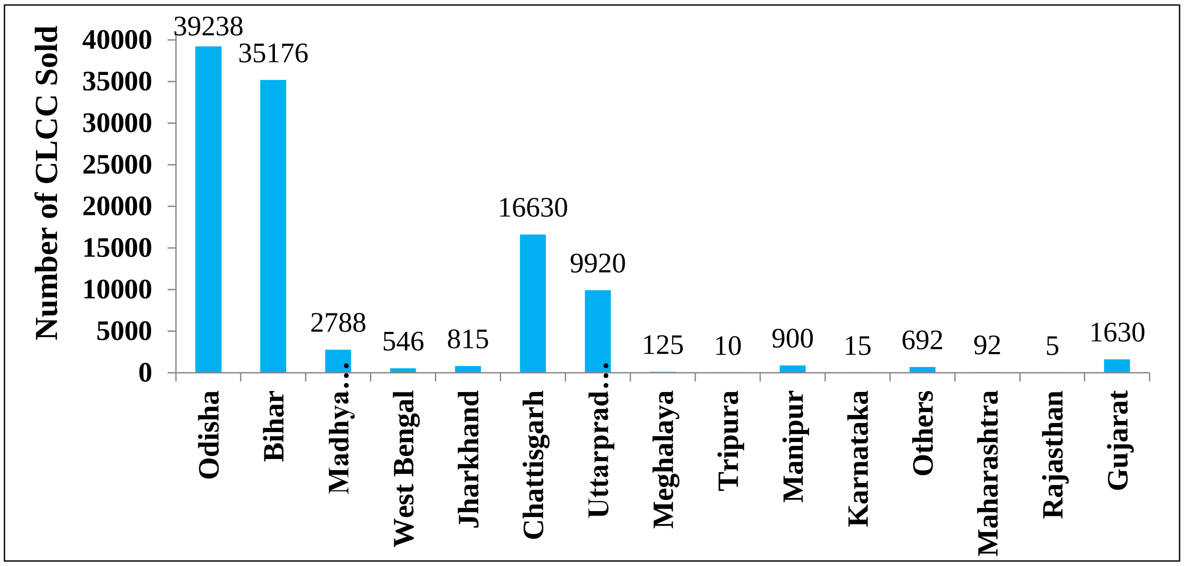
- Mohanty, S., Swain, C.K., Sethi, S.K., Dalai, P.C., Bhattachrayya, P., **Anjani Kumar**., Tripathi, R., Shahid, M., Panda, B.B., Kumar, U., Lal, B., Gautam, P., Munda, S., Nayak, A.K., 2017. Crop establishment and nitrogen management affect greenhouse gas emission and biological activity in tropical rice production. Ecological Engineering. 104, 80-98. (NAAS rating 9.02)

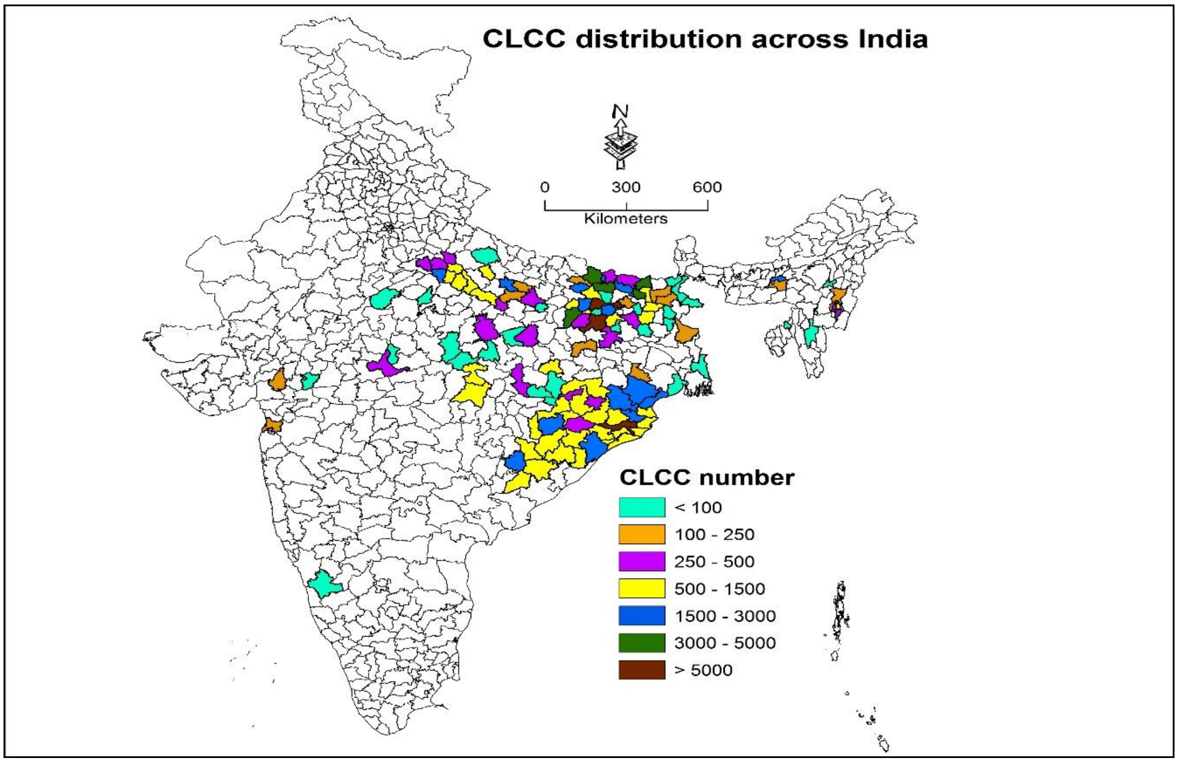
- Nayak, A.K., Mohanty, S., Raja, R., Mohammad Shahid, Lal, B., Tripathi, R., Bhattacharyya, P., Panda, B.B., Gautam, P., Thilagam, V. K., **Anjani Kumar**., Meher, J. and Rao, K.S. (2013). Customized leaf color chart for nitrogen management in rice for different ecologies. Central Rice Research Institute, Cuttack (India)].

Success Story

- Nayak, A. K., Mohanty, S., Raja, R., Shahid, M., Lal, B., Tripathi, R., Bhattacharyya, P., Panda, B. B., Gautam, P., Kasthuri-Thilagam, V., **Anjani Kumar**., Meher, J. and Rao, K. S. (2017). Customized leaf colour chart (CLCC): A paradigm shift in real time nitrogen (N) management in lowland rice. A ICAR-NRRI, Success story, ICAR-National Rice Research Institute, Cuttack, Odisha.
- This CLCC is reflected in the Salient Acheivements-2013 of the ICAR and is included as one of the important technology in the field of agriculture developed in Odisha during 2013 http://www.icar.org.in/files/Greetings.pdf (dated 23-12 2013).

Purchase of CLCC by different stakeholders across different states of India





CLCC distributed in different states across India

Revenue generated

Under the project entitled "Enhancing nutrient use efficiency and productivity in rice based system" A total income of Rs. 3.1 lakhs was generated through royalty for **CLCC.** The developed CLCC have been commercialized by providing nonexclusive rights to Nitrogen Parameters, Chennai for manufacturing and distribution of the product at a royalty of 7.5% on the sale price. So far 48000 numbers of CLCC have already been sold @ Rs 110/- per unit (previously Rs. 90/- per unit) generating Rs. 44.5 lakhs.

The CLCC is commercialized and an MoU was signed with M/S Nitrogen Parameters, Chennai for manufacturing and distributing the CLCC. Trainings were imparted to 130 state government officials of Odisha and SMS of different KVKs of Zonal Project Directorate VII, Jabalpur (MP) regarding the use of CLCC. The company has received about 84000 orders from the IRRI, state government of Odisha and several ICAR Institutions of Odisha, WB and AP. (copy of some orders are attached.

This CLCC is reflected in the **Salient Acheivements-2013 of the ICAR** and is included as one of the important technology in the field of agriculture developed in Odisha during 2013 *[published in Odia newspaper Dharitri on 25th December 2013].*

2. 'RiceXpert' mobile app *(Co - Developer)*

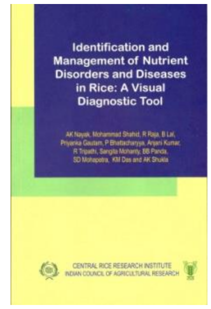
Mobile app 'RiceXpert' (Version: 1.6), developed by ICAR-NRRI, Cuttack in Android platform (Android 4.0.1 and above) is a real time tool for solution of insect pests, nutrients, weeds, nematodes and disease-related problems. This app also deals with rice varieties, farm implements and post-harvest related problems of rice farmers. Other components such as information about news, fertilizer calculator, weather, e-rice marketing, announcement and e-advisory services, frequently asked questions on the related subject, team involved, etc. are also included. RiceXpert is developed in four different languages such as English, Hindi, Odiya and Asamese.

The mobile app was launched by Hon'ble Agril. & Farmers Welfare Minister on 9th May 2016 which was covered in more than 15 important print and electronic media viz. Times of India, Business Standard, Millenium Post, Rural Marketing, ICAR website, face book, NRRI website, Zee TV, OTV, Kalinga TV, and Kanak TV

Published

- Part of Ministry of Agriculture and Farmers Welfare document **"Agricultural Advancement, Our Priority - Two years of Modi Govt." during 2016.**
- Nayak AK, Mohapatra SD, Lal B, Tripathi R, Shahid M, Gautam P, Patnaik SSC, Patil NB, Raghu S, Yadav MK, Guru PK, Mohanty S, Kumar A, Pandi GGP, Gowda BG, Panda BB, Dash SK, Sah RP, Raja R, Saha S, Lenka S, Jena M, Chatterjee D, Mondal B and Sinha SK. 2017. **"riceXpert" one-step revolution in agriculture**. A NRRI Success story, ICAR-National Rice Research Institute, Cuttack, Odisha.
- Mohapatra SD, Tripathi R, Acharya P, Shahid M, Raghu S, Guru PK, Mohanty S, Kumar A, Gowda BG, Panda BB, Dash SK, Lenka S, Nayak AK and Pathak H (2018). NRRI 'riceXpert' APP: Taking rice technologies in the doorstep of farmers. In: Souvenir, 3rd ARRW International Symposium on Frontiers of Rice Research for Improving Productivity, Profitability and Climate Resilience, February 6-9, 2018, ICAR-NRRI, Cuttack. pp. 75-79

3. Nutrient deficiency diagnostic kit *(Co- Developer)*



A diagnostic kit comprising visual symptoms of nutrient deficiencies and toxicities as well as major rice diseases was developed in the form of a book. The diagnostic kit details the description of the symptoms on different plant parts at different growth stages along with various management options and are being used by farmers. The kit is of high demand and request received from and distributed to stake holders including VAW, SMS of KVKs and farmers. About 500 copies of the same have already been distributed

Published as:

Nayak A K., Shahid M., Raja R., Lal B., Gautam P., Bhattacharyya P., **Anjani Kumar**, Tripathi R., Mohanty S, Panda BB, Mohapatra SD, Das KM, Shukla AK. (2013). Identification and Management of Nutrient Disorders and Diseases in Rice: A Visual Diagnostic Tool. Central Rice Research Institute, Cuttack, India, pp. 1-54

4. A new Rice Variety CR DHAN 309 which was released in Assam, Chhattisgarh and UP (Co-Developer)

We developed a new Rice Variety CR DHAN 309 which was identified by varietal identification committee for release in Assam, Chhattisgarh and UP in the year 2018. The elite line IET 25345 (CR Dhan 309) was developed from the breeding materials of cross IR 77080-B-34-3/IRRI 132. This promising variety exhibited stability for yield and other characters in region V of the country. The mean yield was higher than the national, regional and local checks, respectively. It possesses intermediate amylose content, long slender grain and other desirable grain quality parameters.

*Developers: Drs. S.K. Pradhan, J.N. Reddy, O.N. Singh, E. Pandit, L. Das, S. P. Mohanty, S.Mohapatra, L.K. Bose, N. Barik, R. Chandra, J. Meher, **Anjani Kumar**, A. Mukherjee and S.S.C. Patnaik.*

Released by CVRC and published in the Gazzette

5. A new Rice Variety CR DHAN 102 which was released in Odisha (Co-Developer)

We developed a new Rice Variety CR DHAN 102 which was identified by varietal identification committee for release in Odisha in the year 2019. The elite line IET 25121 (CR Dhan 102) was developed from the breeding materials of cross IR 64/PSB RC 52. This promising variety established yield superiority over Sahbhagidhan, Narendra 97 and other local checks in three years of AICRP trials and observed to be promising for Odisha state.

*Developers: Drs. S.K. Pradhan, L.K. Bose, P Swain, J.Meher, P. Sanghamitra, **Anjani Kumar**, S. P. Mohanty, L. Das, G.P.G. Pandi, N. Barik.*

Released by SVRC Odisha

6. **Formulated Agglomerated urea briquettes for higher N use efficiency (Co-Developer)**

   a. ***Oil as binding and nitrification inhibiting agents***

Urea briquettes were prepared at NRRI by mechanical compaction method using a urea briquetting machine. To improve the strength of briquettes and reduce the breakability, urea was mixed thoroughly with oils of neem (*Azadirachta indica*) and karanj (*Pongamia pinnata*) at a rate of 40 ml oil per 1 kg urea before compaction. Apart from being good binding agent the oils used, contain active ingredients that reportedly inhibit nitrification activity in soil. Mixing oil reduced the breaking percentage to 2-5 % as compared to 25 - 30 % in urea pellets without a binding agent *[**Published in** ICAR-NRRI Research Bulletin No. 12 (2017)]*.

Urea briquettes/urea pellets prepared from granular urea in briquette/pellet making machine (breaking 25-30%)

Urea briquettes/urea pellets prepared after mixing granular urea with oil (breaking 2-5%)

Agglomerated urea briquettes with different filler material

Suitable amendments viz. phospho-gypsum, fly ash, silica powder, neem cake and rice husk as filling materials and biodegradable binding agents to prepare agglomerated urea briquettes from prilled urea by mechanical compaction method using a urea briquette machine *[**Published in** ICAR-NRRI Research Bulletin No. 12 (2017)]*.

Basal and top dressing urea briquette applicator based technology for enhancing productivity and reducing GHGs emission

- Suitable method of application of urea briquette in flooded rice (*Oryza sativa* L.) not only increases nitrogen use efficiency, but at the same time sustain yield and reduce greenhouse gas emission in general and nitrous oxide emission in particular. A farm technology involving application of urea briquette by three row briquette applicator (TRBA) and top dressing applicator (TDA) was developed and compared with manual application of urea super-granule. This technique resulted in highest grain yield with the higher agronomic N use efficiency, reduced nitrous oxide emission and ammonia volatilization. Apart from that, issue of adequate skilled labour for precise depth of application of urea briquette could be tackled by effectively adopting mechanical placement of urea briquette. The mechanical placement of briquette (relatively larger size particle) in tropical flooded rice is more precise and less labour intensive, hence this is an efficient environment friendly approach of N management *[**Published in** CRRI research bulletin No. 12 (2017); Agriculture, Ecosystems and Environment (2018,) 252 178–190]*.

Technology up-scaling (Demonstration at farmer's field)

- Farmer's field demonstration of developed technology was conducted at farmer's field. Demonstration of UBA-I & II was conducted on date 25 February 2016 and UBA-V on 22 March 2016 at village Singiri PO Chasapa Block Balikunda District Jagatsinghpur, Odisha in four plots having area of 450 m^2. Rice variety Naveen was selected for demonstration. Rice husk was used as filler material in order to get optimum N application rate. Four treatments, viz. T1 [UBA-I (basal) + UBA V (top dressing)], T2 [UBA II (Basal) + UBA V (Top dressing)], T3 [Manual placement of urea briquettes (basal+ top dressing)] and T4 [farmers practice (Manual broadcasting of prilled urea)] were selected. Fertilizer nitrogen was applied @ 80 kg N ha^{-1} in three splits (50%-25%-25%): as 50% basal, 25% at maximum tillering and 25% at panicle initiation.
- During operation, the field capacity of UBA-I, UBA-II & UBA-V was found 0.068 ha h^{-1}, 0.082 ha $h^{-1}$and 0.023 ha h^{-1}. Increase in grain yield of 19.6 % was observed with T1 over T4. Based on demonstration results three row urea briquette applicator for basal application and Injector type applicator for top dressing were recommended for deep placement of urea briquettes.

Adoption

There is growing awareness for using CRCT in different rice ecologies. Positive responses of farmers in Salipur villages (10 locations) in Odisha; Future strategies to be designed and adopted by the state Govt, NGOs and private-public partnership for door step procurement of farm machineries and chemicals.

7. Developed Urea briquette applicator for placing urea briquette in the reduced zone of rice to enhance N use efficiency. (Co-Devloper)

Till date, an applicator that is easy to use, affordable and efficient for deep placement of urea briquettes in rice fields of varying soil condition is not available. Five hand-operated applicators for basal and top dressing of urea briquette were developed and evaluated for placement of circular shape urea briquettes in line transplanted rice. Out of these five applicators, three applicators were continuous type (Manually pulled two row briquette applicator, Manually pulled three row urea briquette applicator, Manually pulled four row drum type urea briquette applicator) and two applicators were non-continuous type (Urea briquette applicator mounted on cono weeder for top dressing and Injector type briquette applicator for both basal and top dressing) applicators. The details of these applicators are given below *[**Published in** ICAR-NRRI Research Bulletin No. 12 (2017); Agriculture, Ecosystems and Environment (2018,) 252 178–190]*.

a. Manually pulled two row briquette applicator (UBAI)

Two row briquette applicator (UBA-I) consists of two hoppers, frame, two cup type metering rollers, one axle, one ground wheel and one handle fitted in the frame. It was made by using material angle iron, GI sheet, etc. The applicator can be used for top dressing and for basal application. The removable furrow openers were fitted for both rows. The furrow opens by furrow openers closes immediately by float after placement of urea briquette. During application, the skids work in the middle of alternate plant rows, leaving the middle row without application for the operator to walk in that row. This process distributes briquettes evenly between plant rows and two rows share the banded fertilizer.

b. Manually pulled three row urea briquette applicator (UBA II)

Manually pulled three row urea briquette applicator (UBA-II) consists of three hoppers, frame, three cup type metering roller, one axle, one ground wheel and one handle fitted in the frame. It is made by using material angle iron, GI sheet, etc. The applicator can be used for basal application only. The removable furrow openers were fitted for all rows. Two ground wheel support applicator from both ends and four cup in metering unit gives the uniform placement of urea briquettes.

c. Manually pulled four row drum type urea briquette applicator (UBA III)

Manually pulled four row drum type urea briquette applicator (UBA-III) consists of two drums, frame, one axle, two ground wheels and one handle fitted in the frame. It is made of using material angle iron, GI sheet, MS flat etc. The applicator is useful for basal application. The working of applicator is similar to drum seeder. Operator has to pull the applicator so the urea briquettes filled in the drums dropped on field in a uniform manner. Two ground wheels support the applicator from both ends and float gives easy movement in puddled field condition.

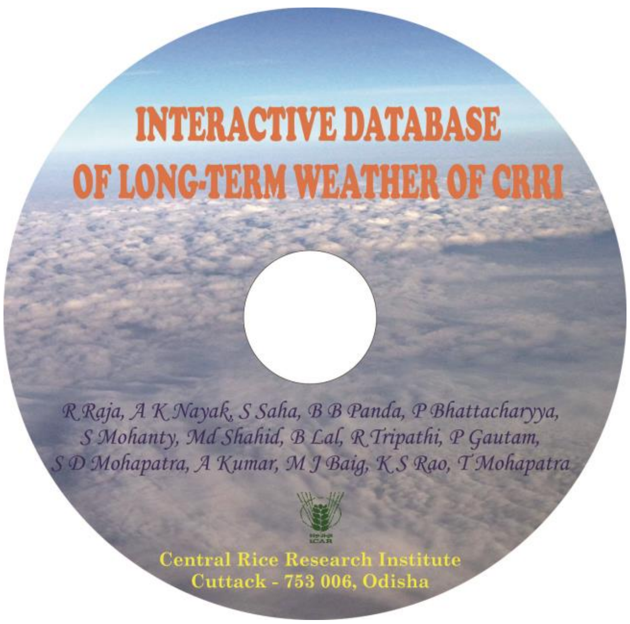
d. Urea briquette applicator mounted on conoweeder for top dressing (UBAIV)

An attachment behind the cono weeder (UBA-IV) can apply urea briquettes simultaneously with weeding operation. It consists of two cones, one float, one briquette hopper, briquette delivery control system, and one handle fitted in the frame. It is made of using material angle iron, GI sheet, MS flat etc. The machine is useful for weeding between rows of wet land paddy crop and urea briquette application. The working of applicator is similar to cono weeder, operator has to push the weeder and at same time at some interval push the clutch fitted on the handle to place one or two urea briquettes at a time. The efficiency of the urea briquette placement depends on the operator's ability to give forward and backward movement for weeding and at the same time push the clutch for dropping of urea briquettes.

e. Injector type briquette applicator for both basal and top dressing (UBAV)

It is a simple device carry in hands to place the urea briquette deep in the soil. Operator has to put urea briquette in the funnel and push the handle to place the briquette 5-6 cm deep in the soil. After every push, operator has to move forward. Handle, funnel, delivery tube and plunger assembly are made of using PVC pipes and depth control ring is made of MS flat. It is light in weight and easy to carry.

8. An interactive Database of Long Term Weather of CRRI farm is developed on DVD ROM (Co-developer)



*[Publication: Raja R, **Nayak AK**, Saha S, Panda BB, Bhattacharyya P, Mohanty S, Shahid Mohammad, Lal B, Tripathi R, Gautam P, Mohapatra SD, Kumar A, Baig MJ, Rao KS and Mohapatra T. (2013). An interactive Database of Long Term Weather of CRRI. DVD ROM].*

9. Developed Carbon and water footprint map of rice in India

Carbon footprint (CF) and water footprint (WF) are useful sustainability indicators for measuring the planet's carrying capacity

The Carbon footprint (CF) that measures emission of greenhouse gases in terms of carbon dioxide equivalents as a by-product of a product or service and water footprint which quantifies the total volume of fresh water used for an individual or a service (Hoekstra, 2011) are important sustainability indicators used to measure anthropogenic pressures on ecosystem and its carrying capacity

The blue water is the amount of irrigation water applied from the sources like, stored surface water or groundwater excluding the effective rainfall and contribution from profile stored soil moisture for growing a crop.

The green water refers the profile stored soil moisture or rainwater until it becomes runoff used by the crop for meeting the evapo-transpiration need during the crop growth period.

The grey water refers to the volume of freshwater required to assimilate the pollutant loadon the basis of existing ambient water quality standards

The CFs of rice in India was calculated as 2.31 t CO_2e ha^{-1}

Among the five regions CF was found highest in northern India (NI) for rice (4.12 t CO_2e ha^{-1}) lowest in North East India for rice (0.46 t CO_2e ha^{-1})

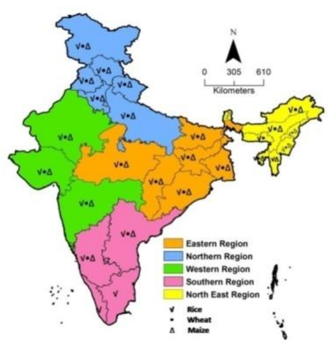
Among the different states in NI, Punjab had the highest TCF for rice (4.91 t CO_2e ha^{-1})

The Total water footprint (TWF) for the production of rice in India were 7.50 $\times 10^3$ m^3 ha^{-1}

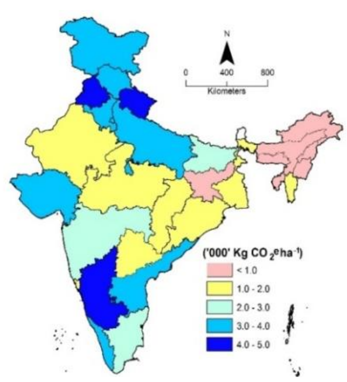
Among all the Indian states, the highest blue WF for rice was in Rajasthan followed by Punjab.

The environmental footprint of rice production is higher in the state of Punjab, Rajasthan, Haryana and Lowest in eastern states.

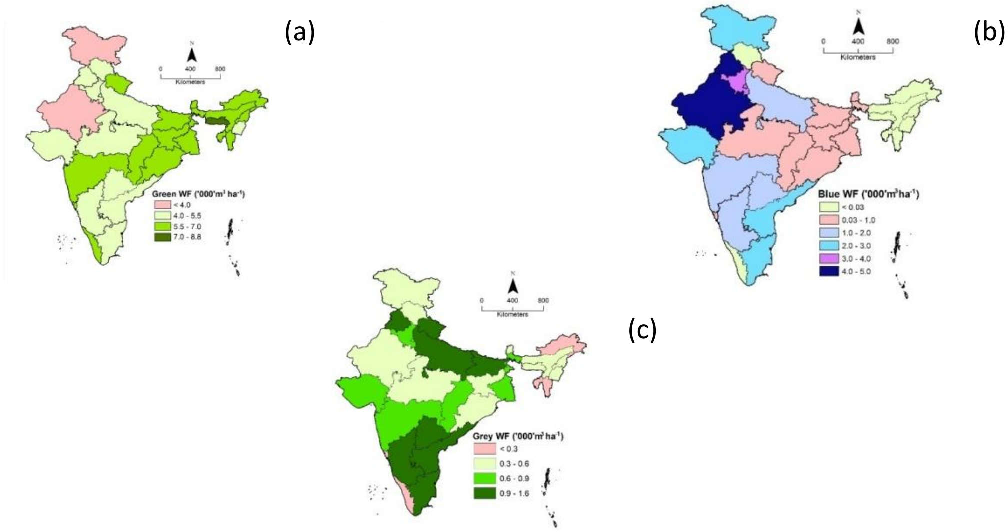
Rice production should be incentivised in eastern states and dis-incentivised in Northern states especially in Punjab and Haryana



Five regions of India used in the study for estimation of environmental footprint (Carbon and water)



Carbon footprint of rice in India.

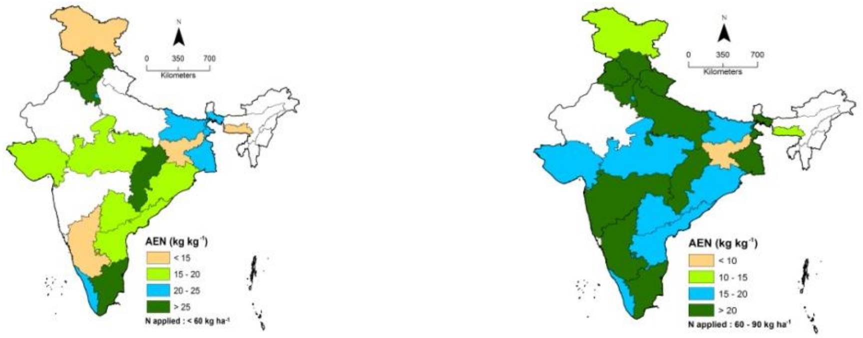


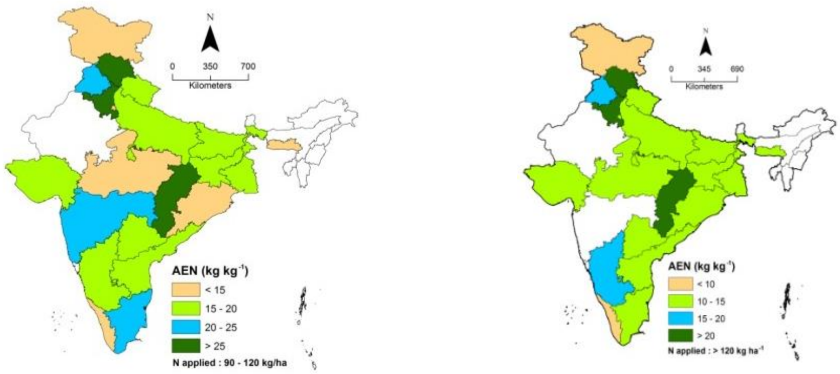
Water footprint of rice in India (a) Green water footprint (Green WF), (b) blue water footprint (Blue WF), (c) Grey water footprint (Grey WF).

[Publication: NRRI annual report, 2019].

10. Nit***rogen use efficiency map of rice across different rice growing states of India***

Yield –N response studies in different parts of the country show great degree of variations in N use efficiency indicators of rice reflecting effects of complexities of agroecosystem. Therefore it is essential to upscale site specific information of N use efficiency to regional and national scale to understand larger impact of N fertilizer use. The database of rice grain and straw yield and grain and straw N uptake under varying N application rate was compiled using the data obtained from scientific journals published and degrees theses submitted to different state agricultural universities between 1972 and 2018 to calculate state wise agronomic N use efficiency.





The agronomic N use efficiency (AEN) of rice at different Nitrogen rates in different states of India

Across the states average agronomic N use efficiency (AE_N) of rice production ranges from the lowest value of 11.1 kg kg^{-1} in Meghalaya to the highest value of 31.0 kg kg^{-1} in Himachal Pradesh. The mean AE_N for rice in India is 18 kg kg^{-1}. Average AE_N in Himachal Pradesh, Tamilnadu, Punjab and Haryana are higher than the national average. Meghalaya, Andhra Prdaesh, Chattishgarh, Madhyapradesh, Jharlhand, Bihar and Odisha are the states where AE_N is lower than the national average. In almost all states AE_N decreases with increasing N rate. At lower N rate of <60 kg ha^{-1} Punjab shows the highest AE_N among all the states, however with increasing N rate it reduced significantly.

[Publication: NRRI annual report, 2019].

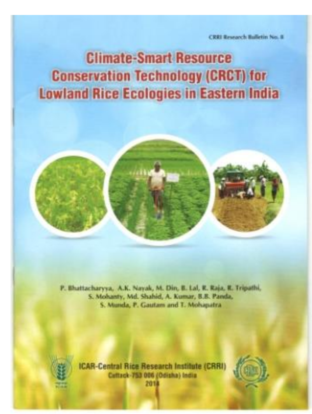
B. Technologies

1. A Resource Conservation technology developed for rice-rice based system

Climate-smart RCT in low land rice ecology

Details of technology

Currently, direct seeded rice in Asia occupies about 29 m ha which is approximately 21% of the total rice area in the region. Low land direct seeded rice ecology faces challenges of low pructivity and profitability along with environmental problems of GHGs emission. Direct seeding is likely to expand in parts of Eastern States of India where low population densities, especially in areas where the labour cost is escalating. Direct seeded rice with mechanization is an efficient resource conserving technology holding good promise in coming days. Climate smart resource conservation technology (RCT) was developed that lowers the GHGs, reduces energy requirement, improves carbon gain while maintain the productivity.



Protocol

Preparatory tillage by mould board plough once in three year followed by pulverization by rotavator/ cultivator; (b) Dry direct seeding of rice and *dhaincha* in paired row system by seed drill; (c) Incorporation of *dhaincha* at 25-30 days after sowing by cono-weeder if standing water is available; (d) Alternatively, knock down of *dhaincha* by 2,4-D at 25-30 days after sowing if standing water is not available; (e) 75% RDF of N and full doses of P and K as basal; (f) Real time Nitrogen application of top dressed N in two splits by using Five panel Customized Leaf Colour Chart (CLCC) of CRRI; (f) Harvesting through reaper or combined harvester.

Benefit

- The grain yield of rice was increased by 9.7% and 4.8% in dry-DSR with brown manuring and green manuring of dhaincha, respectively, over transplanted rice (control).
- An average reduction in global warming potential (GWP)and GWP/Yield ratio by 2.5% and 7%, respectively in CRCT as compared to control
- Internal energy saving of 32 % in climate smart RCT over control

Published as:

- Bhattacharyya P, Nayak AK, Din M, Lal B, Raja R, Tripathi R, Mohanty S, Sahid M, **Anjani Kumar,** Panda BB, Munda S, Gautam P and Mohapatra T. Climate-smart resources conservation technology (CRCT) for lowland rice ecologies in eastern India. In CRRI Research Bulletin no. 8.

2. Integrated nutrient management practice for reduced fertilizer N use and N loss in low land rice

Integrated nutrient management practice including 50 % RDN from urea + 25 % RDN from blue green algae + 25 % N from FYM could reduce N2O emission by 22.71% as compared to 100% RDN in low land rice at similar level of yield.

(Ref: Mohanty, S., Nayak, A.K., Swain, C.K., Dhal, B.R., **Anjani Kumar**, Kumar, U., Tripathi, R., Shahid, M. and Behera, K.K., 2020. Impact of integrated nutrient management options on GHG emission, N loss and N use efficiency of low land rice. Soil and Tillage Research, 200: 104616.)

3. Recommendation of use of fly ash as soil ameliorant and source of plant nutrient (Co-Developer)

The efficacy of fly ash in improving and maintaining the productivity of rice based cropping system was evaluated by conducting field experiments at Central Rice Research Institute, Cuttack under transplanted, wet direct seeded and rainfed dry direct seeded conditions. The results revealed that application of fly ash @ 50 t ha^{-1} along with 75% RDF and 25% through FYM on N basis has recorded on par yield with that of Lime + 100% RDF under transplanted (Table 17) as well as direct seeded conditions. Application of fly ash alone @ 50 t ha^{-1} and 100 t ha^{-1} has resulted in decreased yield than farmers' practice and significantly lower yield than the 100% recommended dose of fertilizers (RDF) under transplanted as well as direct seeded conditions. The fly ash application @ 100 t ha^{-1} improved the soil pH and was comparable with lime application. The physico-chemical properties of soil were improved due to bulk application of fly ash either alone or in combination with FYM and inorganic fertilizers. Benefit Cost ratio was highest under the treatment applied with application @ 50 t ha^{-1} + 75% NPK through chemical fertilizers + 25% of RDF through Farm Yard Manure on N basis in all the three situations *viz.*, transplanted rice, wet direct seeded rice and dry direct seeded rice under rainfed upland condition. This was further tested in the farmer's field covering the major soil groups of the Odisha state. *[Published as **Nayak, A.K.,** Raja, R., Rao, K.S., Panda, B.B. and Shukla, A.K. 2011. Fly Ash Utilization in Rice Production: A Success Story. Central Rice Research Institute, Cuttack (India). p6. **(In English); Nayak, A.K.,** Raja, R., Rao, K.S., Panda, B.B., Mohammad Shahid and Anjani Kumar. 2011. Fly ash kachawalutpadan main prayog. Central Rice Research Institute, Cuttack (India). p6. **(In Hindi); Nayak, A.K.,** Raja, R., Rao, K.S., Panda, B.B., and Shukla, A.K. 2011. Dhan chaser fly ash rasadupayog. Central Rice Research Institute, Cuttack (India). p6. **(In Oriya)].***

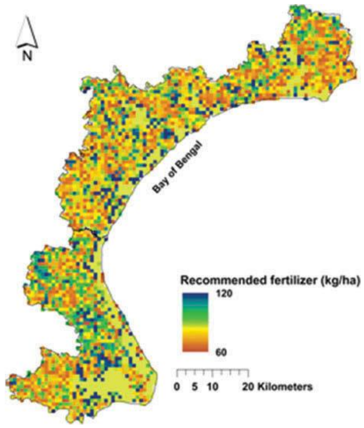
4. Site specific map for N management in costal blocks of Odisha (Co-Developer)

Details about Concept: Current estimates of nutrient uptake efficiency of crop rely heavily upon experimental data of small plot extrapolated to match implementation acreages. In practice, however, landscape-scale variability in physical, environmental, and farm management parameters makes estimation of the actual magnitude of crop N uptake complex. Developments in sensor and satellite technology, computers and positioning systems has brought new opportunities for N fertilizer management. This technology recognizes the inherent spatial variability associated with soil characteristics and crop growth, and uses this information to prescribe the most appropriate management strategy on a site-specific basis. There is potential to accurately predict the N fertilizer need of rice using this technology. Since most leaf nitrogen is contained in chlorophyll molecules, there is a strong relationship between leaf nitrogen and leaf chlorophyll content. This strong positive relationship is also the basis for predicting crop nitrogen status by measuring leaf reflectance and normalized difference vegetation index (NDVI). The NDVI, which correlates closely to plant leaf area index (LAI), has been used successfully to measure the biomass, N status, and chlorophyll content. The risk of encountering a nitrogen deficiency and not being able to correct it prompts many farmers to apply excess fertilizer. This ultimately results in over-application of nitrogen on some fields, which impacts the grain quality as well as the environment.

Proof of concept

Keeping all this in view, this a methodology was developed which explores the spatial variability of available nitrogen in soil and estimates the values at unsampled locations using geostatistical tools and estimate the fertilizer N requirement at spatial scale.

This technology can be used for recommendation of nitrogenous fertilizer in rice using real time remote sensing imagery. Leaf area index—global 1 km (MOD15A2) product composited every 16 days at 1-kilometer resolution will be used along with MODIS vegetation indices (MOD 13) vegetation–index products. These imageries can be obtained from HDF-EOS data format (Knyazikhin et al. 1999). For developing the algorithm for a particular location, ground truth has to be conducted during the peak vegetative growth stage of rice crop for data collection related to rice growth stages and sample collection for biomass and leaf nitrogen determination. Satellite-derived vegetation index (NDVI) with on-farm biomass and N content measurements would be correlated to calibrate the image interpretation. Total N uptake by rice crop per unit area may be calculated by multiplying the aboveground biomass per unit area and N content of rice leaves. Then dose of N fertiliser was calculated by following formulae; Recommended dose of fertilizer N = (total uptake of N by crop- uptake of N in control plots)/(recovery efficiency of fertilizer N).



Nitrogen fertilizer recommendation developed for the study area using MODIS NDVI and LAI product.

The information derived using MODIS images can be used to decide whether supplemental N fertilizer is needed within the growing season to improve the rice production. Crop N needs are often spatially variable. Remote sensing provides spatially dense information that may help us understand and predict spatially variable crop N needs *[**Published as** Tripathi, R., Nayak, A.K., Raja, R., Shahid, M., Mohanty, S., Lal, B., Gautam, P., Panda, B.B., **Anjani Kumar**, and Sahoo, R.N., 2017. Site-specific nitrogen management in rice using remote sensing and geostatistics. Communications in Soil Science and Plant Analysis, 48(10), pp.1154-1166.].*

5. Agro-technology for managing iron toxicity

The soils od eastern states are rich in Fe and suffers from drainage congestion creating reduced condition resulting Fe toxicity problem for rice. Fe toxicity has been reported to reduce rice yields by 12–100% depending on the intensity of the stress and tolerance of the rice cultivars We developed agro-technology for the management of iron toxicity in lowland iron toxic acid lateritic soil for rice cultivation. The application of lime (75 % LR) and limiting plant nutrients, such as K, Mn and Zn along with tolerant cultivars (Lalat and Naveen) were proved to be important components of iron toxicity management in iron toxic acid lateritic soils.

Protocol

- Application of Lime @ 3 t ha-1 befoe 15 days transplanting and thereafter, the soil is puddled and mixed thoroughly using cage-wheels up to 15cm depth. Other treatments

- Application of 50 % recommended dose of N @ 80 kg N and full dose of P @ 40 kg P_2O_5, and K @ 40 kg K_2O ha^{-1} as basl application and rest of N in two equal split at maximum tillering and panicle intiation stage is applied.

- Application of excess Zn @ 50 kg $ZnSO_4$ ha^{-1} in Zn deficient soiland Mn @ application of 50 kg$MnSO_4$ ha^{-1}

- Mid- season drainage where ever possible

Benifit

- Increased yield 25–64 % over control
- Bringing Iron toxic acid lateritic soil under cultivation

Published in:

Shahid, M., Nayak, A.K., Shukla, A.K., Tripathi, R., **Anjani Kumar**, A., Raja, R., Panda, B.B., Meher, J., Dash, D., **2014.** Mitigation of Iron Toxicity and Iron, Zinc and Manganese Nutrition of Wetland Rice Cultivars (Oryza sativa L.) Grown in Iron-Toxic Soil. ***Clean-Soil, Air, Water****, 2014, 42-1604-1609*. (NAAS 7.34)

6. V**alue added fly ash with rice husk biochar mixtures for enhancing fertilty yield of lowland rice**

The addition of rice husk biochar (BC) with coal fly ash (FA) at a certain proportion enhances the value of fly ash in terms of enriching organic carbon and soil microbe stimulation that helps in enhancingn growth and yield of rice and soil properties of lowland rice soil. Yield increase was 16.4% when BC+FA were applied together with 50% of the recommended dose of nitrogen (N) compared with the recommended dose of N, phosphorus and potassium (NPK). Post-harvest soil analysis suggested that BC and FA both act as a supplier, as well as a reservoir of nutrients. Accumulation of heavy metals in soil and plant parts after harvest was below the toxicity threshold for plants and humans. There was also no significant change in microbial population compared with the initial soil. Therefore, combined application of BC and FA supplemented with chemical fertilisers could be recommended to improve soil fertility and crop productivity without affecting the soil quality.

[Ref: Munda, S., Nayak, A.K., Mishra, P.N., Bhattacharyya, P., Mohanty, S., **Anjani Kumar**., Kumar, U., Baig, M.J., Tripathi, R., Shahid, M. and Adak, T., 2016. Combined application of rice husk biochar and fly ash improved the yield of lowland rice. Soil Research, 54(4), pp.451-459.]

7. **Integrated Farming system model developed**

a.Crop- livestock –agroforestry based Integrated farming system for lowland rice ecologies

In order to improve and stabilize farm productivity and income from rainfed water logged lowland areas, at National Rice Research Institute, Cuttack we developed an adoptable technology of rice-fish diversified farming system.

Details of technology

Crop-livestock- horticultural and agroforestry based integrated farming system (CLAIFS) model for 1 ha land integrates different components*i.e.* rice, fish, livestock's (duckery, poultry, goatery), horticultural plants (perennial: coconuts, mango, guava; annual: papaya, banana etc.), agro forestry(*Acacia mangium, A. auriculiformis*, Eucalyptus) and seasonal vegetables (okra, gourd, radish, brinjal, tomato, french bean, radish, pumpkin, and leafy vegetables. In addition to above, apiary, floriculture, creeper vegetables, tuber crops (in shaded area i.e. Amorphophallus, Yam, Colocasia, Turmaric, Ginger), and fodder crops (Napier, Gunia grass, Legume fodder cowpea/ lobia) are also cultivated in the bund area.

System Design

The system design involvesshaping of lands (earth work) with wide bund (dykes 3 m wide in south, east, west side and 6 m in north side) (20% area, 2000 m^2), water refuge trench on three sides (15% of area, 1500 m^2) and rice fields (65% area, 6500 m^2). The total bund area (2000 m^2) includes agro forestry: 660 m^2 (6.6 %), vegetables : 470 m^2 (4.7 %), orchard and fruits : 500 m^2 (5 %) and animal and pasture : 370 m^2 (3.7 %) of area. The duck and poultry shed are constructed on the bund adjoining to water refuge and are projected towards water area. The goat house constructed on the bund area using locally available materials.Rice crops are taken up both in kharif and dry season (with irrigation), alternatively other dry season crops can be taken up.Among the livestock's, ducks (50-60 nos. of Khaki campbell (egg layer) or White pekin (meat type) varieties) are most suitable for integration with rice fields. Poultry birds (50-60 nos.) breeds of Rhode island, Leghorn, Black rock and Van raja are suitable and can be cultivated in four cycles (3 months duration) during a year. In goatry unit 10-15 nosof goat (Black Bengal breed) is ideal. In the bund area location specific summer season vegetables such as okra, gourd, radish, brinjal and leafy vegetables and during winter season tomato, french bean, radish, pumpkin and leafy vegetables are grown. The vermicompost and compost pits (8.0 x 5.0 m) will be used for recycling of on-farm waste and provide organic manure to the system. The system is also designed in such a way to utilize wastes (Chaff rice, straw, animal excreta, vegetable wastes) for feeding to animal.

Benefit

- The system requires initial investment of Rs. 2.0 lakhs and annually produced 18 to 20 t of food crops, 0.6 t of fish and prawn. 0.6- 0.9 t of meat and 10,000 nos of eggs.

- The productivity expressed in term of rice equivalent yields (REY=28.5 t ha^{-1}), which is 3.9 times higher as compared to traditional rice-rice farming system (REY =7.3 t ha^{-1}). The cost benefit ratio is 1: 2.95.

- The integrated farming system generates additional farm employment of around 350- 400 man days/year.

Publication

- Nayak PK, Nayak AK, **Anjani Kumar**, Kumar U, Panda BB, Satapathy BS, Poonam A, Mohapatra SD, Tripathi R, Shahid M, Chatterjee D, Panneerselvam P, Mohanty S, Pathak H (2020). Rice-fish integrated farming systems for eastern India. NRRI Research Bulletin No. 24, ICAR-National Rice Research Institute, Cuttack

8. Microbial technology/ product process developed

	I. Concept/ Methodology	
	1. Cyanobiont diversity in six *Azolla* spp. and relation to *Azolla*-nutrient profiling	The taxonomy of *Azolla*-cyanobiont is a long-term debate within the scientific community. To understand furthermore, Illumina-Miseq®-based cyanobiont diversity and biomass were analyzed in six species of *Azolla* (*A.*

		microphylla, *A. mexicana*, *A. filiculoides*, *A. caroliniana*, *A. pinnata* and *A. rubra*). Results revealed that 93-98% of total operational taxonomic units (OTUs) belong to Nostacaceae followed by *Cylindrospermopsis* with about 1-6% OTUs. Biplot analysis revealed that *A. pinnata* and its cyanobiont abundance were positively correlated with neutral and acid detergent fibers. **Reference/Evidence:** ***Published in*** *Planta (2019)* 249 (5): 1435-1447
	Genetic stocks registration (Source: http://www.ncbi.nlm.nih.gov/)	
	❖ Deposited 27 *nifH* gene sequences of cultivable bacteria to NCBI and received accessions (MH021860 to MH021867; MH038052 to MH038062; MH048043 to MH048050). ❖ Diversity analysis of cultured prokaryotic 16S rRNA (67 nos.) was done through molecular analysis and the efficient strains were registered with NCBI with accession number from MH048043 to MH048062, MH061353 to MH061366, MH071270 to MH071277, MH084699 to MH084714.	

Director please,

Sub: Request for applying for patent for the developed Eco-friendly Irrigation Alert System (e-IAS) - reg

Sir,

We have developed an Eco-friendly Irrigation Alert System (e-IAS). The details of the developed system is attached for your kind reference. Kind request is made to permit for applying for patent for the developed Eco-friendly Irrigation Alert System (e-IAS).

Submitted for kind perusal and necessary actions please.

Anjani Kumar
1/7/2021
(Anjani Kumar)
Scientist
Crop Production Division

Forwarded

Head, Crop Production Division

Chairman PTMC for n/a p.

01/07/21

Eco-friendly Irrigation Alert System (e-IAS)

Anjani Kumar and A K Nayak

ICAR – National Rice Research Institute, Cuttack – 753006 (Odisha)

In traditional rice cultivation, farmers generally keep the field continuously flooded from transplanting to physiological maturity of rice crop. However, it is well established that continuous flooding is not necessary for rice to achieve high yields. After seedling establishment phase, even in the absence of standing water in field, rice plant can extract soil water from the below surface soil around root zone. Over the past few decades, water scarcity has emerged as one of the biggest challenges for sustaining rice production. Development of novel irrigation scheduling technologies is an important step to help rice farmer cope with water scarcity.

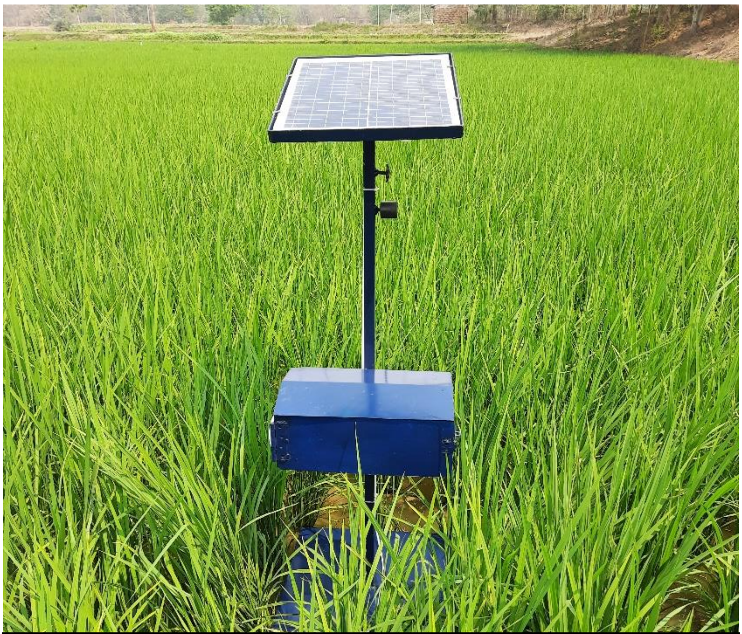


Fig. 1. Eco-friendly Irrigation Alert System (e-IAS) installed in the field

One of the important decisions in irrigation scheduling is to decide the right time of irrigation. One of the methods is the use of perforated pipe in rice fields for deciding the right time of re-irrigation. In this practice a perforated pipe (40 cm length and 15cm diameter) with drilled holes (2 cm apart) is sunk into the rice field until 20 cm protrudes above soil level. The perforations permit the water to enter inside the tube from the soil, where a scale is used to measure water depth below the soil surface. The water level in the pipe is monitored regularly and the field is irrigated as soon as the water level reaches a threshold level (15 cm). Monitoring the water level in the pipe on regular basis in the distant fields is a difficult task for the farmers, very often, the monitoring is not done properly, which results in late irrigation, and ultimately the adverse effect is reflected in the crop performance. For overcoming the manual monitoring, ICAR – NRRI has developed Eco-friendly Irrigation Alert System (e-IAS). In this system, a sensor is attached with the perforated pipe installed in the rice field at desired depth. The sensor is connected to a microcontroller and relay module. The whole system is powered by a 12V battery and the battery is charged by a solar panel installed at the top of the structure. As soon as the water level in the rice field goes down below the desired level, the sensor communicates the signal to the microcontroller, which switches on the red bulb and alarm. The glow of red bulb and alarm sound aware the farmer for the irrigation event. Moreover, on reaching the threshold level, the microcontroller and GSM modem also sends an alert message to the farmers mobile number registered with the system.

Methodology

This is a fully automated system controlled by microcontroller (ATmega 328) and powered by photovoltaic system consisting of solar panel and battery as energy storage.

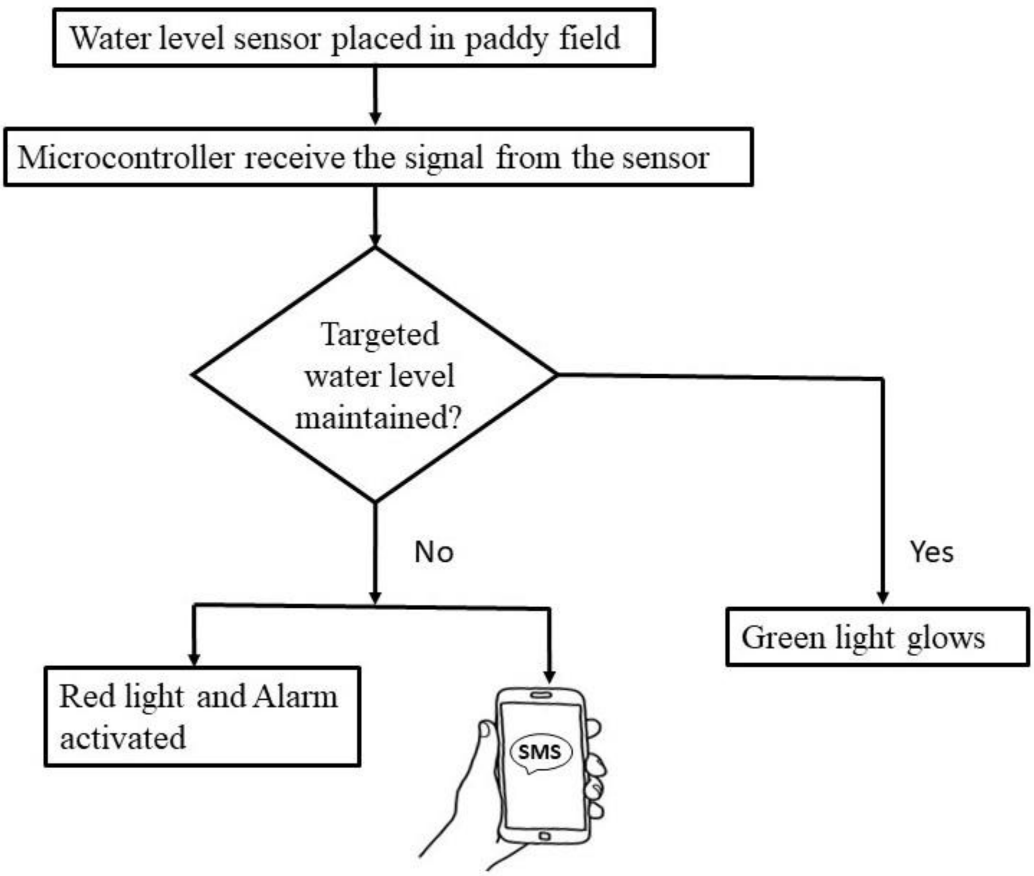


Fig. 2. Flowchart of Operational Procedure of Eco-friendly Irrigation Alert System

The system consists of:

1. **The Sensing Module**
2. **The Control Module**
3. **The Communication Module**

1. The Sensing Module

This unit is responsible for real time sensing the water level in the field. The system consists of a perforated pipe and a water level sensor. The sensor is placed inside the perforated tube (40 cm length and 15cm diameter) with drilled holes (2 cm apart). The perforated tube is sunk in the field and the perforations present in the pipe allows the soil water to enter the pipe. The sensor is placed at a depth of 15 cm in the perforated tube. Once the water level in the tube falls below 15 cm, the sensor sends signal to the microcontroller.

2. The Control Module

The control module generates a control action based on the water level. It consists mainly of an Arduino AT mega 328 microcontroller (Master Arduino), and a relay block module for receiving instructions from the Arduino AT mega 328 microcontroller (master controller). The master Arduino via the water level sensor receives the real time water level data and with the help of relay block it controls the light and sound alert system.

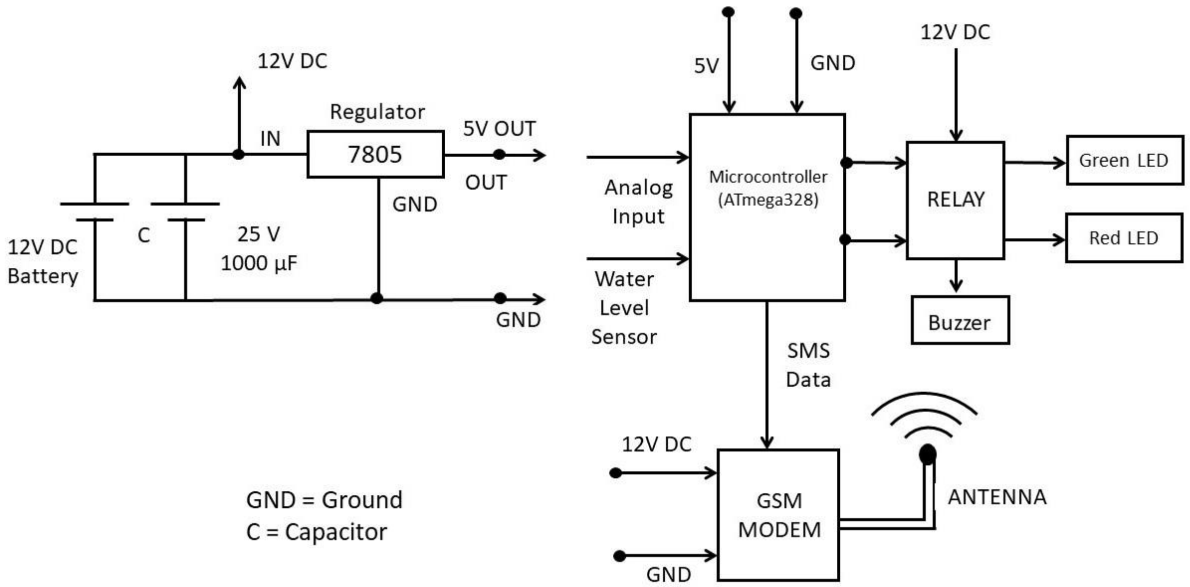


Fig. 3. Schematic Circuit Diagram for Eco-friendly Irrigation Alert System (e-IAS)

Range A – The microcontroller sends a signal to enable the green light, until the water level in the field is upto desired level.

Range B – The microcontroller sends a signal to enable the red light and sound alert system as soon as the water level in the field falls below the desired level.

Range C – The microcontroller sends a signal to enable the GSM modem to send an SMS to registered mobile number of the end user as soon as the water level in the field falls below the desired level.

3. The Communication Module

The GSM communication system is connected to the microcontroller directly and text messages (SMS) are sent to the registered mobile number of the end user.

Power Requirements

The system is powered via a combination of a solar panel and a 12V battery system. The solar panel charges the battery and powers the system during the day and the battery pack supplies the required power at night and gets recharged the following day in sunlight via the solar panel and solar charge controller.

Advantages

This system provides real time monitoring and is automatically controlled. This system avoids over irrigation or/and under irrigation and thus reduces the wastage of irrigation water. This system runs on clean energy (solar power), hence, it eliminates the necessity of electricity. This system alerts the end user through SMS, light and sound alarm and thus it facilitates effective monitoring of real time water level in the field. It has the potential to save around 30% of irrigation water without having any negative impact on grain yield. Thus, it increases the water productivity by 40%. It also increases net return for farmers by reducing pumping costs and fuel consumption. It also curtails the methane emission from rice field by around 37%.

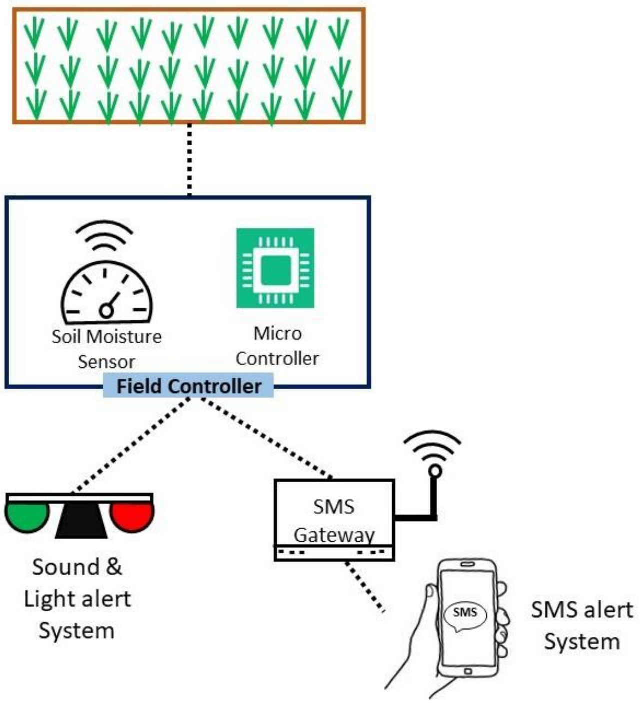


Fig. 4. Operational Procedure of Eco-friendly Irrigation Alert System

भाकृअनुप - राष्ट्रीय चावल अनुसंधान संस्थान
कटक (ओडिशा) ७५३ ००६, भारत
ICAR - NATIONAL RICE RESEARCH INSTITUTE
CUTTACK (ODISHA) 753 006, INDIA

डॉ. दिपंकर माईती
निदेशक (कार्यकारी)
Dr. Dipankar Maiti
Director (Acting)

1946-2021 PLATINUM JUBILEE

ICAR-NRRI/DC/21/147
15th July, 2021

To,
Anjan Sen
Principal & Managing Patent Attorney & Advocate,
Anjan Sen & Associates
Patent & Trade Mark Attorneys,
17,Chakrabberia Road South,
Kolkata-700 025
INDIA:
Mob Nos.: 9830050839;9903050839
E mail:- anjansen@ipindiaasa.com; info@ipindiaasa.com

Dear Mr. Sen,

An "Eco-friendly Irrigation Alert System" is developed by ICAR – National Rice Research Institute, Cuttack, Odisha – 753006, which provides significant improvement in deciding the right time of re-irrigation in rice farming. This can be effective in enhancing the water productivity in rice production. This cutting edge device provides real time information about irrigation scheduling in the form of message on the registered mobile number of the stakeholder. This system is environmentally friendly, energy efficient, and cost-effective. It also reduces methane emission from the rice fields and thus lowers the global warming potential. This devise is automatic, economical, very easy to install and operate. The system invented is unique, since it provides real time alert message on the mobile phone and hence curtails the need of regular physical monitoring of the rice field.

Since, your attorney firm (M/S Anjan Sen and associates), is one of the empaneled firm for filing patent /IPR and authorized by ICAR, New Delhi, therefore, I am submitting the proposal for your kind perusal and filing the patent application to the patent office.

Thanking you,

15/7/21

(D. Maiti)

5. Books and technical bulletins

List of books/bulletins indicating name of author(s), year of publication, title, name of the publisher and page No.				
Item	**Year**	**Details**	**Pages**	Score (for office use)
A) Books Published				
Books Authored	2013	Nayak A.K., Shahid Mohammad, Raja R, Lal B, Gautam Priyanka, Bhattacharyya P, **Anjani Kumar**, Tripathi R, Mohanty S, Panda BB, Mohapatra SD, Das KM and Shukla AK. (2013). *Identification and Management of Nutrient Disorders and Diseases in Rice: A Visual Diagnostic Tool*. Published by Central Rice Research Institute, Cuttack, India	54	
Authored Book	2016	Nayak A.K., Bhattacharyya P., Shahid Mohammad, Tripathi R, Lal B, Gautam Priyanka, , Mohanty S, **Anjani Kumar**, Chatterjee D. (2016). *Modern Techniques in Soil and Plant Analysis*. Published by Kalyani Publishers.	272	
B) Research/Technical Bulletin				
Research Bulletin	2020	Nayak, P.K., Nayak, A.K., **Kumar, A.**, Kumar, U., Panda, B.B., Satapathy, B.S., Poonam, A., Mohapatra, S.D., Tripathi, R., Shahid, M., Chatterjee, D., Paneerselvam, P., Mohanty, S., Das, S.K. and Pathak, H., 2020. Rice based Integrated Farming Systems in Eastern India: A Viable Technology for Productivity and Ecological Security. NRRI Research Bulletin No. 24, ICAR-NRRI, Cuttack-753006, Odisha. pp 44. http://icar-nrri.in/wp-content/uploads/2020/05/NRRI-Research-Bulletin-24.pdf.	**44**	
Research Bulletin	2017	Nayak, A.K.,Mohanty, S., Chatterjee, D., Guru, P.K., Lal, B., Shahid, M., Tripathi, R., Gautam, P., **Kumar, A.**, Bhattacharyya, P., Panda, B.B. and Kumar, U., 2017. Placement of Urea Briquettes in Lowland Rice: An Environment-friendly Technology for Enhancing Yield and Nitrogen Use Efficiency. NRRI Research Bulletin No. 12, ICAR-NRRI, Cuttack-753006,	**26**	

		Odisha. pp 1-26. http://icar-nrri.in/wp-content/uploads/2019/07/8.-Placement-of-Urea-Briquettes-in-Lowland-Rice-An-Environment-friendly-Technology-for-Enhancing-Yield-and-Nitrogen-Use-Efficiency_12.pdf.		
Research Bulletin	2018	Patel, S.P., Guru, P.K., Borkar, N.T., Debnath, M., Lal, B., Gautam, P., **Kumar, A**., Bhaduri, D., Chatterjee, D., Shahid, M., Tripathi, R., Nayak, A.K.and Pathak, H., 2018. Energy Footprints of Rice Production. NRRI Research Bulletin No. 14, ICAR-NRRI, Cuttack-753006, Odisha. pp 1-26. http://icar-nrri.in/wp-content/uploads/2019/07/6.-Energy-Footprints-of-Rice-Production_14.pdf.	**26**	
Research Bulletin	2014	Bhattacharyya, P., Nayak, A.K., Din, M., Lal, B., Raja, R., Tripathi, R., Mohanty, S., Sahid, M., **Kumar, A**., Panda, B.B., Munda, S., Gautam, P. and Mohapatra, T., 2014. Climate-smart resources conservation technology (CRCT) for lowland rice ecologies in eastern India. CRRI Research Bulletin No. 8, ICAR-CRRI, Cuttack-753006, Odisha. pp 1-28.	**28**	
C) Book chapter				
Book chapter	2020	Sangita Mohanty, C K Swain, **Anjani Kumar**, A K Nayak. Nitrogen Footprint: A Useful Indicator of Agricultural Sustainability R. S. Meena (ed.), Nutrient Dynamics for Sustainable Crop Production, Springer Nature Singapore Pte Ltd. 2020, https://doi.org/10.1007/978- 981-13-8660-2_5	Published by Springer Nature Singapore	
Book chapter	2020	Kamaljit Ray, S. D. Attri, H. Pathak, **Anjani Kumar,** and Dibyendu Chaterjee. Climate. B. B. Mishra (ed.), The Soils of India, World Soils Book Series, , Springer Nature Switzerland AG 20201082-0_3, https://doi.org/10.1007/978-3-030-3	Published by Springer Nature Switzerland	
Book chapter	2018	A.K. Nayak, Debarati Bhaduri, Sangita Mohanty, Anjani Kumar, and Suman G. Sahu (2018). Management of Fly Ash for Sustainable Soil Health. In Soil Amendments for Sustainability; Challenges and Perspectives. Edited by Amitava Rakshit, Binoy Sarkar, P C Abhilash. Boca Raton, FL 33487-2742	Published by CRC Press, Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300,	
Book chapter	2018	Mohammad Shahid, AK Nayak, R Tripathi, S	Published by	

		Mohanty, D Chatterjee, A Kumar, D Bhaduri, P Guru, S Munda, U Kumar, R Khanam, B Mondal, P Bhattacharyya, S Saha, BB Panda and PK Nayak (2018) Resource Conservation Technologies under Rice-based System in Eastern India. In Rice Research for Enhancing Productivity, Profitability and Climate Resilience.	ICAR-National Rice Resaerch Institute, Cuttack, Odisha	
Book chapter	2018	AK Nayak, Sangita Mohanty Rubina Khanam, D Chatterjee, D Bhaduri, M Shahid, R Tripathi, A Kumar, S Munda, P. Bhattacharyya, BB Panda, U Kumar and H Pathak (2018) Nutrient Management for enhancing productivity and nutrient use efficiency in rice. In Rice Research for Enhancing Productivity, Profitability and Climate Resilience.	Published by ICAR-National Rice Resaerch Institute, Cuttack, Odisha	
Book chapter	2018	R Tripathi, M Debnath, S Chatterjee, D Chatterjee, A Kumar, D Bhaduri, A Poonam, PK Nayak, Md Shahid, BS Satpathy, BB Panda and AK Nayak. Assessing energy and water footprints for increasing water productivity in rice based systems. In Rice Research for Enhancing Productivity, Profitability and Climate Resilience.	Published by ICAR-National Rice Research Institute, Cuttack, Odisha	
Book chapter	2018	Upendra Kumar, P Panneerselvam, TK Dangar, A Kumar, D Chatterjee, C Parmeswaran, SD Mohapatra, G Prasanthi, K Chakraborty, P Swain and AK Nayak. Microbial Resources for Alleviating Abiotic and Biotic Stresses and Improving Soil Health in Rice Ecology. In Rice Research for Enhancing Productivity, Profitability and Climate Resilience. ICAR-National Rice Research Institute, Cuttack, Odisha	Published by ICAR-National Rice Research Institute, Cuttack, Odisha	
Book chapter	2017	Measurement of greenhouse gas flux. Kumar A, Chatterjee D, Nayak A.K, Mohanty S, Bhattacharyya P, Das PK, and Shahid M. In Nayak AK, Sarkar RK, Chattopadhyay K, Reddy JN, Lal B and Chatterjee D (eds.) Enhancing climate resilience in Rice: Abiotic stress tolerance and Greeenhouse gas mitigation. ICAR – NRRI, Odisha India	Published by CRRI, Cuttack	
Book chapter	2017	Eddy covariance technique for micrometeorological measurements. Chatterjee D, Nayak A.K, Chatterjee S, Bhattacharyya P, Kumar A, Lal B, Swain CK, and Tripathi R. In Nayak AK, Sarkar RK, Chattopadhyay K, Reddy	Published by CRRI, Cuttack	

		JN, Lal B and Chatterjee D (eds.) Enhancing climate resilience in Rice: Abiotic stress tolerance and Greeenhouse gas mitigation. ICAR – NRRI, Odisha India		
Book chapter	2012	A.K. Nayak, R. Raja, **Anjani Kumar**, Md. Shahid, Rahul Tripathi, Sangita Mohanty, P. Bhattacharya and B.B. Panda (2012). Soil organic carbon sequestration in rice based cropping system in Indo-Gangetic Plains. In: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). Climate change: Green-house gas emission in rice farming and mitigation options.	Published by CRRI, Cuttack	
Book chapter	2012	A.K. Nayak, Md. Shahid, A.K. Shukla, **Anjani Kumar**, R. Raja, Rahul Tripathi and B.B. Panda (2012). Soil organic carbon sequestration in agriculture: Issues and priopritiеs. In: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). Climate change: Green-house gas emission in rice farming and mitigation options.	Published by CRRI, Cuttack	
Book chapter	2012	Sangita Mohanty, A.K. Nayak, P. Bhattacharya, **Anjani Kumar**, V. Kasthuri Thilgam and Annie Poonam (2012). Nitrous oxide emission from rice and rice based production system and its mitigation strategy. In: Bhattacharya, P., Nayak, A.K., Raja, R. and Rao, K.S. (Eds.). Climate change: Green-house gas emission in rice farming and mitigation options.	Published by CRRI, Cuttack	
Book chapter	2018	M. Rana, R. Gajghate, G. Guleria, RP Sah, **Anjani Kumar**, And ON Singh. 2018. Teosinte (makchari) In Forage Crops of the World, Volume I: Major Forage Crops (pp. 133-146). Apple Academic Press.	Published by Apple Academic Press	
Book chapter	2018	RP Sah, **Anjani Kumar**, M. Rana, And U. Kumar. 2018. Maize (corn) In Forage Crops of the World, Volume I: Major Forage Crops (pp. 33-56). Apple Academic Press.	Published by Apple Academic Press	
Book chapter	2018	Anjani Kumar (2018).Technological Innovations for Soil Health Preservation. Kurukshetra December. 2018	Published by Ministry of Rural Development, Govt of India	
Book chapter	2018	Anjani Kumar and R K Mohanta (2018).	Published by	

		Preserving Soil Health for Sustainable Development. Kurukshetra February. 2018	Ministry of Rural Development, Govt of India	
Book chapter	2017	Anjani Kumar and R K Mohanta (2017). Micro Irrigation and Approaches for Improving Water Use Efficiency in Agriculture. Kurukshetra November. 2017	Published by Ministry of Rural Development, Govt of India	