ICAR-IIWM Publication No.73

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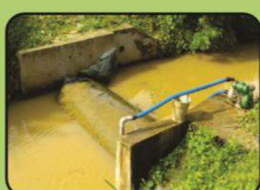

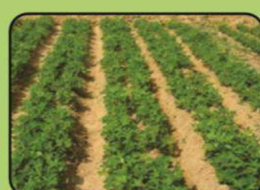

भारतीय जल प्रबंधन संस्थान
ICAR-IIWM

ICAR-Indian Institute of Water Management
Bhubaneswar – 751 023
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Compiled by:

Roy Chowdhury S., Rautaray, S.K., Panda, R.K., Das, M., Srivastava, R.C. and Ambast, S.K. 2016. Technological Options for Agricultural Water Management in Eastern Region of India. ICAR-Indian Institute of Water Management, Bhubaneswar. P. 39

Published by:
Director
ICAR-Indian Indtitute of Water Management
Chandrasekharpur, Bhubaneswar
Odisha-75013, India
www.iiwm.res.in

This publication is based on the research outcome generated from the completed research projects carried out by ICAR-IIWM, Bhubaneswar under different research programmes. The institute duly acknowledges the contribution of principal investigators and associated scientists of different projects, farming community, line departments and sponsors of external funded projects who have contributed to implement the projects successfully with the generation of viable agricultural water management technologies.

Printed at:
M/s Space Setter Press & Publicity (P) Ltd.
84, Chandaka Industrial Estate, Patia
Bhubaneswar-751024

Preface

Retrospection of glorious past is always a matter of great satisfaction, especially when the activities during the said period could largely accomplish its objectives. The synchrony of ever evolving challenges in agriculture and its mitigation through development of suitable technologies, has been priority for Indian Council of Agricultural Research for fostering the cause of farmers. But when it comes to the development of technologies in the domain of agricultural water management, it becomes even more demanding due to increasing share of other emerging sectors for water with agricultural sector. Under this back drop and ever changing climate scenario, the effort is made to aggregate the various technologies in agricultural water management developed by the Institute just after its commemoration of Silver Jubilee Year. Attempts were made for such compilation earlier also. However, information on relevance of a particular technology with brief description of the technology and its scalability is critically lacking in an abridged manner. Therefore the effort made in the present publication is duly acknowledged to everyone who made contribution for technology development ranging from scientists to participating farmers to personnel from line departments for such useful effort. The contribution made by Dr. G. Kar is also deeply acknowledged for his inputs to bring out this publication.

We hope that the information compiled in this publication will be useful to researchers, farm practitioners and other professionals directly or indirectly associated with the field of agricultural water management.

January, 2016 **Authors**
Bhubaneswar

Content

Introduction

India with 2.4% of the world's total land area and 4% of the total replenishable fresh water (4,000 billion cubic meter, BCM) has to cater to 17.5% of the world's population. With an average annual rainfall of 1,170 mm, annual precipitation in India is about 4000 BCM. The rainfall in the country is unevenly distributed, dependent mainly on the south-west monsoon from June to September, accounting for 75% precipitation of the country. Eventhough rich in terms of annual total water resources, uneven topography causes severe regional and temporal water shortages and excess in different states. The highest and annual rainfall of 11,690 mm is recorded at Mousiniram near Cherrapunji, Meghalaya and lowest 209 mm at Jaisalmer of Rajasthan. Changing global climate coupled with declining per capita availability of surface and ground-water resource have made sustainable agriculture production challenging in India. With increasing water demand from other sector like industry, domestic, agricultural water use in India will face stiff competition for limited water resource in future. Water quality both in rural and urban India warrant urgent attention at policy level as it has degraded at an alarming level. Therefore in future available water resource would not be sufficient to fulfill water needs of all sectors, unless water is used efficiently and utilizable quantity is increased by all possible means.

Inspite of impressive achievements in foodgrain production, net sown area in the country remains at about 142 Mha and net irrigated area is only 60.3 Mha. To meet the projected food grains demand of 450 mt by 2050, it is essential to increase the crop productivity from present 2.3 t/ha to 4 t/ha under irrigated conditions and from 1 t/ha to 1.5 t/ha in rainfed area. Therefore, to produce more food with the same amount of water, productivity of water has to improve through better irrigation water management. Better timing of water supplies can reduce stress at critical stages of crop growth period and increase yield. With reliability in water supplies farmers can confidently invest on inputs for higher productivity.

To achieve the goal of 'more crop per drop' through research and development, the ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha (which was established as Water Technology Centre for Eastern Region, by ICAR on May 12, 1988 at Bhubaneswar and subsequently upgraded as Directorate of Water Management on 13th June 2009 alongwith shifting of two AICRPs viz., AICRP on Water Management and AICRP on Groundwater Utilization at present merged as AICRP on Irrigation Water Management) is working dedicatedly under 5 research programmes, namely (i) Rainwater management (ii) Canal water management (iii) Groundwater management (iv) Waterlogged area management (v) On-farm research and Technology dissemination. During last 25 years the institute has developed and up-scaled many viable water management technologies at regional and national level which has helped to improve land and water productivity and to stabilize farmers' income of the country.

Location of the Institute

The Institute is located at Chandrasekharpur, Bhubaneswar with its main office-cum-laboratory building, guest house and residential complex (20°15' N and 85° 52' E and 23 m above mean sea level). The 63.71 ha research farm of the Institute is located at Deras, Mendhasal (20°30' N and 87°48' E) and is 30 km away from main institute.

Mandate of the Institute

- To undertake basic and applied research for developing strategies for efficient management of on-farm water resources to enhance agricultural productivity on sustainable basis.
- To provide leadership role and coordinate network of research with the State Agricultural Universities in generating location-specific technologies for efficient use of water resources.
- To act as a center for training in research methodologies and technology update in the area of agricultural water management.
- To collaborate with national and international agencies in achieving the above objectives.

Research Background

With initial challenges in agricultural water management mainly for eastern India, the main issue was to provide assured irrigation with good quality water during water scarcity and at the same time removal of excess rain water received during monsoon. Inefficient use of surface and ground water resources, insufficient surface water storage sites, unreliable water supply schedule of canals, excess water management during *kharif* were certain researchable issues before the Institute. Accordingly research programmes were steered through four different sections like Soil-Water-Plant Relationship, Cropping System and Water use, Irrigation Technology and Water management, Agricultural Drainage and Watershed Management. With increase in demand in researchable issues, the QRT in 1997 suggested three more sections Ground Water management, Resource Appraisal and monitoring and coordinating cell. Since the year 2000 the core research activities of the Institute were carried out under five programmes *viz,* rainwater management, canal water management, ground water management, waterlogged area management and on-farm research, extension and training to address the researchable issues in the field of agricultural water management. Agricultural water management related problems at the national level are being addressed by the Institute under the All India Coordinated Research Programmes (AICRP) on Irrigation Water Management. Comprehensive water and energy efficient farming system technology package have been developed to improve productivity of rainfed, irrigated and waterlogged areas. The different technologies which have emerged of research activities of the Institute are described in this publication.

VIABLE AGRICULTURAL WATER MANAGEMENT TECHNOLOGIES

1. Water Resource Development Through Tank Cum Well System

Relevance: For rainwater harvesting and utilization, creation of additional water storage, enhancement in irrigation command area, cropping intensity and crop productivity.

Description of the technology: In order to capture rainwater and utilization of the harvested rainwater, the tank cum well system technology along the drainage line in a watershed is suitable for plateau areas having slope of 2 to 5%. The site for the technology should be selected in such a way that the area should have a well-defined valley where the runoff flows either as overland flow or channel flow. The well is constructed about 100 to 300 m downstream of the tank to tap the water that is lost by seepage from the tank. The schematic diagram of tank cum well system and multi tank and multi well system in a watershed are shown below. In general for a catchment area of 500 ha, set of 15 tanks and wells can irrigate 60 ha area. The cost of implementation of the technology is Rs. 100,000/ ha of gross irrigated area (2015 price).

Output and scalability: The technology can be implemented along drainage lines in any watershed located in plateau areas with a moderate slope of 2 to 5%. The unit cost of construction is Rs. 100,000 per ha of gross irrigated area. The technology has a potential to generate Rs. 30,000/- extra gross income per year with additional employment generation of 115 man days per ha. It can increase the cropping intensity to up to 166%.

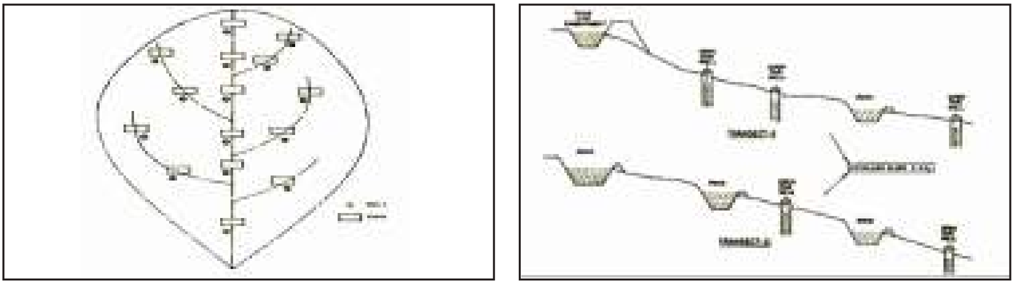


Fig.1. Schematic plan of tank cum well system in a watershed

Tank cum well system in a watershed

2. Rainwater Conservation Through Increased Dyke Height

Relevance: The rainfed agriculture is predominant in the eastern region. Although the region receives high (1008 to 3126 mm), the rainfed agriculture is subjected to vagaries of monsoon due to dry spells at critical crop growth stages. Unstable yields are major constraints for investment in rainfed agriculture. There cannot be any significant development of the region till agricultural production is made stable. Since total annual rainfall in the region is about 80-85 % of potential evapotranspiration, proper management of rainwater can meet the evapotranspiration demand of crops.

Description of the technology: Proper bunding of rice fields help in conservation of rainwater. Rice plots with bund height of 6 cm can store about 57% of the rainwater. There is an exponential relationship between rainfall excess or runoff as percent of rainfall and bund height with 30 cm high bund storing as much as 99% of rainfall. Consequently the irrigation requirement declines significantly with increase in bund height. While 6 cm high bunded plot required four irrigations (each of 6 cm depth) plots having 10 to 14 cm high bund required three irrigations and plots with18 cm high bund required only two irrigations.

Output and scalability: The bund height of 6 cm can store upto 57% of the rainwater whereas bund height of 30 cm could store as much as 99% of the rainwater. This decreases irrigation water requirement. The loss of sediment and nutrient in runoff water is exponentially related to bund height and bund with 6 cm height recorded maximum value. The losses are minimized considerably with 22 cm bund height. The technology is applicable in rice growing areas vulnerable to moisture stress during critical growth stage of the crop.

Increased dyke height for in-situ rainwater conservation

3. Sub-surface Water Harvesting Structure For Coastal Areas

Relevance: In general due to lack of irrigation the crops in post monsoon season suffers from scarcity of water in coastal areas. But below sub-surface profile lighter fresh water floats above the heavier saline water in coastal areas. This could be tapped through subsurface water harvesting structures to meet the irrigation demand of *rabi* crop and can also be used for pisciculture.

Description of the technology: Water harvesting structures are dug in fields. The capacity of structure may vary from 200 to 1500 m^3.The dimension of the structure will depend upon the size of land holding. The depth of the structures may vary from 2-4 m. As located in coastal areas, the depth of structure should be restricted up to sandy zone, otherwise there would be risk of saline water intrusion. These structures (SSWHS) make utilization of freshwater existing over saline zone in coastal areas. The system is also helpful in mitigating early drought during *kharif* season and to provide irrigation for *rabi*and summer crops. To lift water from these structures, 1-2 hp pumps are recommended so as to avoid ingression of saline water in to the fresh water layer. These structures act as an off-season source for increasing cropping intensity and crop productivity.

Output and scalability: The average benefit: cost ratio of sub-surface water harvesting structure (SSWHS) is 1.55 in the first year of construction itself. The average unit cost for SSWHS construction is Rs. 14 /m^3.The average total net benefit from the system is about Rs.20,000 /ha/year . The technology has been developed and demonstrated in the farmers' field and already in public domain. The average water productivity of SSWHS with pisciculture and rabi vegetables is Rs. 36 /m^3 of water. The technology has been adopted by farmers of Chaulia, Kiyada and Ambiki village of Erasama block of Jagatsinghpur district, Odisha and has potential for its application in coastal areas.

SSWHS and adjoining crops in farmers' field at Jagatsinghpur district

4. Use Of Rubber Dams For Rainwater Harvesting In Watersheds

Relevance: A rubber dam is a flexible structure and can be inflated and deflated in order to regulate flow of water in streams. The rubber dam is mainly use to harvest rainwater, increasing irrigation command area there by improving crop productivity.

Description of the technology: As an innovative hydraulic structure, the rubber dam mainly consists of i) a concrete foundation, ii); a rubberized fabric dam body, iii) anchoring mechanisms, iv) inflation and deflation mechanisms through inlet/ out let piping system. When inflated, it serves as a weir and once deflated it functions as a flood mitigation device. The fabricated fibre structure was fitted to the concrete base structure with proper size and spacing of foundation nuts and bolts. Inlet and outlet pipes are provided for entry and release of water respectively. As rubber dam is inflated by supplying water into the dam through inlet pipe. Inflated condition acts as barrier to flow of water in the stream helps in rising of water level in upstream side thus making it a dam and the stored water can be utilized for irrigation in lean period. Water is required to be released from the dam through outlet pipe allowing the stored water to flow towards downstream side at the time of heavy flood to avoid damage of the structure.

Output and scalability: As first indigenous rubber dam in our country, rubber dams were installed in watersheds at different locations in the country with innovative manufacturing, fabrication and installation technology. This technology has potential to create an additional water storage capacity of about 52,000 to 80,000m^3 for irrigating about 30-40 ha of paddy in *kharif* and 6 ha of pulses, oilseeds and vegetable crops in *rabi* season. In rubber dam command the productivity of rice in *kharif* season enhanced up to 62% and in *rabi* season productivity of vegetables increased up to 47% due to installation of rubber dams in watersheds. In addition, it has potential to enhance the net returns of the farmers up to Rs.48,000/ha (2013 prices). The positive impact of rubber dam for additional water storage, increase in irrigation command area, cropping intensity and crop productivity increased net returns of about 85 farmers of Baghamari and Chandeswar villages of Odisha. The farmers (of Badapokharia) also benefitted through additional ground water recharge through installation of rubber dam at check point of percolation tank.

Rubber dams installed in the farmers' field

5. Residual Soil Moisture Utilization during Rabi Season

Relevance: After harvest of *kharif* rice good amount of moisture remains in field and farmers generally do not grow any crop leading to rice-fallow cropping system in about 11 Mha area in eastern India. It generates problems like depletion of nutrients and soil moisture from the uncovered field during dry season, poor cropping intensity and low income of farmers. Growing of pulse crop under residual soil moisture condition can overcome this problem to a great extent. These crops require less water and are tolerant to moisture stress.

Description of the technology: The crops like greengram, blackgram, horsegram and sesamum can be grown as *paira* crop as well as sequence crop for efficientutilization of residual soil moisture in *rabi* season. Local varieties as *paira* crop produce higher yields as compared to HYVs sown in similar situation. However, HYVs sown as sequence crop after field preparation give higher grain yields as compared to local varieties.

Output and scalability: The yield potential of greengram, blackgram, horsegram and sesamum grown under residual soil moisture is found to be 950 kg/ha, 980 kg/ha, 800 kg/ha and 450 kg/ha, respectively. The practice of residual soil moisture utilization in *rabi* season provides additional net returns about Rs.6,000 to Rs.7,800 / ha.


Residual soil moisture utilization in rainfed low lands

6. Lining of Runoff Recycling Tanks for Seepage Control

Relevance: The eastern region of our country receives high rainfall ranging between 1008 to 3126 mm. But due to inadequate irrigation coverage the rainfed agriculture dominates the agricultural scenario in the region and is vulnerable to unpredictable monsoon .The rainfed agriculture is always risk prone with occurrence of dry spells at critical growth stages of crop plants leading to unstable yields even crop failure. Since total annual rainfall in the region is about 80-85 percent of potential evapotranspiration, proper management of rain water can meet the evapotranspiration demand of crops emphasizing scope for conservation of rain water through *in-situ* management.

Description of the technology: Two methods of lining of tanks for seepage control has been developed: one by finding an alternative to expensive kiln burnt bricks and another by using LDPE film overlain by mud block, an inexpensive but stable material. It has been found that compressed mud block with 4% cement additive is a very good alternative to brick lining. These compressed mud blocks can be made by manual soil block press designed by Housing and Urban Development Corporation.

Output and scalability: It is evident from that hydraulic conductivity of these compressed mud blocks is about 73% less and the cost is about 50% less. A design of tank linked with mud block and LDPE film has been developed and it is performing satisfactorily.

Manual soil block press for making mud blocks and tank with mud block and LDPE film

7. Rainwater Conservation for Rice-fish Integrated System

Relevance: About 60% of cultivated land is under rainfed agriculture. In rainfed areas crops are frequently vulnerable to deficit monsoon leading to crop failure. Water conservation structures like ponds in rice field itself can serve as source of water at critical stage of crop growth both for paddy in monsoon season and other light duty crops in post monsoon season in addition to aquaculture.

Description of the technology: In 8 to 10% of the rice field, small dugout ponds of 2.0 to 2.5 m depth and 1:1 side slope is beneficial at downstream areas. This pond is used for short-duration aquaculture during monsoon and its embankment can be used for growing horticultural crops. The conserved rainwater is used for supplemental irrigations to *kharif* paddy and irrigating light duty *rabi* crops. The cost of intervention and output per unit area is Rs.67,000/ha. The technology helps in *in-situ* conservation of rain water for drought proofing and bringing crop diversification in rainfed ecosystem.

Output and scalability: The *kharif* paddy yield can be increased from 1.8 t/ha to 4.9 t/ha with additional fish yield of 1.4 t/ha. The technology has been adopted by farmers of Sadeiberini and Gajamara village of Dhenkanal district, Odisha. There is an improvement in assets of farm families during post-adoption period. The physical, social and financial assets increased considerably to above average level. Maximum improvement occurred in physical assets (82%) followed by social (71%) and human assets (59%) suggesting improvement in living condition and socio-personal profile of farm families. Financial assets gained by 58%, natural assets by 40%. Improvement in socio-economic condition and social recognition motivated entrepreneurial abilities of the farmers. The increased income on adoption of technology has motivated the farmers to invest and intervene further leading to the growth in physical and financial assets. The technology has potential to be implemented in medium and low lying rice growing areasin the country.

Rice-fish integration with conserved rainwater in farmers' field

8. Crop Diversification In Drought Prone Areas In Rainfed Upland

Relevance: The productivity of rice is very low in rainfed upland areas. Indian has 6.1 Mha area under rainfed upland condition of which 4.3 Mha is in eastern India. Crop diversification alongwith *in situ* rain water conservation provides an opportunity for increasing and stabilizing farm income by mitigating drought and dry spells.

Description of the technology: Crop diversification with low water requiring crops like maize, groundnut, pigeonpea, groundnut, cowpea through sole or inter cropping following ridge and furrow methods of sowing. Cost of implementing the technology in 1 ha of land is Rs. 10,000-14,000/ha(2002 prices).

Output and scalability: Higher rice equivalent yield per annum was obtained through maize cob (8125 kg/ha with net economic return upto Rs. 26,000/ha), groundnut + pigeon pea (5550 kg/ha with net economic return upto Rs. 21592/ha), sole groundnut (5640 kg/ha with net economic return upto Rs. 18960/ha), sole pigeon pea (5550 kg/ha with net economic return upto Rs. 16200/ha), sole black gram (with net economic return upto Rs. 11650/ha)or rice+pigeon pea (with net economic return upto Rs. 12500/ha) compared to only rice (with net economic return upto Rs. 5400/ha ; 2002 price) The technology has ability to give Rice equivalent yield of 7.5 t/ha with average net return of Rs. 25,000/ha per annum (2002 price).

Crop diversification through sole cropping (left) and inter-cropping (groundnut+pigeonpea;right)

9. Residual Soil Moisture Utilization with Conservation Tillage in Rice Fallow in *Rabi* Season under Shallow Water Table

Relevance: Medium and lowlands with shallow water table are relatively heavier in texture, slightly acidic to neutral in soil reaction and have better moisture holding capacity. These lands have ability to support a good second crop with residual moisture but are mostly kept fallow after rice because water becomes scarce for growing second crops in rice fallow during winter (*rabi*/dry) season.

Description of the technology: Medium and lowlands with shallow water table can be brought under double cropping through proper utilization of carry-over residual moisture with conservation tillage. In addition to carry-over residual soil moisture in shallow lowland, water table contribution to supply crop water use to second crop may be important in rainfed regions because soil upward flux or groundwater contribution to crops are dependent on water table depth.

Output and scalability: In medium land with shallow water table (0.58 to 1.05 m), 37 - 58.1%, 36.9 - 55.6%, 34.4- 52.7% and 38.1 - 51.9% of crop water requirements is met with in groundnut, blackgram, greengram and chickpea, respectively. As a result, with one or even no irrigation, economic yield can be obtained from these crops in rainfed rice fallow with shallow water table. With one irrigation to second crops on such land, Rs.29,375, Rs. 25,355, Rs. 23,085, Rs. 20,530 /ha net return was obtained from rice-groundnut, rice-blackgram, rice-greengram and rice-chickpea, respectively (2003 price). Whereas, net return from rice with farmers' management practices was only Rs. 6980 /ha. With two ploughinges, 68.5 %, 106.6 %, 67.5 % and 122.7 % higher yield can be obtained in lathyrus, blackgram, pea and chickpea respectively over traditional relay cropping system.

Crops utilizing residual soil moisture in low land under shallow water table

10. Residual Soil Moisture Utilization In *Rabi* Season With *Utera/paira* Cropping

Relevance: After harvest of *kharif* rice adequate moisture remains in field and farmers generally do not grow any crop leading to rice-fallow cropping system in about 12.9 Mha area in eastern India. But carry-over residual soil moisture can be utilized to grow low water requiring, short duration pulses and oilseeds like blackgram, greengram, horsegram, pea, chickpea and *Lathyrus,* linseed, mustard.

Description of the technology : Relay cropping of soaked seeds of pulses (blackgram, greengram, horsegram, pea, chickpea and *Lathyrus*) or oil seeds (linseed, mustard) are broadcasted in well drained field inside the standing rice crop, 10-15 days before harvest for efficient utilization of residual soil moisture during rabi season.. To ensure germination 40-50% extra seed is used.

Output and scalability:

Case study in Bhuban block, Dhenkanal, Odisha

In rainfed lowland of Bhuban block, Dhenkanal, Odisha, under farmer's traditional relay cropping system, only 350, 300, 400 and 220 kg/ ha yield was obtained in lathyrus, blackgram, pea and chickpea, respectively. Through our scientific intervention crop productivity of 34-55% and water use efficiency of 35-48% was increased in these four crops.

Crops utilizing residual soil moisture in low land under shallow water table

Case study in Cuttack, Odisha

The yield potential of greengram, blackgram, horsegram and sesamum grown under residual soil moisture was recorded as 950, 980, and 450 kg/ha, respectively which provided additional net returns of about Rs.6,000 to Rs.7,800 / ha (2004 price).

Residual soil moisture utilization through *utera/paira* cropping in Safflower

11. Mulching for Better Water Management

Relevance: Rice is a major crop of the eastern region and rice-rice has been predominant crop rotation under irrigated conditions. Eventhen in the changed scenario, crop diversification under irrigated agriculture is imperative and technology for water management for crops other than rice is warranted.

Description of the technology: Significant soil water is lost under increasing evaporative demand especially under late post-monsoon period affecting crop yield of groundnut and pointed gourd. Application of straw mulch @5/tha has given best yield in ground nut with irrigation schedule of IW /CPE of 1.2. Similarly in pointed gourd straw mulch application @15 t/ha gives best yield in comparison to no mulch or farmers practice.

Output and scalability: The mulch kept soil cool by 3 to 5°C of both at surface and upto 30 cm depth and also produces fruits of better quality, quantity, size and luster. The straw mulch also helps in raising pH of acid soils and renders benefit for weed control, saving Rs. 8490/ ha as cost of labor. The number of irrigations in mulched plots was 25 against 32 irrigations in non-mulched plots. The net return from mulched plot was Rs.60,792/ ha against Rs.28,203/ ha from non- mulched plot.

Pointed gourd crop without mulch (left) and with mulch (right)

Mulching in potato: The 77–103 mm less soil moisture depletion occurred in the different treatments due to the application of straw mulch @ 5 t/ha with increase in available phosphorus and potassium in the soil. Water use efficiencies for the mulched plots with 3-4 irrigations increased upto 34.19 kg / ha-mm.

Potato crop with mulch (left) and without mulch (right)

12. Low Cost Management of Acid Soils for Higher Productivity and Water Use Efficiency

Relevance: Pure lime like calcite, dolomite are expensive and sometimes beyond the reach to the farmers to ameliorate acid soils. Therefore low cost liming material like by-product of paper mill *i.e*. paper mill sludge can be very well used to ameliorate acid soils. This by-product of paper mill has potential to improve agricultural production with low cost and helps in reducing environmental pollution in the surrounding areas of the factory.

Description of the technology: Low cost liming materials like paper mill sludge, seeds of crops like maize, groundnut, black gram, cowpea and green gram, fertilizers and necessary agro-inputs unit cost: Rs 12,000 to Rs. 15,000/ha depending on the soil pH (2007 price).

Output and scalability: Paper mill sludge could ameliorate acidic soils and increased the yield of different crops by 34-68%. Additional income generated was Rs. 20,000/ha and the water use efficiency increased by 36-60%. The Government of Odisha adopted the technology and targeted to ameliorate 2.4 lakh hectares acidic land in 2008 by supplying Paper Mill Sludge. From the year 2008-09, the Odisha Government started supply of paper mill sludge at subsidized rate (Rs. 101/50 kg). During *rabi* season 2008-09, the IFFCO, Bhubaneswar adopted the technology of paper mill sludge application in 120 acres areas in Balasore district in Odisha for growing groundnut crops by involving 223 farmers.

Groundnut with PMS at 35 DAS with paper mill sludge (left) and without paper mill sludge (right)

Fruiting of ground nut with or without paper mill sludge

13. Water and Energy Efficient Integrated Farming System for Rainfed Farmers

Relevance: In India, more than 80% of the farming community belongs to marginal and small farmers and the per capita land availability may reach 0.09 ha by 2020 AD. Thus, Integrated Farming System is the foreseeable management option for the small and marginal farmers of rainfed ecology to generate more income, food, and employment per unit area. Increased demand for water and energy, and declining soil productivity are the problems inherent in input intensive agriculture. In spite of large-scale expansion of irrigation system, 60% of the cropped area is under rainfed system.Climate change effect on distribution and amount of rainfall has accentuated the problem. So, water and energy efficient farming system is necessity especially in rainfed areas where agriculture depends only on monsoon.

Description of the technology: Water and energy efficient farming system could be achieved through optimum cropping system (rice-horse gram and rice sunflower), less use of agro-chemicals (green manuring and vermi-compost), mulching, ring method of irrigation (cucurbits), paired row bed planting (okra), multiple use of water (pisciculture, horticulture, apiculture, poultry and mushroom cultivation), growing of widely spaced crop with large ground coverage (bottle gourd and water melon)and redgram cultivation on field bunds.Residue recycling of poultry and duckery for pisciculture, paddy straw for mushroom cultivation, and bio-waste for vermi-compost production saved energy on fish feed and fertilizer.The farming system model (3408.44 m^2) was based on water harvesting pond (30 m x 30 m x 2.8 m depth), dyke around pond (556 m^2), field crop unit (1879 m^2) and field bund (73.44 m^2).

Output and scalability: Growing of paddy crop in wet season under integrated nutrient managed with *in-situ* green manuring gave higher energy output: input ratio (18.7) and net returns(Rs. 27982/ha; 2011 prices) as compared to use of chemical fertilizers alone (energy output : input ratio of 13.9 and net returns of Rs. 23412/ha). After paddy harvest, growing of legume (horse gram) under reduced tillage, and use of farm generated vermi-compost reduced energy requirement and resulted in high energy output : input ratio, water productivity, net returns and beneficial residual soil fertility (organic carbon, available N, P and K).Net return/ha and employment generation were Rs188341/ha and 509.3/ha respectively under Integrated Farming System as compared to wet season rice (Rs. 27982 and 157.7/ha). Net water productivity under Integrated Farming System was also very high (Rs. 53.7/m^3) due to multiple use of water.This technology can enhance low productivity of rainfed areas and surplus labour under small and marginal holdings can be gainfully employed.


Different components of an efficient integrated farming system in rainfed area

14. Rainwater Harvesting Through Check Dam And Its Multiple Use

Relevance: In India, rainfall is mainly unevenly distributed, dependent mainly on the south-west monsoon from June to September, accounting for 75% precipitation of the country. With an average annual rainfall of 1,170 nm, annual precipitation in India works about4,000 billion cubic meter including net water contributions from the national boundaries. While India may be rich in terms of annual total water resources, its uneven geographical distribution causes severe regional and temporal water shortages and excess in different states.

Description of the technology: Based on hydro-meteorological parameters, an earthen check dam of 120 m length was designed and constructed in Bahasuni watershed, Dhenkanal. The collected water was utilized through both consumptive and non-consumptive uses like pisciculture, horticulture, growing of widely spaced crop with large ground coverage (bottle gourd and water melon), field crops etc. The cost of construction was Rs.35/m^2 (2005 price).

Output and scalability: Water productivity of the implemented area increased from Rs. 1.6/m^3 to Rs. 8.5/m^3 and after intervention farm income increased from Rs. 8000/ha to Rs. 35,000/ha (2005 prices). The harvested rainwater was also helpful to overcome drought and dry spells.

Earthen check dam with stone patching : a case study in Bahasuni watershed, Dhenkanal

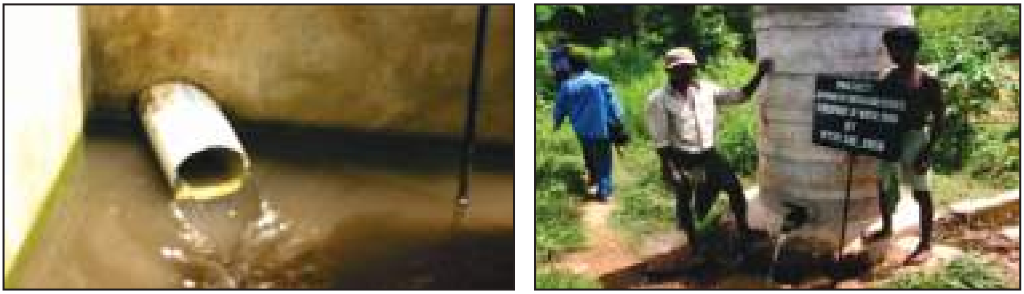
Fish reared inside check dam and banana grown with harvested water of check dam

15. Spring Water Collection and Its Utilization to Grow High Value Crops

Relevance: Changing global climatic patterns coupled with declining per caput availability of surface and ground-water resource have made sustainable agriculture production a great challenge in India. With increasing water demand from other sector like industry, domestic, agricultural water use in India will face stiff competition for the scarce limited water resource in future. Water quality both in rural and urban India is an issue requiring urgent attention at policy level as it has degraded at an alarming level. Thus, there is an urgent need to trap alternative sources of water like spring water which can be utilized to grow high value crops for higher land and water productivity.

Description of the technology: A cement tank cum underground pipe line system at the cost Rs. 10,000/ha was developed to tap perennial spring water from hill top (ridge line of watershed) atMajhisahi village, Dhenkanal. Water from spring is available @ 30 liter per minute in lean periods to 170 liter per minutes during monsoon months.

Output and scalability: By growing high value crops like vegetables, flower (marigold) and short duration fruits (papaya, banana) with that collected spring water farmers earned about Rs. 35,000 per hectare (2005 base price). Irrigated areas of the village were increased from 1.2 ha to 8.5 ha of that village comprises of 20 tribal families. Water use efficiency increased by 25-40% and farm net income increased up to Rs. 28,000/ha (2005 base price). Conveyance loss of water also reduced.



Spring water collection from Saptasajya hill, Dhenkanal, Odisha

Growing of carrot (left) and merigold (right) using spring water

16. CAM Plants for Enhancing Water Use Efficiencies in Rainfed Ecosystem

Relevance: About 11.5 m ha area in eastern India remains fallow after cultivation of *kharif* rice without any crop with progressive loss of residual soil moisture after harvest of the *kharif* paddy crop. This type of area was targeted for fitting in this technology of growing pineapple crop.

Description of the technology: The growth of pineapple (a CAM plant, crassullacean acid metabolism a water saving photosynthesis mechanism)) was standardized for fitting into the rainfed system after harvest of *kharif* rice. The suckers of pineapple plants planted in polythene bags were kept under full light conditions till the rice was harvested. In the month of December, after harvest of kharif rice, 8 months old pineapple seedlings were transplanted on raised beds. Approximately 50 days after planting in the main field then the plants were forced to flower by application of Ethephon hormone. Flowers appeared after 30 days and fruits were harvested within 130-150 days. The Planofix spray significantly improved fruit yield up to 16.92 t/ha.

Output and scalability: The total cost of cultivationis Rs.127518/ha and the gross returns of Rs 219995/ ha whereas the net returns is Rs 92477/ha (2014 prices). The benefit-cost ratio of the technology is 1.82. Growing pineapple for first eight months in polythene bags saves time and individual plant care keeps seedlings healthy. Thereafter transplanting the pineapple crop and raising it with residual moisture puts the crop in water saving CAM mode and provides yield.

The fallow lands after cultivation of *kharif* rice can be utilized by use of this technology through cultivation of pineapple in polybags for its early vegetative growth and completing its final fruiting stage in rice fallows after harvest of paddy.

Pineapple suckers in polythene bags and at flowering stage in rainfed rice fallow

17. Simulation Model for Integrating Water Balance of Cropped Area And Tank as Runoff Recycling Management of Rain Water

Relevance: About 60 % cultivated area is rainfed and are prone to risk due to unpredictability of rainfall. Sub-optimal yield or crop failure due to water deficit stress at critical period of crop growth is main concern. However the total annual rainfall in the region is almost 80-85% of potential evapotranspiration. This provides scope for scientific management of rain water so as to match the evapotranspiration demand of crops. Keeping this in view, development of a model for integrating water balance of cropped area and tank as runoff recycling management of rain water was done to conserve rainwaterto avoid water deficit stress of crops.

Description of the technology: Role of the water harvesting system in semiarid and arid zone is to provide life-saving irrigation to low duty crops in post-monsoon season and if possible, one or two irrigations to raise another crop in the following dry season. But in sub-humidand humid regions, the runoff recycling system should be capable to provide sufficient water for rice crop in conjunction with rain water conservation during *kharif* season and also to provide supplementary irrigation to a low duty crop in following dry season. Hence the design of runoff recycling system should satisfy following condition, water requirement pattern of rice (a function of rainfall and evaporative demand) should match the water availability pattern in tank and the transplanting takes place within the desired time.

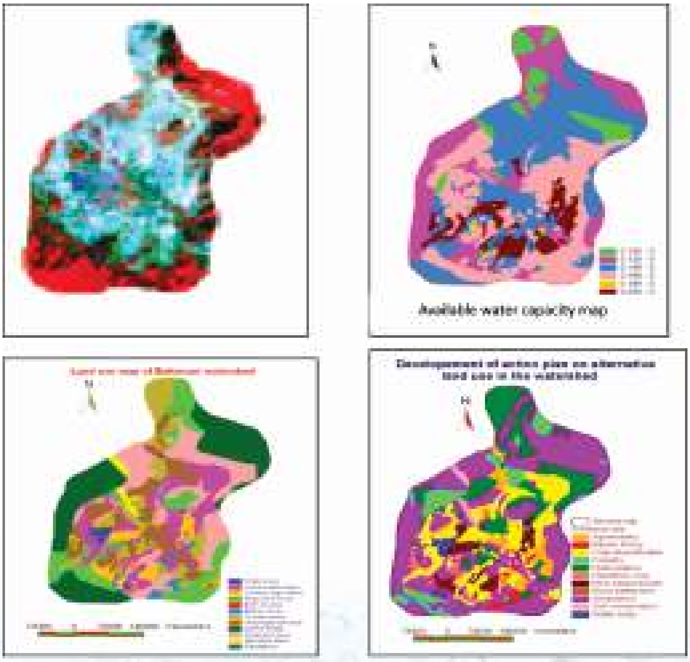
Output and scalability: To design such system, a simulation model integrating water balance of cropped area as well as tank was developed. The simulation study for 16 years data of rainfall and open pan evaporation showed that a tank capacity of 1750 m^3/ha command area with catchment command area ratio of $\geqslant$3.0 is sufficient to meet up the demand of transplanted rice-groundnut rotation for a return period of 5 years. For rice, the short duration variety of 110-115 days duration should be used. For optimal benefits, the tank should be located in such a way that the conveyance efficiency could be maintained around 80% at an affordable cost.

18. Multi-criteria Analysis for Sustainable Land Use Planning of Watershed Using Remote Sensing And Gis

Relevance: In recent years, remote sensing technology has made great achievements and contributed significantly in management of natural resources, disaster management, environment monitoring etc. Remarkable developments in space technology currently offers satellite which provide better spatial, spectral and temporal resolutions, (more frequent revisits) stereo viewing and on board recording facilities. Now the availability of high-resolution data from RESOURCESAT, CARTOSAT has further opened up new vistas in the area of watershed management.

Description of the technology: Based on biophysical capability of existing natural resources (soil physical properties, soil fertility, slope, land, hydrology), an alternative sustainable water and land resources plan were developed using high-resolution satellite data (IRS P6 data with 5.8 m resolution) and GIS tool along with extensive ground truthing in a tribal dominated watershed (Buhasuni), Dhenkanal, Orissa.

Output and scalability: Decision rules were developed in GIS environment to develop sustainable alternative landuse plan based on potential and prospects of existing soil and natural resources. Based on potential and prospects of existing soil hydro-physical properties, land use/land cover and slope, action plan on alternative sustainable land use and cropping system was developed using GIS tools.



19. Raised and Sunken Bed for Higher Productivity in Canal Command

Relevance: Out of total land area of the eastern region, about 48 per cent (12.9 mha) is under rainfed lowland. For food and livelihood, farmers of this region heavily depend on the rainfed and irrigated medium and lowland ecosystem. In high rainfall region to reduce the vulnerability of low land agriculture suitable land modification with sunken and raised beds has potential to reduce the risk and stabilize farm income considerably.

Description of the technology: Alternate sunken and raised beds, each of 30 m length and 5 m width and 60 cm higher than the adjacent sunken beds are to be raised by putting the dugout soil over the adjacent strip. The top 20-30 cm. soil of the raised beds remains in unsaturated condition and allows cultivation of different vegetable crops. Brinjal-Okra, okra-brinjal or tomato-cowpea, pointed gourd+ snake gourd or pointed gourd+ bitter gourd, cabbage + snake gourd or pointed gourd + papaya were observed to be remunerative cropping systems for the raised beds. The rice or crops like taro(*Colocasia*) can be grown simultaneously in adjacent sunken beds where soil remains submerged. Fish spawn can also be raised up to fingerling stage in the sunken beds together with rice within 90 days. Application of FYM or compost @10 t/haor growing *Sesbania* in sunken beds during dry season in the initial 1-2 years increases the fertility of the system.

Output and scalability: The technology is suitable for growing vegetable crops and rice or other crops like *Colocasia* in medium and low lands of eastern India. The cost of intervention per unit area is Rs. 50,000/ ha. The adoption of the technology increased *kharif* paddy and pointed gourd yield from 4.2 to 5.2 t/ha and 4.24 to 4.74 t/ha, respectively alongwith fish yield of 1 t/ha. The technology can generate additional benefit of Rs.70,000/ha/yr compared to conventional technologies. The highest net return of Rs.153,634 ha/yr with a benefit cost ratio of 4.01 can be achieved from the system. The technology has been adopted by farmers of Balipatna village of Khurda district, Odisha. The technology has been developed and demonstrated in the farmers' field and is already in public domain.


Crops grown with raised and sunken bed Technology in Khurda District, Odisha

20. Pressurized Irrigation System in Surface Flow Based Minor Irrigation System Commands

Relevance: The efficiency of surface flow based minor irrigation systems in India is very low; it is only 30-35%. The use of pressurized irrigation systems is an option for increasing the efficiency of such systems. But use of pressurized irrigation systems in canal commands is difficult as canal systems operate in on-off mode and turbidity in the canal water causes clogging in micro-irrigation systems. Therefore provision of an adjunct reservoir can change the supply of water from on-off mode to continuous mode and provision of suitable filters can avoid the clogging of micro-irrigation systems. This can improve the efficiency of surface flow based minor irrigation system.

Description of the technology: The Deras minor irrigation project in Khurda district of Odisha runs continuously during monsoon season; but during post-monsoon season, it is on-off schedule at weekly interval. To maintain continuous supply of water, one adjunct reservoir of 2,500 m3 capacity was constructed to store the diverted water from canal. There are two outlets one at higher elevation and another at lower elevation connected to catchwell. First outlet is to facilitate gravity flow and drip system alongwith pump and filtration unit is connected to catch well to provide clean water to drip irrigation system. Both gravity flow outlet and outlet from pump system is connected to main line which is further connected to submains connected to sprinkler and drip systems. The main line is designed to facilitate gravity flow for irrigating rice during kharif, and submains designed for sprinkler and drip.

Output and scalability: The irrigation efficiency increased by 67.3% in case of sprinkler irrigation systems and 95.5% in case of drip systems. The average total annual saving of water in a command area of 4.7 ha was 12,614 m^3. Total additional receipt from the crops was less than the annual cost of the system. However, considering the cost of saved water, the economic analysis in dicated a benefit-cost ratio of 2.55.


Adjunct reservoir and pump house with on-dyke horticulture and sprinkler irrigated potato

21. Wet Seeded Rice in Spot Sowing: A Water Saving Rice Cultivation Technology

Relevance: Now a days, labour availability for paddy transplanting and water scarcity are the major problems in rice growing countries. Morelaboursare required for the transplanting of rice seedlings and also their demand is maximum during transplanting activity. On the other hand, direct seeding requires less labour but gives low yield along withgreater weed infestation and also requires very high seeds rate. Wet-seeding in spot is an alternative method, which gives higher yield with less requirement of water and labour than conventional transplanting methods.

Description of the technology: For wet seeding in spots, 3-7 pre-germinated seeds are sown in each spot at a spacing of 20 cm x 10 cm. Fertilizers were applied @ 80 kg N, 40 kg P_2O_5 and 40 kg K_2O per hectare. Required N fertilizer was applied in three split doses and K_2O in two splits, whereas P was applied as basal during field preparation. Starting from the three-leaved seedling stage (7 days after sowing), standing water of 5 cm depth was maintained in the field in wet seeding. The plots were drained out seven days before physiological maturity of the crop under all the treatments.

Output and scalability: This method of rice cultivation gives about 12% more yield than conventional transplanting method but importantly saves about 10% water. Wet seeding reduces 5-20% labour requirements compared to transplanting method and weeding is found easier and less labour intensive. The labour requirement of wet-seeded rice cultivation is also found less coinciding with the peak demand of labourers during the transplanting season. The technology is scalable in 4 m ha rice growing area in *rabi* season in our country.

Wet- seeded paddy cultivation in spot sowing demonstrated in rice field

22. Integrated System of Rice Intensification (SRI)

Relevance: During the rainy season, there is no control over water for rainfed rice. Therefore both waterlogging as well as long dry spells in the rice field reduce the yield. It is also difficult to use any water-saving irrigation methods in the rice field during this season. System of Rice Intensification (SRI) is a known superior management practice of rice cultivation giving better yield. In order to avoid waterlogging in SRI field, excess water from field is stored in a refuge for short-duration aquaculture. This ensures proper water management in SRI field, supplementary irrigation at critical dry spell and adds value to system through integrated aquaculture and horticulture.

Description of the technology: To enhance land and water productivity of rainfed paddy land, 10% of the total rice field was converted into small dugout pond (refuge) at downstream to harvest rainwater from the field. The stored water in the pond is used for short-duration fish culture during monsoon and its embankment is used for growing horticultural crops (Banana and papaya). The conserved rainwater in the pond is used for giving supplementary irrigations to *kharif* paddy and irrigating horticultural crops. This technology referred to here as 'Integrated SRI' (ISRI) includes combing SRI methods of rice cultivation and refuge to conserve rainwater for multiple use.

Output and scalability: The *kharif* paddy yield increased from 2.89 t/ha to 6.16 t/hawith fish yield of 2.6 t/ha. The net water productivity in the integrated SRI system enhanced from Rs. 0.31/m^3 (conventional rainfed rice) to Rs. 18.91/$m^3$of water. The output value over cultivation costs ratio (OV:CC) suggested that in the Integrated SRI system, an investment of Rs. 1, yields a return of Rs. 2.97 , while the conventional paddy cultivation this ratio is 1:1.13 (2010 prices). The technology is scalable in rice cultivated area under mid-land ecology.

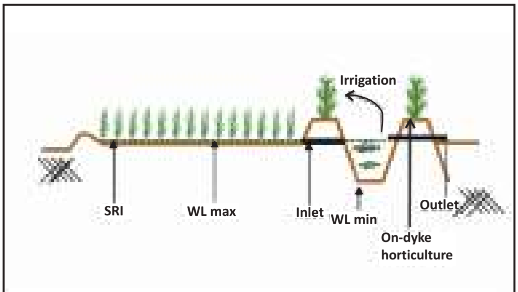
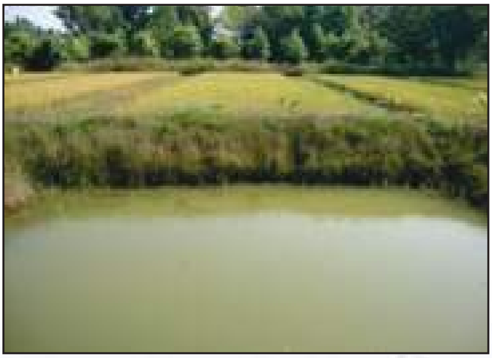


Fig.1. Lay-out Design of Integrated System of Rice Inrensification



Integrated system of rice intensification

23. Improved Planting Technique for Saving of Irrigation Water in Post-rainy Season Crops

Relevance: Many of the traditional practices of planting techniques of important of-monsoon crops lack proper methods from the perspective of water management especially when availability of water is limiting.

Description of the technology: The groundnut when cultivated in post-rainy season, planting in paired-row at 45 x 15 cm spacing (paired row at 15 cm on raised beds with 45 cm furrow spacing) is recommended. This planting technique can save water over flat-bed method of planting for groundnut and potato. In the crop of potato planting is recommended in similar paired-row at 75 x 20 cm spacing (paired row at 25 cm on raised beds with 75 cm furrow spacing) and can save irrigation water over normal method of planting for potato. As input for implementation of the technology, seeds, fertilizers and other necessary agro inputs are necessary.

Output and scalability: For expense of Rs.1.0, the maximum net return is Rs.2.10- for groundnut (45 x 15 cm) and Rs. 2.15 for potato (75 x 20 cm) can be obtained in addition to substantial saving of irrigation water. The adoption of paired row planting technique on raised beds gave pod yield advantage by 13-20% over flatbed planting of groundnut, with27-41 % saving of irrigation water and 40-45%.the enhancement of crop water use efficiency (WUE). Similarly, the paired row planting technique in potato can save 18-20%, irrigation water and increased irrigation WUE by 15-21 % over normal method of planting. Irrigation water applied through furrows facilitates wetting as well as aeration of crop root zone. The improved planting technique has the potential advantage of saving irrigation water and can bring more areas under irrigation for post-rainy season crops.

Paired row potato crop planting (left) and groundnut crop planted in paired row (right)

24. Micro Tube Wells in Coastal Areas Having Saline Groundwater Below 10 M

Relevance: The existing technology of exploiting groundwater through shallow/ deep tube wells will lead to draw water from saline aquifers in coastal areas especially those very near to sea within 2-5 km away from coastline. Therefore to provide irrigation to small farm holdings mainly during *rabi* season or at critical stage during long dry spell even in *kharif* season, strategically designed tube well is necessary.

Description of the technology: The design of very shallow tube wells should be such that the saline aquifer is not subjected to any withdrawal pressure. The depth of shallow tube well is within 10 m. The length of blind pipe and strainer pipe will depend upon the lithology of the area. The diameter of the well should be 5 cm and size of pump should be within 2hp capacity .The investment cost for providing irrigation through this system will be about Rs 4500 and it can command 1-1.5 ha area for standard *rabi* season crops. The cost of implementation of the technology is approximately Rs.14500 /ha.

Output and scalability: The technology has potential to generate Rs. 8,000/- extra gross income/ year with additional employment generation of 50 man days/ha. It can provide assured irrigation for growing paddy in 1 ha of land and increase in yield from 1.5 to 2 t/ha.

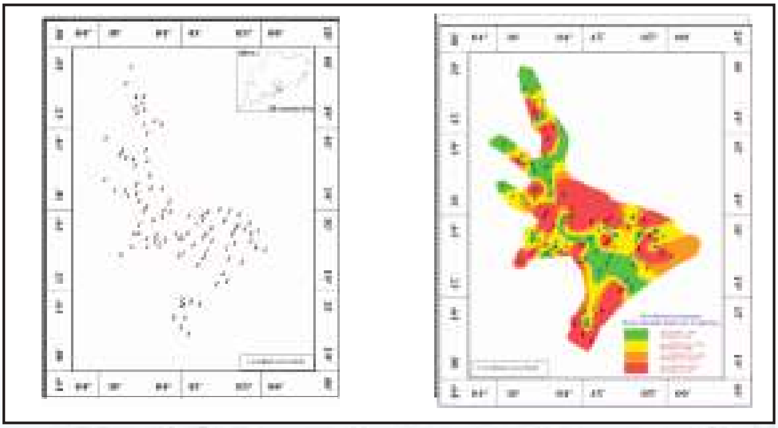
Crops grown with ground water in coastal area using micro tube well

25. Water Quality Index:tool to Assess Water Quality for Irrigation

Relevance: Water resources are not only becoming scarce but its quality is also deteriorating every day due to overexploitation of groundwater and discharge of untreated wastewater in surface water bodies. The increasing use of poor quality water in agriculture is adversely affecting the natural resources like soil, crop, and groundwater posing threat to agriculture. To assess the suitability of poor quality water/wastewater for irrigation,an Water Quality Index (WQI) was developed.

Description of the technology: WQI is an integration of the individual effect of all the parameters in right proportion in deciding the quality of water. The WQI single score is derived by considering different important parameters of water quality and computed in three steps. At first, each parameter is assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes based on per cent of samples within the permissible limit as per the standards. Weights of 5, 4, 3, 2, 1 are assigned to the quality parameters when 0-20, 21-40, 41-60, 61-80 and 81-100 % of samples are within the permissible limit respectively. Secondly, the relative weight (Wi) is computed and third step involves, assignment of a quality rating scale (qi) for each parameter according to the guidelines laid down by FAO and Bureau of Indian Standards(BIS) for irrigation and potable water quality respectively. For computing the WQI, the Sub Index (SI) is first determined for each chemical parameter, which is then summed up for all parameters to determine the WQI. The computed WQI values are classified "none", "slight", "moderate" and "severe" restrictions for irrigation use.

Output and scalability: The index was validated for irrigation water quality using Central Groundwater Board data and was found reliable and easy to compute. The index was also validated for groundwater quality of different villages along *Daya*River near Bhubaneswar city. Its applicability will help in decision making in reusing poor quality water safely for irrigation and also help in finding the causative contaminating factor for irrigation water.



Sampling location (left) and variation in irrigation water quality (FAO, right) at Rushikuliya command

26. Drainage Water Management in Medium and Lowlands

Relevance: About one-fourth of the cultivated area of 6.47 Mha area in Odisha is low land and are subjected to various degrees of waterlogged condition. Thereby productivity in these lands is dwindling. The major reasons are (i) the crops face an adverse edaphic environment due to excess water; and (ii) the traditional varieties grown are of long duration, constraining the increase in cropping intensity.

Description of the technology: A properly designed surface drainage system accelerates flow to an outlet without siltation and erosion of soil, and reduces depth and duration of ponding.

Output and scalability: The surface drainage density in Kushabhadra-Bhargabi doab (the land between two rivers) region of Mahanadi Delta increased the drainage density from 0.51 km / km^2 to 0.78 km / km^2 and thereby modifying the hydrograph of surface ponding in crop fields . Due to introduction of surface drainage system, the maximum ponding in the crop field was modulated to less than 0.5m whereas ponding of more than 1.1m was observed in the drain facilitating growing long duration high yielding paddy cultivars. The HYV of paddy cultivars which are about meter tall could be very well cultivated by the farmers. The post drainage HYV paddy varieties like CR-1009, CR-1014, CR-1018 and Samalai suitably replaced commonly used local varieties like Mayurkanta, Bhutia, Kalabegunia, Chanda and Kalakhajura .

Nutrient application through only FYM in pre drainage system period was 13.8 kg N / ha, 5.5 kg P_2O_5/ ha and 13.8 kg K_20 / ha. However after creation of well-designed drainage system, there is increase in chemical fertilizers application at an average rate of 283 kg/ha. Average productivity of paddy increased from 1.8 to 2.4 t/ ha. Further, there is scope to build auxiliary water bodies adjacent to the drainage system for fish production and irrigation to post- monsoon low duty crops.The technology can be upscaled in these areas affected by surface waterlogging condition.

Surface drainage network at Kushabhadra-Bhargavi Doab, Odisha

27. Optimum Crop Growth Stage for Drainage in Rice

Relevance: Rice farms in India suffer from both high water table and also surface waterlogging scenario The extent of damage to rice production due to poor drainage is about 20-30 percent of the total *Kharif* season production. Identification of crop growth stage of rice which responds well to drainage is the important factor that can augment the crop productivity in the areas where surface drainage is feasible. In addition to crop yield, this would also improve nitrogen use efficiency of rice crop.

Description of the technology: In the areas where surface drainage can be practiced, the farmers are required to drain the water from the field during tillering stage for about 8-10 days. The fertilizer N, P_2O_5 and K_2O of 60 kg/ha, 50 kg/haand 50 kg/ha respectively are required for *rice crop*. Drainage should not be done during panicle initiation stage of rice as this stage is very critical for moisture stress and maximum water is consumed during this period.

Output and scalability: In comparison with normal farmers' practice *i.e.* complete submergence, drainage at tillering stage has potential to result in 22 % higher grain yield and 18 % higher straw yield. In addition, drainage at tillering stage results in highest nitrogen use efficiency and generates additional net return of about Rs.3000 to Rs.4000/ ha compared to normal farmers' practice.

Effect of drainage on Improved growth of paddy

28. Biological Drainage of Waterlogged Lands in High Rainfall Areas

Relevance: In deltaic region of Orissa, with flat topography and 0.02% sto about 0.01% in the coastal proximal areas makes drainage very difficult especially in high rainfall scenario. The use of bio-drainage vegetation appeared feasible in deltaic areas both in inland topographical depressions and in areas where the natural drainage is incapacitated by sea water intrusion .

Description of the technology: *Eucalyptus* was planted at inland sites and *Casuarina* at coastal areas due to their salt tolerance ability. The 30 cm tall saplings were planted at 4mx4m spacing on raised mound to avoid submergence of roots during monsoon at least six month before onset of monsoon. The space in between the biodrainage trees were utilized for cultivation of other crops *i.e.* paddy during *kharif* and watermelon, green gram, black gram, cow pea and groundnut during *rabi* season. In topographically depressed areas plantations tolerated both surface waterlogging during monsoon and subsurface waterlogging during rest of the season. In coastal areas, *Casuarina* vegetation tolerated waterlogged condition during monsoon and also showed resilience against cyclones in coastal areas.

Output and scalability: In *kharif* season paddy intercrop produced upto 3.51 t/ha grain. In *rabi* season, intercrops like ground nut (yield upto 1.4 t/ha), watermelon (24.16 t/ha) showed better yield than non-biodrained areas. Accelerated drainage through biodrainage advanced watermelon cultivation in *rabi* season by 15-20 days with additional benefit of Rs.15,000 /ha due to better market price and avoiding market glut. The aquaculture intervention in the refuge at lowest point in the field gave yield of 1.35 t/ha Indian major carp, grass carp and air breathing fish. From watermelon cultivation under *Casuarina* plantation profit was Rs. 45,500/ha with B:C ratio of 3.67 (2009 prices). Under *Eucalyptus* groundnut cultivation gave Rs. 10,000/ha profit with B:C ratio of 2.0.*Casuarina* plantation gave an additional yield of upto 2.3 t/ha of twig biomass through pruning of trees as fuel wood worth Rs. 5500/ha as annual income to the farmer. Developed in collaboration with CADA, Govt. of Orissa, the technology is being popularized through line departments of State Government.

Paddy (in *kharif* season) and Watermelon crop intercrop (in *rabi* season) in *Casuarina* vegetation

29. Over-aged Rice Seedlings Cultivation for Waterlogged Areas

Relevance: India has 11.6 Mha area affected due to waterlogging. Paddy is single dominant crop in waterlogged environment. But yield is poor mainly due to unpredictability of extent of waterlogging in low lying areas. Use of over aged rice seedlings is promising in avoiding seedling mortality and low productivity in low-lying areas prone to waterlogging and can stabilize yield under such challenging ecosystem. Hence efforts were made to standardize agro-techniques for optimizing the age and size of seedlings for transplanting in low-lying areas.

Description of the technology: Technology for use of older seedlings was developed to enhance productivity of waterlogged areas. In low lying areas paddy crop is often affected by submergence due to water logging. Under such unfavourable ecology, use of taller, over aged 60d an old seedling avoid risk of submergence and has been found suitable for cultivation in low lying areas. The spacing were maintained at 20x20cm and PK fertilizers was applied @ 40:40 kg /ha.The entire dosage P and K was applied during sowing time.The application of N was split in three stages, *i.e.* 7 days after planting,at maximum tillering stage (58 days after transplanting) and at panicle initiation stage (93 days after transplanting) @ 20:10:10 kg /ha.

Output and scalability: Application of 40 kg/ha of N through mud ball (as in photograph below) significantly increased grain yield. Application of N through mud ball in three splits, at 7 days after planting, at maximum tillering and at grain filling was effective. Therefore cultivation of 60d old rice seedlings with 40kg/ha N through mud ball can be recommended for cultivation in low lying, submergence prone areas to avoid risk of crop failure due to submergence as well as to achieve better productivity.

Tall over-aged seedling being transplanted in farmers field at Jagatsingpur district, Odisha

30. Fitting Medicinal Plants in Rice Based Cropping System in Waterlogged Areas in Post Rainy Season

Relevance: Remarkable area under waterlogged ecosystem comes under seasonal waterlogging where after harvest of rice, the water recedes gradually within one month and it acts like a medium land situation. In such seasonal waterlogged areas, the land is kept fallow in general and in some patches, cultivation of blackgram is prevalent whose productivity is very low. Hence, there is a need to develop suitable alternate crop(s) after the harvest of rice in post rainy season under seasonal waterlogged ecosystem. Some medicinal plants like *Coleus forskholii* and *Eclipta alba* have better adaptation to such scenario and they have potential to be fitted well under such scenario.

Description of the technology: In post rainy season, the land is prepared for planting of stem cuttings of medicinal plants like *Coleus forskholii* and *Eclipta alba*. Fertilizer N, P_2O_5 and K_2O of 60 kg/ha, 50 kg/ha and 50 kg/ha are required for *Coleus forskholii*. Cuttings are planted at a spacing of 60x45 cm and the cost of cuttings is Rs.8000/ha. Two irrigations may be given at crop critical growth stages like tuber initiation and tuber development.

Output and scalability: The yield potential of *Coleus forskholii* in post rainy is 900 to 1200 kg /ha. The cultivation of coleus in post rainy season in waterlogged ecosystem results in the gross water productivity (Rs. 13.3/ m^3) and net water productivity (Rs. 5.42 /m^3) and provides additional net returns about Rs.32,000/- to Rs.44,000/ha (2009 prices).

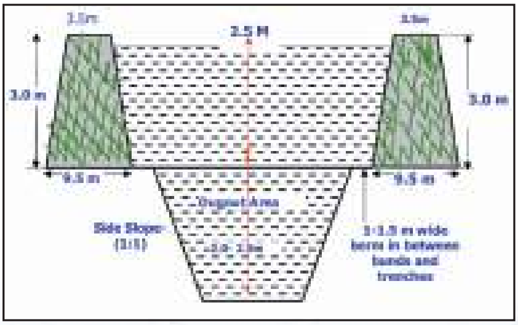
The crop of *Coleus forskholii* and *Eclipta alba* grown in waterlogged area in post rainy season

31. Pond Based Farming System for Deep Waterlogged Areas

Relevance: Due to poor drainage, saucer shaped topography and high monsoon rainfall, some parts of east coast of India remain waterlogged (> 1m surface water logging) and unproductive. To stabilize and enhance income from such waterlogged ecosystem, pond based farming technology was developed for seasonal deep waterlogged scenario of more than one meter surface waterlogging during monsoon.

Description of the technology: In such areas pond based farming technology (deep water rice in *kharif* + salt tolerant vegetables like watermelon, ladies finger, spinach, chili in winter + on-dyke vegetables-fruits + fish inside pond) was developed in deep waterlogged coastal areas(1-2.5 m water depth) of Puri district, Odisha. Micro-water harvesting system was designed (in Fig) and pond based farming system was implemented in the coastal areas of Puri district, Odisha. During rainy season waterlogging tolerant rice varieties were grown in command areas of each pond. After harvesting rice during dry season, second crops were grown on the same land with supplemental irrigations from the harvested rainwater in the pond. The cost of intervention is Rs. 65,000/ ha of net command area (2011 prices).

Output and scalability: The technology can generate additional net return of Rs. 25,000-30,000 /ha/year with increased water productivity of Rs. 7.2 /m^3 from the system. In a pond based farming area of 0.63 to 0.82 ha, Rs. 28317 to Rs. 31392 per ha net returns was obtained . From deep water rice farmers can get 2.4 – 2.8 t/ha yield but it depends on distribution of monsoon rainfall. The technology has potential to generate higher income due to intensive cropping with harvested water along with fisheries, and on-dyke horticulture. Farmers can also use harvested pond water for timely transplanting of rice during post flood period. Thus the non-productive waterlogged area can be converted into a productive and profitable system. The deep water rice represents 4.9 Mha areas of Eastern India and the technology has potential for adoption in the area.



A view of a pond in deep waterlogged area in Puri district, Odisha and its design(left)

32. Enhancing Productivity of Seasonal Deep Waterlogged Coastal Region

Relevance: Enhancing productivity in waterlogged area is a challenge as conventional agriculture is not feasible under such challenged ecosystem. Traditional rice variety fails to grow in areas with surface logging depth more than 0.75m. Therefore, high yielding deep waterlogging rice varieties needs to be tried on such challenging ecology to stabilize rice productivity for food security.

Description of the technology: Based on analyses of soil resources, hydrological parameters and agro-climate in seasonal coastal waterlogged area deep water rice cultivars like 'Hangseswari', 'Saraswati', 'Ambika', 'Sabita' were grown in *kharif* season. The aquaculture was taken up in the adjacent pond.

Output and scalability: The use of deep water rice cultivar 'Hanseswari' produced 2.4-2.5 t /ha yield in *kharif* season in deep waterlogged situation which was double than that of local cultivars. The State Government of Orissa released 'Hanseswari' to put under State Seed Chain and adopted for seed production in State Farm . By *kharif* 2009 about 180 farmers in 105 ha area adopted deep water rice production technology. The technology can be replicated in 3.4 Mha deep water areas of eastern India.Package of practices for cultivation of aquatic medicinal plants, Bach (*Acorus calamas*) was standardized and implemented in farmers' field of seasonal waterlogged areas with deep water rice.

Performance of Hanseswari in farmers' fieldin Puri district, Odisha

A medicinal plant batch (*Acorus calamas*) in deep waterlogged area

33. Integrated Water Chestnut Cultivation and Aquaculture Technology

Relevance: Aquatic crop like water chestnut (*Trapa bispinosa* Roxb.) or 'singhara phal or 'pani phal' or 'pani singhara' has natural adaptability to grow in areas where surface waterlogging extends more than six months in a year. As fish and aquatic crops integrate well under waterlogged ecology, integrated aquaculture is economically lucrative for better water productivity. The integration of water chestnut also offers surface cover protection to unprotected aquaculture.

Description of the technology: Depth of water between 0.5- 1.5 m is favorable for water chestnut cultivation and planting is done from early June to 1st week of July. Before planting seedlings are treated with fungicide and insecticide *i.e.* captan or carbandazime @0.1% with chloropyriphos @0.2% by dipping overnight (12 hour).Three to four young seedlings are loosely tied at the bottom in a knot. The knot is planted in the muddy bottom of the water body with gentle push with toe. At a spacing of 1.5m x 1.5m about 4400 bundles/ha of seedlings (each containing 3-4 seedlings) are required.

In fish-water chestnut integration, Indian Major Carp (IMCs), fingerlings of 35±5 g MBW size can be released during 2nd week of July at stocking density of 3000/ha, whereas cat fish (like Magur; *Clarius batrachus*) of 15 g MBW can be released with 5000-7500/ha stocking density during 1st week of August. In this co-production system fish gets natural food even in presence of supplemental feed. About 25-30% feed can be reduced during each meal. It also results an increase in gross and net water productivity of the system.

Output and scalability: The assessment of impact of the technology on farming situation and livelihood of farmers (on 35 farmers adopting integration of water chestnut (WCN) cultivation and aquaculture in Balasore district) showed increased average income of farmers by about Rs. 76000 /ha/year. The total average income of the farmers from the farming has increased by more than 50% after adoption of integrated water chestnut cultivation with aquaculture technology.The technology of integrated cultivation of fish and water chestnut was demonstrated to farmers of Balasore, Bhadrakh and Jagatsinghpur district in coastal Odisha. The shallow low land ecosystem provides ideal environment for cultivation of this crop during *kharif* season.

A view of integrated water chestnut aquaculture field in Bhadrak and Baleshwar district in Odisha

34. Cat tail (*Typha*) Production Technology for Waterlogged Areas

Relevance: In general under waterlogged condition, productivity of crops is extremely uncertain due to unpredictability of extent of rainfall, degree and duration of waterlogging and crop submergence. Therefore to address these uncertainties cultivation of aquatic hydrophytes with commercial importance like *Typha* provides assured income and stability of income even under severe waterlogged condition.

Description of the technology: Cat tail (*Typha elephantina* or *T. aungustifolia*, *T. domingensis* locally known as 'hogla') plant is an emergent hydrophyte. *Typha* grows well in marshy soils and make these areas productive. Though it is economically important and grows under subsistence farming, the plants rarely receive care of standardized cultivation practices. Application of N fertilizer @ 90kg/ha at basal stage before monsoon gave more leaf yield with better size and quality in waterlogged environment.

Output and scalability: The production of cat tail enhances the income of the farmers both from fresh leaves and mats. Total cost of cultivation including harvest and transport to mat knitter is about Rs.11, 900 per ha. Knitting cost of mats is about Rs.45,000 / ha @ Rs.10/mat. Income from fresh leaves is Rs.30,000/ha when considered @ Rs.40.00/bundle with 750 bundles/ha.Similarly, income from preparation of mats comes out to be Rs. 1,80,000/ha, when computed @ Rs.40/mat with 6 mats /bundle. The total B:C ratio from fresh leaves and mats realized is 2.52 and 3.16, respectively (2014 prices).

The crop needs minimum care and as non-food commercial crop has annual market demand for mats which are used as roof shed or light weight house material. The thread like leaf splits are also used to prepare floral garlands. The crop occupies marginal waterlogged areas mainly located in river banks and inland perennial waterlogged areas therefore do not compete for land with other crops. The main marketable produce is knitted mats and knitting work generates source of livelihood and better empowerment of rural women.

Farmers harvesting cat tail (*Typha* sp.) leaves and mats for sale in market

35. Crop Management Interventions in Post-flood Scenario

Relevance: In the recent years, due to climate change, the extent of crop damage due to flood incidence has further enhanced limiting the crop establishment and productivity. It warrants evaluation and adoption of crop management interventions for better flood resilience and contingency crop planning on the event of complete crop damage for post flood situation. This will benefit the farmers in about 40 million ha flood prone areas in India.

Description of the technology: In the flood prone areas, the crop establishment is a challenge and cultivation of suitable crops like okra, sunflower, sweet potato and bittergourd under zero tillage practice is found ideal due to better crop productivity and net economic returns. Inputs such as seed or stem cuttings are necessary in addition to fertilizer N, P_2O_5 and K_2O. The land should not be disturbed with farm implements during crop cultivation.

Output and scalability: In comparison with normal farmers' practice *i.e.* sole rice cultivation or rice-greengram cropping system, the cultivation of alternate crops *i.e.* okra, sunflower and bittergourd under zero tillage would result in additional crop productivity. Sun flower gave in seed yield of 0.91 t/ha under zero tillage compared to 0.82 t/ha under conventional tillage. Okra gave superior fruit yield of 3.73 t/ha under zero tillage compared to 3.26 t/ha under conventional tillage. Bitter gourd gave fruit yield of 4.30 t/ha under zero tillage compared to 4.06 t/ha in conventional tillage. The implementation of contingency crop plan, is expected to benefit farmers by generating additional net returns of Rs. 18,300/ha with sunflower, Rs. 26,100/ha with okra, Rs. 35,250/ha with bittergourd and Rs. 22,100/ha with sweet potato compared to their pre project status i.e. fallow land. This has potential to give advantage for farmers who practice of green gram cultivation after rice in non-flood prone areas in the vicinity with lower net returns of Rs. 13,600/ ha (2012 prices).

Paddy in flood prone waterlogged area in *kharif* season and Okra crop with zero tillage in *rabi* season

36. Swamp Taro: A Promising Vegetable Crop in Waterlogged Condition

Relevance: The cultivation of conventional crops in marshy waterlogged area is difficult and at times not economical. But a vast area of marshy or swamp land in India remains uncultivated where some crops can be economically grown. Few ariods mainly *Colocasia* sp. locally known as "pani kachu" or "lati" or "kachu lati" grow in marshy land or swamp land (hence known as swamp taro). The entire plant *viz* leaves, petioles and stolon or runners are popularly consumed as green vegetable in Uttar Pradesh., Assam, Bihar and West Bengal.

Description of the technology: The crop can be planted at a spacing of 60x75 cm during the month of January in marshy water logged condition. Defoliated petiole with root stock is used as planting material. The farm yard manure @ 8 t/ha was added at the time of field preparation and N:P:K fertilizers @ 52:60:63 kg/ha need to be applied in three doses at 2nd 5th and 8th month stage of the crop. Hand weeding were done each time before application of fertilizers. The runner, the edible part of the plant, is periodically harvested from 4-5th month stage after planting depending on the growth of the crop and marshy condition.

Output and scalability: The plants started yielding runners, which is the main edible part, from 4th month onwards. However yield increased significantly from 5th month reaching its peak at 7th month stage during peak monsoon period of July- August, which is a lean period for availability of other vegetable in the market. The runner yield decreases from 8th month onward till 10th month stage. A medium harvested crop can give up to Rs. 43, 000/ha gross income (2006 prices).Considerable area of marshy or swamp land in India remains uncultivated where this crop can be profitably grown.

The crop of swamp taro grown in field and close view of runners as edible part of the crop

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