वार्षिक प्रतिवेदन
ANNUAL REPORT

2013-2014

जल प्रबंधन निदेशालय

Directorate of Water Management

An ISO 9001:2008 Certified Organization

(Indian Council of Agricultural Research)

Bhubaneswar-751 023, Odisha, India

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(भारतीय कृषि अनुसंधान परिषद)
भुवनेश्वर, ओडिशा, भारत

Directorate of Water Management

(Indian Council of Agricultural Research)
Bhubaneswar-751023, Odisha, India
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भाकृ अनुप
ICAR

Annual Report 2013-14

DWM

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जल प्रबंधन निदेशालय
D. W. M

PREFACE

It is my privilege to bring out the Annual Report of Directorate of Water Management for the year 2013-14 containing the research achievements of the Institute under five different research programmes, *i.e.* rainwater management, canal water management, groundwater management, waterlogged area management and on-farm research and technology dissemination and other related information for the said period. During the year, Institute has made several significant research achievements through development and implementation of several on-farm water management technologies like successful installation of rubber dam technology in watersheds in different parts of the country, water and energy efficient farming system technology package have been developed to improve productivity of rainfed areas, understanding CO_2 emissions and sequestration, carbon and energy balances of multiple cropping systems under irrigated ecosystem, understanding soil water hydraulics for better water management in Indo-Gangetic plain and Black-Soil Region, use of industrial waste water, development of water quality index of ground water for irrigation, DSS driven strategic designs for water harvesting structures in waterlogged areas of Mahanadi basin for sustainable crop production, increasing nutrient utilization efficiency in waterlogged ecosystem. A web based information system on agriculture water management is also being developed for dissemination of state of the art on farm water management technologies for stake holders across the country. Twenty five centres operating under the All India Coordinated Research Project on Water Management have been engaged in research in different themes like basic studies on soil- water- plant relationships , application of pressurized irrigation system, management of rain and other natural sources of water and their interactions, water management for different agricultural production system including horticultural and other high value crops etc. in addition to organizing farmers and trainers training programmes. Under the All India Coordinated Research Project on Groundwater Utilization, nine centers were operating and were engaged in different areas like regional groundwater assessment and modeling, conjunctive use of surface and groundwater, artificial groundwater recharge, groundwater pollution and transfer of technology through organizing different training programmes for farmers. The report presents findings research activities of aforesaid different water management research programmes. I am sure that content of the report will be useful for the stakeholders at various levels engaged in the field of agricultural water management in the country.

As recognition of its significant contribution and excellence in research, DWM has been awarded ISO: 9001-2008 Certified Institute for Research in the field of Agricultural Water Management. The research accomplishment of the Institute has also been recognized by various institutions like Fulbright-Nehru Senior Research Fellowship 2012-13, USIEF Alumni Award 2012-2013, GCBR Award for popularization of Biological Sciences - 2013, several best paper and poster awards along with other recognitions.

During the year the Institute published 38 research papers in scientific peer reviewed journals of national and international repute along with twenty one research bulletins, information brochure, leaflets, training manual and books. In addition to Research Advisory Committee meeting and Institute Research Council meetings, the institute has also organized a ICAR sponsored 21 days summer school on “Bio-drainage for Reclamation of Waterlogging in High Rainfall Deltaic Areas”, a sensitization workshop on “Enhancing water use efficiency in Yamuna basin” along with NRM division of ICAR, inception Workshop on Evaluation of IWMP Watershed Projects, workshop on “Software installation-cum-training program” on SAS, a national workshop on “Water quality issues, opportunities and socio-cultural concerns of wastewater use in agriculture” supported by USIEF Alumni Award, Pre-Commercialization and stakeholders workshop on Rubber dam etc. In order to strengthen the statistical computation, the Institute provided training to 53 scientists and stakeholders on “Data Analysis using SAS”. One day stake holders' workshop on “Rubber dam technology for agricultural water management” was organized on 14th May 2013 on the occasion of foundation day of the Institute.

I express my sincere gratitude to Dr. S. Ayyappan, Director General, ICAR and Secretary, DARE, Government of India for his constant support and guidance. I am extremely grateful to Dr. A.K. Sikka, Deputy Director General (NRM), ICAR for his valuable guidance and suggestion at every stage of research and development planning of the Institute. My thanks are due to Dr. S.K. Chaudhari, Assistant Director General, (S&WM) for his help and cooperation for smooth functioning of the Directorate. I place on record my appreciation for the commendable work done by all the members of publication committee to bring out the annual report in time.

May 2014

(Ashwani Kumar)

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कार्यकारी सारांश

वर्षा जल प्रबंधन

- वर्ष 1990 से ओडिशा के चरम वर्षा सूचकांक के अध्ययन से तापमान में तेजी से वृद्धि के साथ लगातर बाढ़ एवं सूखा दोनों आपदाओं के अधिक होने का पता चला। समय के साथ चरम वर्षा सूचकांक विकास ने प्राकृतिक आपदाओं की भयावहता में वृद्धि की परिवर्तनशीलता का भी सुझाव दिया। वर्ष 1990 की पूर्व अवधि की तुलना में वर्ष 1990 के बाद गर्मी की लहर आवृत्ति एवं तीव्रता में एक सकारात्मक परिवर्तन हुआ।

- धान की उपज में कमी पर शुष्क अवधि के प्रभाव का विश्लेषण करने के लिये खरीफ 2013 में अनाज की उपज, पुआल (चारा) उपज एवं शुष्क बायोमास उर्वरक की सिफारिश की पूरी मात्रा के तहत सबसे अधिक प्राप्त हुए तथा उर्वरक मात्रा में 60% कमी के तहत सबसे कम प्राप्त हुयी। दो अनुपूरक सिंचाइयाँ धान की अधिक उपज के लिये एक सिंचाई की तुलना में बेहतर थी। एक्वा क्रॉप मॉडल की जांच के लिये प्रथम वर्ष के प्रयोग के आँकड़ों का उपयोग किया गया एवं द्वितीय वर्ष के प्रयोग के आँकड़ों से मॉडल का सत्यापन किया गया। सांख्यिकीय मूल्यांकन ने एक अच्छे मॉडल के अशांकन एवं सत्यापन का सुझाव दिया।

- एनएआइपी उप परियोजना "जल संभरण क्षेत्रों के लिये रबड़ बांधों का डिजाइन एवं विकास" के अंतर्गत रबर बांध की आधार संरचनाओं को इनलेट - आउटलेट तंत्र के साथ नौ स्थानों पर सफलतापूर्वक स्थापित किया गया। ओडिशा राज्य के विभिन्न जल संभरण क्षेत्रों में रबड़ बांधों के विकास ने फसल सधनता, ग्रामीण आजीविका में सुधार के विकल्प, फसल विकल्पों एवं फसल उत्पादन में वृद्धि का सुझाव दिया है। भारत के विभिन्न कृषि परिस्थितिकी एवं भू जलीय क्षेत्रों में अच्छी तरह सर्वेक्षण, डिजाइन एवं अनुमान करके 25 नये स्थानों पर रबड़ बांधों की आधार संरचनाओं की तकनीकी, हाइड्रोलॉजिकल एवं सामाजिक - आर्थिक मापदंडों के आधार पर स्थापना की गयी।

- आम की फसल पर विनियमित घाटा सिंचाई (आरडीआई) एवं पेड़ की आंशिक जड़ क्षेत्र सुखाने की विधि (पीआरडी) के साथ ड्रिप सिंचाई प्रयोग ने 10% एमिटर प्रवाह भिन्नता, 9% विभिन्नता गुणांक एवं 92% वितरण एकरूपता के माध्यम से ड्रिप पद्धति का सतोंषजनक हाइड्रोलिक प्रदर्शन दिखाया। पूर्ण सिंचाई उपचार के तहत आम पौधे की ऊंचाई, तने का व्यास एवं पत्तियों का आयतन सबसे अधिक पाया गया। 80% आंशिक जड़ क्षेत्र सुखाने की विधि (पीआरडी) के तहत अधिकतम फल उपज प्राप्त हुई एवं इसके बाद पूर्ण सिंचाई उपचार से अधिक फल प्राप्त हुये। सिंचित उपचार के तहत अधिकतम फल उपज, वर्षा आधारित पेड़ों की तुलना में 133% अधिक प्राप्त हुयी।

- ऑन स्टेशन खेती इकाई (3408.44 वर्ग मीटर), धान परती फसल अनुक्रम (₹27982:157.7 आदमी दिनों) की तुलना में अधिक शुद्ध लाभ (₹ 1,88,341/हेक्टेयर) एवं रोजगार (509.3 दिन हेक्टेयर) देती है। बंध के साथ तालाब द्वारा फसल में उच्चतम शुद्ध जल उत्पादकता (₹ 11.4/घन मीटर) प्राप्त हुई। इसके बाद तरबूज, भिंडी एवं सूखे मौसम वाली फसलों से अधिक जल उत्पादकता प्राप्त हुई। यधपि एकीकृत कृषि पद्धति में शुद्ध जल उत्पादकता (₹ 53.7 प्रति घन मीटर) अधिक प्राप्त हुई। लेकिन धान परती फसल अनुक्रम की तुलना में इससे ऊर्जा उत्पादकता कम प्राप्त हुई। 51 किसानों के सर्वेक्षण परिणाम ने दिखाया कि धान परती फसल अनुक्रम से शुद्ध लाभ केवल ₹ 17,750 था जबकि भूमि संशाधन के माध्यम से तालाब आधारित खेती पद्धति अपनाने से ₹ 50,680 प्रति हेक्टेयर तक की वृद्धि हो सकती है।

- धान-मक्का फसल पद्धति में पारंपरिक जुताई को धान एवं मक्का की अधिक उपज के लिये न्यूनतम एवं जुताई नहीं (जीरो टिलेज) से बेहतर पाया गया लेकिन संरक्षण प्रभाव की वजह से पिछले कुछ वर्षों में काफी अंतर कम हुआ। 50% अकार्बनिक +50% गोबर की खाद एवं 50% अकार्बनिक + 50% हरे पत्तों की खाद उपचारों की तुलना में अकार्बनिक उर्वरक (100%) के प्रयोग ने धान एवं मक्का की अधिक उपज का उत्पादन किया। गोबर की खाद का उपज पर प्रभाव हरे पत्तों की खाद की तुलना में बेहतर था। बिना जुताई (जीरो टिलेज) उपचार में फसल की कटाई के बाद मिट्टी में उच्चतम जैविक कार्बन पाया गया एवं मिट्टी में उपलब्ध नमी भी अधिक पायी गई। इसी प्रकार गोबर की खाद के उपचार ने एनपीके एवं हरे पत्तों की खाद के उपचार की तुलना में मिट्टी में बेहतर जैविक कार्बन एवं नमी को बनाये रखा।

- कार्प पॉलीकल्चर पद्धति में विभिन्न उपचारों (टी$_1$-6000 फिंगरलिंग/हे, टी$_2$-8000 फिंगरलिंग/हे एवं टी$_3$- 10000 फिंगरलिंग/हे) के हिसाब से अनुमानित कुल जल उपयोग क्रमशः 3.61, 3.82 एवं 4.24 हेक्टेयर मीटर था जबकि उपभोगी जल उपयोग सूचकांक क्रमशः 6.28, 5.51 एवं 5.79 घन मीटर प्रति किलोग्राम बायोमास था। इसी तरह, पी.मोनोडोन झींगा मोनोकल्चर पद्धति में विभिन्न भंडारण घनत्व के उपचारों के तहत (टी$_1$-15000 पोस्ट लार्वा / हे, टी$_2$-20000 एवं टी$_3$-25000) के हिसाब से कुल जल उपयोग क्रमशः 2.88, 3.14 एवं 3.49 हेक्टेयर मीटर था जबकि अनुमानित उपभोगी जल उपयोग सूचकांक क्रमशः 5.02, 4.62 एवं 4.86 था। कार्प पॉलीकल्चर में 8000 फिंगरलिंग्स के भंडारण घनत्व प्रति हेक्टेयर एवं मोनोडोन झींगा मोनोकल्चर में 20000 लार्वा प्रति हेक्टेयर से काफी अधिक उपज, आर्थिक लाभ एवं शुद्ध उपभोगी जल उत्पादकता प्राप्त होती है।

- एकीकृत कृषि पद्धति मॉडल के तहत बांध बागवानी, मछली पालन, मुर्गी पालन एवं बतख पालन के लिये पानी का अधिकाधिक उपयोग 10 जल संग्रहण संरचनाओं में किया गया। आर्थिक विश्लेषण ने बताया कि खेती पद्धति मॉडलों से शुद्ध लाभ में सुधार लाने के लिये ऊपरी भूभाग में मुर्गी पालन, तालाबों में मछली पालन एवं तालाब के तटबंधों के आसपास गहन खेती करना जरूरी है। तीन 1 दिवसीय प्रशिक्षण कार्यक्रम एवं दो एक्सपोजर दौरे किसानों के लिये आयोजित किये गये। इन तकनीकी उपायों के प्रभाव के विश्लेषणात्मक अध्ययन से किसानों के जीवन के रहने के समग्र स्तर के मानक मूल्य में (5-25 के पैमाने पर) 13.47% से 18.01% तक वृद्धि हुई।

नहरी जल प्रबंधन

- वर्ष 1993 से 2013 के दौरान हिराकुंड नहर कमांड क्षेत्र के मल्टी डेट रिसोर्स सेटेलाइट-1 एवं 2 से प्राप्त आँकड़ों से धान के क्षेत्र में 58-80% तक एवं अन्य फसलों के अंतर्गत क्षेत्र में 4.1-5.3% तक वृद्धि का पता चला। धान के खेतों से वाष्पीकरण, वाष्पोत्सर्जन एवं टपकन दरें क्रमश: 1.15 -2.15, 3.4-4.55 एवं 1.0-2.35 मिमी /दिन के बीच रही। लाइंड नहर में, अनलाइड नहर की तुलना में जल संप्रेषण हानि 84.8% कम थी। जबकि सिंचाई प्रयोग क्षमता 23.95 से 53% के बीच दर्ज हुयी। इस अनुकूलित फसल मॉडल तकनीक ने इष्टतम भूमि एवं जल के उपयोग के लिये प्रत्येक आउटलेट के लिये पानी की उपलब्धता की समस्या के साथ खेती से अधिक से अधिक क्षेत्र का उपयोग करने के उद्देश्य को अपनाये जाने का सुझाव दिया। प्रत्येक आउटलेट के लिये पानी की उपलब्धता की कमी की समस्या के साथ हेवी ड्यूटी फसल (धान) की प्राथमिकता के साथ अधिकतम क्षेत्र का उपयोग करने के उद्देश्य को अपनाया जा सकता है एवं धान के तहत कम से कम एक तिहाई क्षेत्र को अपनाया जाये।

- शुद्ध पारिस्थितिकी तंत्र एक्सचेंज में दैनिक भिन्नता (एनइइ) ने बताया कि अधिकतम एनइइ 11.30 घंटे पर प्राप्त हुयी जो कि पत्ती क्षेत्र सूचकांक से अत्यधिक प्रभावित होती है। भिंडी में माध्यमिक शाखाओं (32 दिन) की अवधि से लेकर फल तोड़ने के 10 दिन पहले (69 दिन) तक की अवधि तक पत्तियों में श्वसन की प्रक्रिया में कार्बन डाई ऑक्साइड छोडने की तुलना में अधिक प्रकाश संश्लेषण की क्रिया में कार्बन डाई ऑक्साइड ग्रहण के कारण एनइइ का नकारात्मक मूल्य दर्ज हुआ। भिंडी में एनइइ का मूल्य, अधिकतम पत्ती क्षेत्र सूचकांक अवधि (55 दिन बुआई के बाद) पर दिन के मध्य में -18.5 माइक्रो मोल कार्बन डाई ऑक्साइड/वर्ग मीटर/सेकंडे के ग्रहण एवं रात में +4.55 माइक्रो मोल कार्बन डाई ऑक्साइड/वर्ग मीटर/सेकंड छोडने के साथ अधिकतम था। टिल्लारिंग अवस्था से धान का खेत एक शुद्ध कार्बन डाई ऑक्साइड सिंक बन गया। धान में एनइइ का मूल्य, बूट लीफ अवधि (76 दिन बुआई के बाद) पर दिन की मध्य अवधि में -22.9 माइक्रो मोल कार्बन डाई ऑक्साइड/वर्ग मीटर/सेंकंड के ग्रहण एवं रात में +4.06 माइक्रो मोल कार्बन डाई ऑक्साइड / वर्ग मीटर/ सेंकड छोडने के साथ अधिकतम था। तीन (3) नहर कमांड क्षेत्रों में बनाये गये जल संसाधनों से तालाब आधारित खेती पद्धतियों (फसलों, बांध बागवानी एवं मछली पालन) को जल उत्पादकता को बढ़ाने के लिये एवं सूखे की अवधि को कम करने के लिये विकसित किया गया। इस क्षेत्र की जल उत्पादकता में 1.1 से ₹ 1.42 /घन मीटर तक वृद्धि हुई जो अकेले धान एवं तालाब आधारित खेती से ₹ 6.35 -7.95 प्रति घनमीटर के बीच प्राप्त हुई। केंन्द्रापाड़ा जिले के तालाब आधारित खेती क्षेत्र में एक निश्चित जल उपलब्धता के कारण तालाब के कमांड क्षेत्रों की फसल सघनता में 2 से 2.5 गुना वृद्धि हुई एवं शुद्ध आय में ₹ 48,665 से ₹ 66,170 तक वृद्धि हुई।

- ओडीशा के नयागढ़ जिले में दसपाला ब्लॉक में कुंवारिया मध्यम सिंचाई परियोजना के अंतर्गत विभिन्न सब माइनरों जैसे खमारसाही, मध्यखंड, लुणीसारा एवं सोरोडा में तालाब आधारित पद्धतियों को बहुत लाभकारी पाया गया। मछली उपज 2.46 से 2.88 टन/हेक्टेयर के साथ सकल एवं शुद्ध जल उत्पादकता क्रमश: ₹ 6.447-7.79 एवं ₹ 4.6-5.72 प्रति घन मीटर के रुप में 210 दिनों में प्राप्त हुई। वर्षा अपवाह जल संचयन टैंक एवं खुले कुओं के निर्माण से खमारसाही उप माइनर में वैकल्पिक फसल पद्धतियों जैसे धान + (तालाब में मछली) - मूंग, धान + (तालाब में मछली)- उड़द एवं धान + (तालाब में मछली)- अरहर आदि को धान - मूंग एवं धान- उड़द फसल पद्धतियों की जगह अपनाया गया; मध्यखंड उप माइनर में धान-परती एवं धान - उड़द फसल पद्धतियों की जगह धान + तालाब में मछली + अरहर (तटबंध पर) - मूंग एवं धान + (तालाब में मछली) + अरहर (तटबंध पर) - अरहर (तटबंध पर) आदि फसल पद्धतियों को अपनाया गया। लुणीसारा उप माइनर तथा सोरोडा उप माइनर में धान-परती फसल पद्धति की तुलना में धान +(तालाब में मछली) - मूंग फसल पद्धति को अपनाया गया। इन चार उप माइनरों में फसल पद्धति में खेती की लागत ₹ 1,19,772 से ₹ 1,24,230 के मध्य प्राप्त हुई।

- सघन धान पद्धति में अकार्बनिक खाद के प्रयोग से उच्चतम अनाज उपज प्राप्त हुई। एसआरआई में समन्वित पौषक तत्व प्रबंधन विधि ने रोपित धान में समन्वित पोषक तत्व प्रबंधन की तुलना में 43% तक अनाज उपज को बढ़ाया। जैविक खाद के तहत एसआरआई पद्धति में रोपित धान की तुलना में 31% तक अनाज भरना (%), एवं 1000 अनाज दानों के वजन में उल्लेखनीय वृद्धि आदि प्रमुख थे। एसआरआई धान की फसल में शारीरिक (पौधे की ऊंचाई, टिल्लरिंग एवं जड़ विकास) एवं आकारिकी क्षमता में काफी सुधार हुआ। रबी सीजन में जैविक खाद प्रयोगित एसआरआई धान के खेत में फसल चक्रण में उड़द की फसल के वर्ग रोपण ने सबसे अधिक उपज दी। वर्ग रोपण में उड़द की औसत उपज में बीज छिड़काव विधि की तुलना में 73% (1.04 टन/हेक्टयर) अधिक वृद्धि हुई जिसका मुख्य कारण पौधे की रूपात्मक (पौधे की ऊंचाई, शाखा एवं पत्तीयों की संख्या में वृद्धि) तथा फसल की उपज योगदान विशेषताओं में महत्वपूर्ण सुधार प्रमुख था।

- दो पार्श्व लेआउट के साथ ड्रिप विधि के तहत घाटा सिंचाई पर क्षेत्र प्रयोग का खरीफ धान एवं शिमला मिर्च की फसलों में मूल्यांकन किया गया। सतह सिंचाई के साथ एवं 1.0 मीटर पार्श्व में इष्टतम ड्रिप सिंचाई के साथ धान की अनाज पैदावार बराबर प्राप्त हुयी। हालांकि, ड्रिप सिंचाई में सतह सिंचाई की तुलना में 30% सिंचाई पानी की बचत हुई एवं सिंचाई जल उपयोग दक्षता में 50% का सुधार प्राप्त हुआ। शिमला मिर्च फसल में ड्रीप सिंचाई जल उपयोग दक्षता में 50% का सुधार प्राप्त हुआ। शिमला मिर्च फसल में ड्रीप सिंचाई 50% क्रॉप इवेपोट्रांस्पिरेसन पर फूल एवं फलने की अवस्था को छोड़कर 1.0 मीटर और 1.4 मीटर पार्श्व दूरी के पार्श्व लेआउट के साथ सिंचाई ने बताया कि फल उपज प्रतिक्रिया उच्च सिंचाई स्तर के साथ अधिक थी। हालांकि, 75% क्रॉप इवेपोट्रांस्पिरेसन पर सिंचाई से पूर्ण सिंचाई के समान फल उपज प्राप्त हुई।

भूजल प्रबंधन

- हाल ही में भारत में जनवरी 2003 से अगस्त 2013 तक ग्रैविटी रिकवरी एवं जलवायु एक्सपरिमेंट (ग्रेस) उपग्रह के आँकड़ों का उपयोग करके स्थलीय जल संग्रहण में परिवर्तन एवं जलवायु परिवर्तन के साथ उसके संबंधों के विश्लेषण के परिणाम ने बताया कि गंगा बेसिन में स्थलीय जल

संग्रहण एवं भूजल दोनों में काफी गिरावट आई है। ग्रेस उपग्रह भारत की मौसमी एवं मासिक स्तर पर जल विज्ञान के बारे में बताता है जिसका उपयोग जल प्रबंधन के लिये कुशलता से किया जा सकता है। पंजाब, हरियाणा एवं दिल्ली के आसपास के क्षेत्रों की सतह एवं उपसतह में जल के स्तर में गिरावट के कारण हॉटस्पॉट के रूप में पहचान की गयी है।

- हार्ड रॉक भूगर्भिय भूजल सिंचित क्षेत्रों के लिये लंपड भूजल मॉडल का विकास किया गया एवं इसका वालायार उप बेसिन के लिये परीक्षण किया गया। सूखे की घटनाओं के कारण अतिरिक्त भूजल पुन:भरण आवश्यकता का अनुमान लगाने के लिये इस मॉडल को प्रमाणित, सत्यापित एवं उपयोग किया गया। वालायार उप बेसिन के पोलाची क्षेत्र में अनुकरण के आधार पर अतिरिक्त भूजल पुन:भरण 21 से 24 सेमी के मध्य था तथा किनथकाडावु क्षेत्र के लिये 26 से 29 सेमी के मध्य था। अतिरिक्त पुन:भरण के अनुकरणित एवं मान्य मूल्य एक समान थे लेकिन ऊपरी सीमा की ओर मान्य मूल्य अधिक थे। इसका प्रमुख कारण पिछले 21 वर्षों में हुयी अधिक गंभीर सूखे की वजह हो सकती है।
- ओडिशा में महाकालपड़ा ब्लॉक के सुनीति गांव एवं आसपास के क्षेत्रों में वर्ष 2000 से 2006 के बीच की अवधि में भूमि उपयोग एवं भूमि कवर परिवर्तन की लैंडसैट इटीएम + छवियों का उपयोग करके निगरानी की गई। वहाँ पर कृषि एवं अन्य वनस्पति क्षेत्र में वृद्धि क्रमश: 2.80% से 8.01% थी जबकि जल फेलाव क्षेत्र, मिट्टी एवं बंजर क्षेत्रों में कमी 6.54% से 4.27% तक थी। हस्त चलित हैंड पंप के जल में पीएच की भिन्नता सतही जल से अधिक दर्ज हुयी जबकि विद्युत चालकता सतही जल में अधिक थी एवं इसका प्रमुख कारण समुद्र से जुड़ा होना हो सकता है। समुद्र की ओर प्रत्येक किलो मीटर दूरी पर जल के नमूनों की पीएच एवं EC में वृद्धि क्रमश: 0.185 $dS\ m^{-1}$ से 1.745 $dS\ m^{-1}$ की दर से वृद्धि हुई। नलकूपों में इनकी मात्रा क्रमश: 0.0682 से 0.778 $dS\ m^{-1}$ थी।
- यूनाइटेड ब्रुअरीज, शक्ति शुगर्स डिस्टीलरी एवं कोस बोर्ड पेपर मिल के अपशिष्ट जल प्रवाह मिट्टी में कार्बनिक कार्बन एवं उसके अंश मे सुधार करते हैं। चार अलग अलग प्रकार की मिट्टियों में कार्बनिक कार्बन उच्चतम मूल्य से लेकर (0.25%) के साथ पाया गया। मिट्टी में कार्बनिक कार्बन पर उच्चतम प्रभाव (प्रारंभिक से 2 से 3 गुना अधिक) डिस्टीलरी अपशिष्ट प्रवाह के तहत पाया गया जबकि पेपर मिल अपशिष्ट प्रवाह एवं ब्रुअरीज अपशिष्ट प्रवाह के प्रभाव बराबर थे। कोस बोर्ड पेपर मिल अपशिष्ट प्रवाह केल्सियम, मेंग्नेसियम, सल्फेट एवं क्लोराइड युक्त तत्वों से भरपूर था जो कि लाल एवं लेटराइटिक, जलोढ़, तथा लाल एवं पीले रंग की मिट्टीयों के लिये एक अच्छे सिंचाई स्रोत के रूप मे उपयोग किया जा सकता है। ढ़ेंकानाल जिले में शक्ति शुगर्स लिमिटेड के आसपास के भूजल स्रोत के जल गुणवत्ता मूल्यांकन ने बताया कि 57.89% जल पीएच से प्रभावित हो रहे हैं एवं प्रत्येक 10.53% जल को क्लोरीन एवं मेंगनीज तत्वों की मात्रा के कारण सिंचाई के लिये पसंद नहीं किया जाता है। पीएच, EC एवं मेंगनीज को इस क्षेत्र में जल की गुणवत्ता की जांच के लिये प्रमुख पैरामीटर माना जा सकता है।
- घरेलू एवं नगरपालिका अपशिष्ट जल में कई कंटामिनेंट्स उपस्थित रहते हैं जिनको छानने के लिये मोटे मेटेरियल के साथ जैसे बजरी, रेत कणों (2 मिमी से कम) एवं जूट फाइबर संयोजन के उपयोग से एक फिल्टर बनाया गया। यह फिल्टर तलछट एवं कुल माइक्रोबियल (कॉलिफोर्म एवं ई. कोलाई) की संख्या को कम करने में सहायता करता है। इस फिल्टर में महीन कण के रूप में चारकोल का उपयोग अपशिष्ट जल से केडमियम तत्व को अलग करने के लिए किया गया एवं इसकी क्षमता को पीएच में फेरबदल करके बढ़ाया जा सकता है।
- एक पोर्टेबल छोटी ड्रिप सिंचाई पद्धति का जल संसाधन से कम मात्रा में जल परिवहन के साथ एक सामान्य ढलान क्षेत्र के लिये डिजाइन किया गया जो 50-75 सेमी दबाव के हैड के साथ काम करती है।
- भारतीय एवं एफएओ मानको के आधार पर रासायनिक मापदंडों की सहायता से पोटेबल एवं सिंचाई के लिये उपयुक्त भूजल की गुणवत्ता के आकलन के लिये जल गुणवत्ता इंडेक्स का विकास किया गया। इसके बाद केंन्द्रीय भूजल बोर्ड, भुवनेश्वर से प्राप्त रूशिकुलिया कमांड क्षेत्र के भूजल गुणवत्ता आँकड़ों को सत्यापित किया गया। लगभग 45.5% भूजल के नमूने (जल गुणवत्ता इंडेक्स 100.98 से 196.32 के बीच) उच्च कठोरता, क्षारीयता, मेंग्नेशियम एवं नाइट्रेट की अधिकता की वजह से पीने के उपयोग के लिये अनुपयुक्त थे तथा 30.03% नमूने (जल गुणवत्ता इंडेक्स 458.3 से 5596.4 के बीच) समुंद्र जल की प्रवेशता के कारण सिंचाई के उपयोग के लिये प्रतिबंधित थे।
- रिमोट सेंसिंग एवं जीआईएस विधि का उपयोग करके कृषि जलवायु क्षेत्र-VI में प्रमुख फसल पद्धति (धान-गेंहू) एवं मिट्टी समूह को चित्रित किया गया। कृषि जलवायु क्षेत्र-VI के कुल भौगोलिक क्षेत्र 11.4 मिलियन हेक्टेयर में से 5.8 मिलियन क्षेत्र (50.87) पंजाब एवं हरियाणा राज्यों में धान-गेहूं फसल पद्धति के प्रसार के अंतर्गत है। इस कृषि जलवायु क्षेत्र में 36 लाख हेक्टेयर धान की फसल का है जिसमें से क्रमश: 2.6 एवं 1.05 मिलियन हेक्टेयर क्षेत्र मुख्य रूप से पंजाब एवं हरियाणा राज्यों में है।
- विभिन्न बायोक्लाइमेटिक सिस्टम के तहत इंडो गंगीय मैदानों एवं काली मिट्टी क्षेत्रों की मिट्टी की संतृप्त हाइड्रोलिक चालकता ने सुझाव दिया कि काली मिट्टी क्षेत्रों में मृदा कण आकार वितरण हाइड्रोलिक चालकता के लिये महत्वपूर्ण कारक है जबकि इंडो गंगीय मैदानों में हाइड्रोलिक चालकता के लिये मिट्टी में जैविक कार्बन प्रमुख निर्धारक था। इस मिट्टी में हाइड्रोलिक चालकता मॉडल को केल्सियम कार्बोनेट एवं विनिमेय सोडियम प्रतिशत (ईएसपी) के आधार पर मजबूत किया एवं प्रबंधन के तरीकों के माध्यम से वांछित स्तर तक मॉडल का स्कोप बनाये रखा गया। मिट्टी की नमी विशेषता ग्राफों के मोड़ बिंदु के आधार पर मिट्टी गुणवत्ता सूचकांक का आकलन किया गया एवं इंडो गंगीय मैदानों एवं काली मिट्टी क्षेत्रों में मिट्टी गुणवत्ता पर प्रबंधन के तरीकों के प्रभाव की व्याख्या की गयी।

जलाक्रांत क्षेत्र प्रबंधन

- ओडिशा के केंन्द्रापाड़ा जिले के पट्टामुंडई ब्लॉक में 41 हेक्टेयर के सतही जलाक्रांत क्षेत्र में चार फार्म तालाबों की पहचान कर स्थानिक खेत जल

संसाधन योजना बनायी गयी। गोल प्रोग्रामिंग तकनीक ने 75% जल उपलब्धता के साथ अधिकतम लाभ एवं उत्पादन के लिये 20 हेक्टेयर में खरीफ धान का, 24.1 हेक्टेयर में रबी टमाटर का एवं 5.9 हेक्टेयर में बैंगन की फसल का इष्टतम फसल आवंटन का सुझाव दिया। एक 3.5 किमी लंबी जल निकास नाली (ड्रेन) फसल के खेतों में सफलतापूर्वक संग्रहीत जल भराव को कम करने के लिये उपयुक्त है इस जल निकास नाली से जल निकासी परिदृश्य के बाद में 2.3 से 3.1 टन/ हेक्टेयर फसल उपज मे वृद्धि हुई तथा जल निकासी परिदृश्य के पूर्व में फसल उपज केवल 1.2 टन / हेक्टेयर ही प्राप्त हुई। 152 मिमी के शिखर वर्षा जल निकासी पद्धति ने सफलतापूर्वक धान के खेत में 49 सेमी तक जल भराव को कम कर दिया।

- जलाक्रांत पारिस्थितिकी तंत्र में धान आधारित फसल पद्धति में पोषक तत्व उपयोग क्षमता का अध्ययन किया गया। इस अध्ययन ने बताया कि उथले जल भराव (10 से 15 सेमी जल भराव) के तहत उच्च धान उपज (3.8 टन/ हेक्टेयर) प्राप्त हुई जबकि 25 से 50 सेमी के मध्यवर्ती जल भराव स्तर से केवल 3.5 टन/हेक्टेयर धान उपज प्राप्त हुई। नाइट्रोजन उर्वरक को 60 किलोग्राम/हेक्टेयर की दर से छिड़काव विधि (3.49 टन/हेक्टेयर) की तुलना में बैंड प्लेसमेंट विधि से प्रयोग करने पर 3.82 टन हेक्टेयर की धान उपज प्राप्त होती है। डाइसाइनोडाइआमाइड (DCD) के मिश्रण के साथ नाइट्रोजन उर्वरक को 60 किलाग्राम /हेक्टेयर की दर से प्रयोग करने पर नीम लेपित यूरिया एवं जल प्रबंधन निदेशालय द्वारा निर्मित खाद की तुलना में उच्चतम धान अनाज उपज 4.1 टन/हेक्टेयर प्राप्त हुई एवं 26.5 किलो अनाज प्रति किलो नाइट्रोजन के रूप में अधिक नाइट्रोजन उपयोग क्षमता भी प्राप्त हुई।
- फसलों में क्रोमियम, केडमियम एवं सीसा (पीबी) तत्वों के स्थानांतरण कारकों का क्रमशः चौलाई (एमेरेन्थस), टमाटर, तरबूज, मालाबार क्लाइम्बिंग, करेला, भिंडी एवं तोरई में घटता हुआ क्रम प्राप्त हुआ। पत्तों के ऊतकों में फल से अधिक धातु (मेटल) जमा हुये। केडमियम की वर्गीकृत सांद्रता के साथ क्षेत्र प्रयोग में उच्च केडमियम स्तर पर शुद्ध प्रकाश संश्लेषण की दर एवं सब्जियों की उपज में कमी देखी गयी। भिंडी की फसल में सिंचाई के दिन कुल कॉलिफोर्म, ई. कोलाई एवं अन्य जीवाणुओं का प्रारंभिक लोड (3.02, 1.80 एवं 3.50 लॉग सीएफयू प्रति ग्राम) सबसे कम प्राप्त हुआ एवं करेला तथा तोरई की सब्जियों में सबसे अधिक था।
- ओरसाक् (ORSAC), भुवनेश्वर से तीन सत्रों खरीफ, रबी एवं जायद (गर्मियों) से अवधि 2005-2006 के लिये लिस-III (1:50000 पैमाने पर) से एकत्र आँकड़ों से ओडिशा में 17 विभिन्न प्रकार के जल निकायों एवं जल भराव क्षेत्रों के होने का पता चला। केंन्द्रापाड़ा जिले में वर्ष भर बहने वाली नदियों एवं धाराओं के तहत उच्चतम 11,229.41 हेक्टेयर क्षेत्र का पता चला तथा जगतसिंहपुर जिले में यह क्षेत्र 10,884.42 हेक्टेयर था। बालेश्वर एवं केंन्द्रापड़ा जिलों में क्रमशः 556.98 एवं 169.97 हेक्टेयर मानव निर्मित जल भराव क्षेत्र का पता चला है।
- कृषि जल प्रबंधन पर एक वेब आधारित सूचना पद्धति (वेब पोर्टल) जिसमें कृषि जल सूचनायें जैसे अनुसंधान, किसानों, सेवा डोमेन, ई-लर्निंग मॉड्यूल एवं अन्य सूचनाओं आदि के साथ विकसित किया जा रहा है। इस पद्धति से एआइसीआरपी, जल प्रबंधन के सभी 25 केन्द्रों से प्राप्त सामान्य एवं अनुसंधान से संबंधित जानकारी को आम जनता द्वारा उपयोग के लिये प्रदान की जायेगी। प्रकाशित साहित्य, बुलेटिनों, क्षेत्रीय भाषा एवं अन्य भाषाओं में कृषि जल प्रबंधन के लिये पत्रक (लीफलेट) आदि को ई-पुस्तकें स्वरूप में वेबपेज में अपलोड किया गया है।
- भारत के प्रमुख तीस कृषि जलवायु क्षेत्रों में 10 साल के लिये धान, गेहूं, मक्का, ज्वार एवं बाजरा की फसलों की वास्तविक फसल पैदावार का अनुमान लगाया गया। पैयार जलवायु क्षेत्र में उच्चतम धान उपज (3.26 टन/हेक्टेयर) दर्ज की गयी जबकि जबलपुर जलवायु क्षेत्र में सबसे कम धान उपज (0.87 टन/हेक्टेयर) दर्ज हुयी। लुधियाना जलवायु क्षेत्र में उच्चतम गेंहु उपज (4.59 टन /हेक्टेयर) का पता चला जबकि पालमपुर जलवायु क्षेत्र में सबसे कम गेंहू उपज (1.37 टन/ हेक्टेयर) का पता चला।

खेतों पर अनुसंधान एवं तकनीकी प्रसार

- ग्रामीण, आर्थिक, सामाजिक एवं संस्थागत विकास की गतिशीलता को संबोधित करने के लिये विश्वसनीय घरेलू, व्यक्तिगत, क्षेत्र विशिष्ट, कृषि, श्रम, व्यय, आय एवं साल भर में खपत के आँकड़ो की उपलब्धता बढ़ाने के लिये नियमित रूप से अध्ययन किया जा रहा है। यह अध्ययन खेत आकार समूहों में घर एवं गांव की अर्थव्यवस्थाओं पर प्रकाश डालकर गरीबी को कम करने की गतिशील प्रक्रिया को समझने के लिये किया गया है।
- राष्ट्रीय कृषि अनुसंधान सिस्टम की कम्प्यूटेशनल क्षमता को मजबूत बनाने के क्रम में पूर्वी क्षेत्र के 33 वैज्ञानिकों एवं शोधकर्ताओं को 6 दिवसीय प्रशिक्षण कार्यक्रम के तहत सास (SAS) सॉफ्टवेयर का उपयोग कर अग्रिम सांख्यिकीय उपकरण एवं तकनीकों के उपयोग के बारे में प्रशिक्षण दिया गया। बीस नोडल अधिकारियों को भी सॉफ्टवेयर स्थापना में प्रशिक्षित किया गया।
- ओडिशा राज्य के सुंदरगढ़ जिले में जनजातीय उपयोजना (टीएसपी) के अंतर्गत घुरलीजोर लघु सिंचाई परियोजना में सिंचाई की बुनियादी सुविधाओं को बढ़ाने के माध्यम से भूमि एवं जल उत्पादकता में सुधार करने के लिये बिरजाबरना गढ़ुआमुंडा लिंकेज टैंक का चयन किया गया क्योंकि यहाँ पर लगभग 50 सक्रिय किसान परिवार विभिन्न लाभकारी कृषि गतिविधियों में लगे हुये हैं। लिंकेज टैंक में इनलेट, आउटलेट एवं सरप्लस इस्केप आदि का कमांड क्षेत्र में नहर के पानी के समुचित वहन के लिये निर्माण किया गया। नीची भूमि वाले क्षेत्रों में ऊँची-नीची क्यारी विधि की तकनीक को फसल विविधीकरण के लिये अपनाया गया।

EXECUTIVE SUMMARY

RAINWATER MANAGEMENT

- The study of extreme rainfall indices of Odisha showed since the 1990's, consistent occurrences of more both the floods and droughts with a sharp rise in temperatures. Temporal evolution of the extreme rainfall indices also suggested of late increased variability in magnitude of the opposite anomalies. There is a positive shift in heat wave frequency and intensity since the 1990's, compared to pre-1990 period.
- In order to analyze the effect of dry spell occurrence on reduction in paddy yield second year experiment in kharif 2013 showed that grain yield, straw yield and dry biomass were highest under recommended dose of fertilizer and was lowest under 60% of that dose. Two supplementary irrigations were better than single irrigation for higher yield. The calibration of the AquaCrop model was done using first year experiment data and validation was done using the second year experiment data. The statistical evaluation suggested a reasonably good calibration and validation of the model.
- Under NAIP sub-project on "Design and development of rubber dams for watershed" rubber dam base structures were installed successfully at nine locations with anchoring and inlet-outlet mechanism. The impact or benefits of rubber dams in different watersheds in Odisha suggested an increase in crop production, cropping intensity and improved rural livelihood options. Reconnaissance survey, design, estimate and installation of base structure of rubber dams at 25 new locations in different agro-ecological and geo-hydrologic regions of India was done, based on technical, hydrological and socio-economic parameters.
- The drip irrigation experiment with regulated deficit irrigation (RDI) and partial root zone drying (PRD) of mango trees showed satisfactory hydraulic performance of the drip system through 10% emitter flow variation, 9% coefficient of variation and 92% distribution uniformity. The plant height, collar diameter and canopy volume were highest under full irrigation treatment. Maximum fruit yield was obtained under 80% PRD treatment followed by full irrigation treatment. The maximum yield under irrigated treatment was 133% higher than the rainfed trees.
- The on-station farming system unit (3408.44 m^2) gave more net return (₹ 1,88,341 ha^{-1}) and employment (509.3 man-days ha^{-1}) than rice-fallow sequence (₹ 27,982; 157.7 man days). The pond with the bund was found best system with highest net return of ₹ 363750 ha^{-1}. Bottle gourd had highest net water productivity of 11.4 followed by water melon, okra and dry season field crops. In integrated farming system eventhough net water productivity was high (₹ 53.7 m^{-3}) the energy productivity was less compared to rice-fallow sequence. Survey result of 51 farmers showed net returns from rice – fallow sequence was ₹ 17,750 ha^{-1} which increased to ₹ 50680 ha^{-1} in pond based farming system through land modification.
- Conventional tillage was found better than minimum and no till system for higher rice and maize yield in rice-maize cropping system but their difference reduced considerably over the years due to conservation effects. Inorganic fertilizers (100%) produced higher rice and maize yield over 50% inorganic + 50% FYM and 50% inorganic + 50% green leaf manuring (GLM). An effect of FYM was better than GLM on yield. Highest soil organic carbon and available soil moisture were found after harvest of the crop in 'no till' compared to other treatments. Similarly, FYM treatment maintained better SOC and soil moisture than NPK and GLM treatments.
- In carp polyculture system, treatment-wise estimated total water use (TWU) was 3.61, 3.82 and 4.24 ha-m, while consumptive water use index, CWUI was 6.28, 5,51 and 5.79 m^3 kg^{-1} biomass, in T1 (6000 fingerlings ha^{-1}), T2 (8000 ha^{-1}) and T3 (10000 ha^{-1}) respectively. Similarly, under different stocking density in shrimp monoculture system of *P. monodon*, treatment-wise estimated TWU was 2.88, 3.14 and 3.49 ha-m, CWUI was 5.02, 4.62 and 4.86 in T1 (150000 post-larvae ha^{-1}), T2 (200000 ha^{-1}) and T3 (250000 ha^{-1}), respectively. The stoking density of 8000 fingerlings ha^{-1} in carp polyculture and 200000 post-larvae ha^{-1} in *P. monodon* shrimp monoculture gave significantly higher yield, economic benefit (OV:CC) and net consumptive water productivity (NCWP).
- Multiple use of water for agriculture, on-dyke horticulture, pisciculture, poultry and duckery was done in 10 water harvesting structures under integrated farming system models. The economic analysis indicated that poultry cultivation in the uplands, fish culture in ponds and intensive cultivation around the embankments of the pond are essential in improving the net return from the farming system models. Three 1-day training programs and two exposure visits were conducted for the farmers. The impact analysis study of the

technological interventions showed that the mean value of overall standard of living of the farmers increased from 13.47 to 18.01 (in a scale of 5 to 25).

CANAL WATER MANAGEMENT

- Multi-date Resource Sat -1 and 2 data of Hirakud canal command area during 1993-2013 showed increase coverage area between 58-80 % under paddy and 4.1-5.3 % under non-paddy. Field evaporation, transpiration and deep percolation rates in paddy fields ranged between 1.15-2.15, 3.0-4.55 and 1.0-2.35 mmday^{-1} respectively. Conveyance loss in lined canal was 84.8% less than unlined canal and irrigation application efficiency ranged between 23.95–53.0%. Optimized crop model technique suggested that objective to utilize the maximum area for cultivation with the constraint of water availability for each outlet may be adopted for optimal land and water utilization. With preference for heavy duty crop (paddy) the objective to utilize the maximum area for cultivation with the constraints of water availability for each outlet and at least 1/3rd area under paddy may be adopted.

- The daily variation of net ecosystem exchange (NEE) revealed that maximum NEE occurred at 1130 hour and was highly influenced by leaf area index (LAI). In okra NEE was negative value from secondary branching (32DAS) to about 10 days before last fruit picking (69 DAS) due to more photosynthetic CO_2 uptake than respiratory release of CO_2 from the canopy. NEE reached its peak at maximum leaf area index stage (55 DAS) with the midday uptake of –18.5 μmol CO_2 m^{-2} s^{-1} and night-time release of +4.55 μmol CO_2 m^{-2} s^{-1}. From the tillering stage the paddy field became the net CO_2 sink. NEE reached its peak at boot leaf stage (76 DAS) with the midday uptake of –22.9 μmol CO_2 m^{-2} s^{-1} and night-time release of +4.06 μmol CO_2 m^{-2} s^{-1}. Pond based farming systems (crops, on-dyke horticulture, fisheries) were developed in created water resources in 3 canal commands to enhance water productivity and to mitigate dry spells. Water productivity of the area enhanced from ₹ 1.1-1.42 m^{-3} through sole rice to ₹ 6.35-7.95 m^{-3} through pond based farming system. Due to assured available water cropping intensity of command area of the ponds increased by 2 to 2.5 times and net return varied from ₹ 48,645 to ₹ 66,170 from the pond based farming area of Kendrapara district.

- In Kuanria Medium Irrigation project, Daspalla block, Nayagarh district in Odisha, pond-based intervention in four different sub-minors *viz.* Khamarasahi, Madhyakhand (2), Lunisara and Soroda-II, was beneficial. The fish yield ranged between 2.46-2.88 t ha^{-1} in 210 days with gross- and net water productivity ₹ 6.47-7.79 and ₹ 4.6-5.72m^{-3} respectively. Construction of rain/runoff water storage tanks and open wells, facilitated alternate cropping systems i.e. rice + (fish in pond) –green gram, rice + (fish in pond) –black gram and rice + (fish in pond) -chickpea compared to rice-fallow, rice-green gram and rice-black gram in the Khamarsahi sub-minor ; rice + (fish in pond) +pigeonpea (on dyke) – green gram and rice + (fish in pond) + pigeonpea (on-dyke)- pigeonpea (on dyke) compared to rice-fallow and rice-green gram only in Madhyakhanda sub-minor; rice+(fish in pond) –green gram compared to rice-fallow cropping system in Lunisara sub-minor; and rice+(fish in pond) – green gram compared to rice-fallow system in Soroda sub-minor. The cost of cultivation for the system ranged from ₹ 1,19,772 to ₹ 1,24,230 and the benefit was ₹ 1,37,210 to ₹ 1,74,012 in four intervened sub-minors.

- Highest grain yield was obtained in SRI with inorganic fertilization. SRI-INM enhanced grain yield by 43% compared to TP-INM. Under organic fertilization SRI increased grain yield by 31% compared to TP and was mainly due to significant increase in number of spikelet/panicle, grain-filling % and 1000-grain weight. SRI grown rice crop significantly improved morphology (plant height, tillering and root growth) and physiological performances of crop. In crop rotation in *rabi* season square planting of black gram gave highest yield in the organically fertilized SRI field. Average yield of black gram in square planting was 73% more (1.04 t ha^{-1}) than broadcasting method mainly due to significant improvement in morphological (plant height, branch and leaf number) and yield-contributing characteristics of the crop.

- The field experiment on deficit irrigation under drip system with two lateral layouts was evaluated in *kharif* rice and capsicum crops. The grain yield of rice with surface irrigation and with optimum drip irrigation regime at 1.0 m lateral was at par. However, drip irrigation saved 30% irrigation water and 50% improvement in irrigation water use efficiency over surface irrigation. The response of capsicum to drip irrigation at 50% ETc, 75% ETc and irrigation at 50% ETc except flowering and fruiting stage (FFS) with lateral layouts of 1.0 m and 1.4 m lateral distance indicated that the fruit yield was higher with higher level of irrigation with lower lateral to lateral distance. However, irrigation at 75% ETc produced the same yield as that with full irrigation.

GROUNDWATER MANAGEMENT

- The analyses of recent changes in Terrestrial Water Storage (TWS) in India and their linkages with the climatic variables using 'The Gravity Recovery and Climate Experiment' (GRACE) satellites records during January 2003 to August 2013 suggested both TWS and groundwater have declined significantly in the Ganga basin, consistent with the previous results. The region around the Punjab, Haryana and Delhi is identified as the hotspot of the surface and subsurface water decline. GRACE precisely captures the hydrology at seasonal and monthly scales, it can be used efficiently for agricultural water management.
- Lumped Groundwater Model developed for groundwater irrigated areas with hard rock geology was tested for Walayar sub basin. The model was calibrated, validated and used in simulation to estimate additional groundwater recharge requirement due drought events. The additional groundwater recharge on basis of simulation in Pollachi region of Walayar sub basin varied from 21 to 24 cm and 26 to 29 cm for Kinathukadavu region. Simulated and observed values of additional recharge were in agreement but observed values towards upper limits were higher. It might be due to more severe droughts which occurred over past 21 years.
- Changes of land use and land cover over a period of 6 years between 2000 and 2006 in Suniti village and its surrounding areas of Mahakalapada block in Odisha were monitored by using Landsat ETM+ images. There was increase in agricultural areas and other vegetation from 2.81% to 8.01% respectively, while water spread-areas, soil and barren areas decreased from 6.54% to 4.27%. The variation of pH in water of hand pump operated tubewell was higher than the surface water from creek whereas electrical conductivity was higher in surface water, and might be due to connect with the sea. The pH and EC in water samples gradually increased at a rate of 0.185 and 1.745 dS m^{-1} respectively every kilometer from inland towards sea. In tube wells the same were 0.0682 and 0.778 dS m^{-1}, respectively.
- Wastewaters of United breweries, Sakthi Sugars distillery and COS Board paper mill improved soil organic carbon and its fractions with highest value in soil with low organic carbon (≤0.25%) in four different soil types. The highest influence on soil organic carbon (2 to 3 times more than the initial) was registered under distillery effluent while the influence of paper mill effluent and breweries was at par. The COS Board - paper mill effluent enriched with Ca, Mg, SO_4 and Cl could be good irrigation source for red and lateritic, alluvial, and red and yellow soil types

Water quality appraisal of groundwater sources surrounding Sakthi Sugars Ltd at Dhenkanal revealed that 57.89% waters are impaired by pH, each 10.53% are not preferred by Cl and Mn contents for irrigation use. The pH, EC and Mn could be indicating parameter for monitoring water quality in that area.

- To filter contaminants present in the domestic and municipal wastewater for its safe use in irrigation, the filter made with coarse materials *viz*., gravels, sand particles (< 2 mm) and jute fibre used in combination, reduced the sediments and total microbial load including total coliform and *E. coli* counts. Coconut shell charcoal used as finer particle in the filter removed Cd from aqueous solution and its efficacy could be increased by altering pH.
- A Portable Small Tank Based Drip Irrigation System was designed for small quantity water transport from water resource to field in a normal terrain and to work with a pressure of 50 -75 cm head.
- The water quality index (WQI) developed to assess the groundwater quality for potable and irrigation purpose using chemical parameters based on Indian and FAO Standards respectively was validated by assessing the groundwater quality data of Rushikuliya Command area obtained from Central Groundwater Board, Bhubaneswar. About 45.5 % groundwater samples were poor in quality for potable use (WQI between 100.98 to 196.32) due to high hardness, alkalinity, magnesium and nitrate content and 30.3 % samples had severe restrictions for irrigation use (WQI between 458.3 to 5596.4) due to sea water intrusion.
- Major cropping system (rice-wheat) and soil group for ACR-VI has also been delineated by using Remote Sensing and GIS. Out of total geographical area of 11.4 million ha in ACR-VI, 5.8 million ha (50.87%) area is under rice-wheat cropping system spread over states of Punjab and Haryana. Rice area of 3.6 million ha in the region existed mainly in Punjab and Haryana covering an area of 2.6 and 1.05 million ha respectively.
- Saturated hydraulic conductivity (K_s) of the soils of Indo-Gangetic Plains (IGP) and the Black Soil Region (BSR) under different bioclimatic systems suggested that particle size distribution is a key factor to predict Ks of the BSR soils, whereas organic carbon was major determinant of K_s for the IGP soils. Models for Ks of these soils were strengthened by inputing $CaCO_3$ and exchangeable sodium percentage (ESP) and provided scope to maintain K_s at desired levels through management practices. An index of soil physical quality (S), derived from the inflection point of the soil moisture characteristic curves explained the impact

of management practices on physical quality in IGP and BSR soils.

WATERLOGGED AREA MANAGEMENT

- On-farm water resources plan with four farm pond locations was identified in 41 ha surface waterlogged area in Pattamundai block of Kendrapara district (Odisha). Goal program technique, suggested the optimal crop allocation of 20 ha *kharif* paddy, 24.1 ha *rabi* tomato of and 5.9 ha brinjal with maximum profit and production with water availability at 75 % probability level. The 3.5 km long field drain of successfully modulated water congestion in the crop fields and increased yield to 2.3-3.1 t ha^{-1} in post-drainage scenario compared to 1.2 tha^{-1} in pre-drainage scenario. At peak rain fall of 152 mm the drainage system successfully reduced ponding up to 49 cm in paddy field.
- Nutrient utilization efficiency study in rice based cropping system in waterlogged ecosystem showed higher rice grain yield under shallow submergence (3.8 t ha^{-1} at 10-25 cm) compared to intermediate level of submergence (3.51 t ha^{-1} at 25-50cm). Band placement of nitrogen fertilizer @ 60 kg ha^{-1} produced higher grain yield (3.82 t ha^{-1}) compared to broadcasting (3.49 t ha^{-1}). Nitrogen @ 60 t ha^{-1} mixed with Dicyanodiamide (DCD) gave highest rice grain yield (4.1 t ha^{-1}) compared to neem coated urea and DWM bio-formulation and also showed highest nitrogen use efficiency (26.5 kg grain kg^{-1} N applied).
- The transfer factors of Cr, Cd and Pb were in the decreasing order in *Amaranthus* followed by tomato, water melon, malabar climbing, bitter gourd, ladies finger and ridge gourd. Leaf tissues accumulated more metals than fruits. Field experiment with graded concentration of Cd showed decrease in net photosynthesis rate and yield in vegetables at higher Cd level. Initial load of total coliform, *E. coli* and other bacteria on the day of irrigation were lowest (3.02. 1.80 and 3.50 log cfu per g) in okra and were highest in bitter gourd and ridge gourd and showed a mean reduction of 1.92 and 2.53 log cfu of E coli at 7 and 10 days after irrigation, respectively.
- The LISS III data (1:50,000 scale) for the period 2005-2006 collected from ORSAC, Bhubaneswar of three seasons, *kharif*, *rabi* and *zaid* (summer) showed 17 different types of water bodies and waterlogged areas in Odisha. Kendrapara district had highest area 11,229.41 ha perennially under rivers and streams, followed by Jagatsinghpur district, 10,884.42 ha. The Ganjam district has highest 8,348.11 ha area perennially under lakes, ponds, reservoir and tanks followed by Bolangir district with 5,449.95 ha area. The Baleswar and Kendrapara district showed 569.98 and 169.97 ha man-made waterlogged area of respectively.
- A web based information system on agriculture water management is being developed with web portal containing different domains like research, farmer's, service-domain, e-learning module and other information etc. It contained general and research related information of 25 All India Coordinate Research Project (AICRP) on Water Management Centres for access by general public. The published literature, bulletins, leaflets for agriculture water management in regional and other languages have been uploaded into the webpage as e-books formats.
- Actual crop yields of rice, wheat, maize, sorghum and pearlmillet for 10 years were estimated for thirty climatic buffer zones of major agro-climatic zones of India. The lowest rice yield (0.87 t ha^{-1}) was recorded with Jabalpur Climate Zone, whereas the highest rice yield (3.26 t ha^{-1}) was recorded with Paiyur zone. The Ludhiana zone showed highest wheat yield (4.59 t ha^{-1}) and Palampur climate zone showed lowest wheat yield (1.37 t ha^{-1}).

ON-FARM RESEARCH AND TECHNOLOGY DISSEMINATION

- Regular high frequency village household data being collected to enhance availability of reliable household, individual, field specific, plot level data on agriculture, labour, expenditure, incomes and consumption throughout the year to address the dynamics of economic, social and institutional development in the study villages. The study aims to understand the dynamic process of reducing poverty by tracking the household and village economies across farm size groups.
- In order to strengthen the computational efficiency of NARS, 33 scientists and researchers of eastern region were trained regarding the application of advance statistical tools and techniques using the SAS software under the 6-days training program. Twenty nodal officers were trained in software installation.
- Under Tribal Sub Plan (TSP) project to improve the land and water productivity through augmenting the irrigation infrastructure in Ghurlijore Minor Irrigation Project in Sundargarh district of Odisha Birjaberna Gadhuamunda linkage tank was selected because of around 50 active farm families are engaged in various remunerative agricultural practices. Inlet, outlet and surplus escape were constructed in the linkage tank for judicious conveyance of canal water in the command. Raised and sunken bed technique was adopted to introduce crop diversification in low lands areas.

Introduction

The Directorate of Water Management (erstwhile Water Technology Centre for Eastern Region) was established on 12th May, 1988 with the aim to cater the research and development need of agricultural water management at national level. The centre is located at Chandrasekharpur, Bhubaneswar on a 5.71 ha of land along with its main office-cum-laboratory building, guest house and residential complex. It is situated about 8 km north of Bhubaneswar railway station and at about 15 km away from Biju Patnaik Airport, Bhubaneswar. The location of the Institute is at 20°15' N and 85° 52' E at 23 m above mean sea level. The research farm of the Institute (63.71 ha of farm land) is located at Deras, Mendhasal (20°30' N and 87°48' E) and is 30 km away from main institute complex.

Mandate

- 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 relevant national and international agencies in achieving the above objectives.

Research Achievements

Core research activities of the centre are carried out under five programmes, *viz*, rainwater management, canal water management, groundwater management, waterlogged area management and on-farm research, extension and training to solve the agricultural water management related problems. Agricultural water management related issues at the national level are being addressed by the centers under the AICRPs on Water Management and Groundwater Utilization. Comprehensive water and energy efficient farming system technology package have been developed to improve productivity of rainfed areas. Multilocational installation of flexible rubber dams for water harvesting and runoff recycling in the watershed have also been done. In the canal command area, significant achievements have been made to increase the water use efficiency and cropping intensity. Canal hydraulics in Hirakud canal command area was utilized for developing a DSS for improving productivity under Mahanadi basin. Strategic designs for water harvesting structures have been planned for water resources development to support sustainable cropping in waterlogged areas. Modern tools like remote sensing and geographic information system (GIS) have been utilized extensively for delineation of waterlogged areas for increasing productivity in such challenged ecosystem. The institute has a team of experienced multidisciplinary team of scientists. The stride of DWM for excellence towards science and technology in agricultural water management is well recognized at national and international levels and has been duly recognized by award of ISO: 9001-2008 Certified Institute for Research in the field of Agricultural Water Management.

Infrastructure facilities and Organization

The centre has state-of-the-art infrastructure facilities and has four well-equipped laboratories, *viz*, soil-water-plant relationship laboratory, irrigation and drainage laboratory, hydraulic laboratory, and plant science laboratory with all the latest equipments for research activities. An engineering workshop and photographic laboratory also cater to the needs of the institute. Four field laboratories at farm, *viz*, meteorological laboratory, pressurized irrigation system, solar photovoltaic pumping system, and agricultural drainage system also add to the research related inputs. The institute has a state of-the-art communication facility with an automatic EPABX system. The institute has its own web server and regularly updated website (www.dwm.res.in). The entire network administration of the computers, internet and website management is looked after by the Agricultural Knowledge Management Unit (AKMU). This unit also accommodates a fully developed GIS laboratory. The library of the Institute has more than 2000 reference books and subscribes to 16 international and 10 national journals. It has a CD-ROM Server with bibliographic, database from AGRIS, AGRICOLA and Water Resources Abstracts. The subscription of electronic journals and its access through LAN to all the scientists is another useful facility of the library. The installed video conferencing and IP Telephony System facility at the Institute as part of the project ICAR net is being utilized for related use from time to time.

The DWM has linkages with various agencies through providing training, consultancy, collaboration or contract research services. It has provided a platform for public and private sector institutions dealing with water management research to address their scientific problems, monitor research and development activities and their evaluation in a cost effective manner. The institute has developed linkages with different state and central government agencies like Watershed Mission (Government of Odisha), Directorate of Agriculture (Government of Odisha), Central and State Groundwater Board, Command Area Development Agency, Government of Odisha, WALMI to implement farmer friendly water management technologies in the region. Entrusted by Ministry of Rural Development, GOI and Watershed Mission, Government of Odisha, the centre evaluated several Integrated Watershed Development Projects in different districts of Odisha. The centre has conducted several ICAR entrance examinations like JRF, SRF at national level. In addition to ongoing in-house research projects, the institute is awarded with many sponsored projects by various organizations like Ministry of Water Resources, GOI, Department of Science and Technology, GOI, IIT Kharagpur, NCAP, IRMARA and ISRO. International linkages have been established through collaborative project of ICAR with University of Nebraska, Lincoln, USA, University of Melbourne, ICRISAT, IWMI and Bill and Melinda Gates Foundation.

Finance

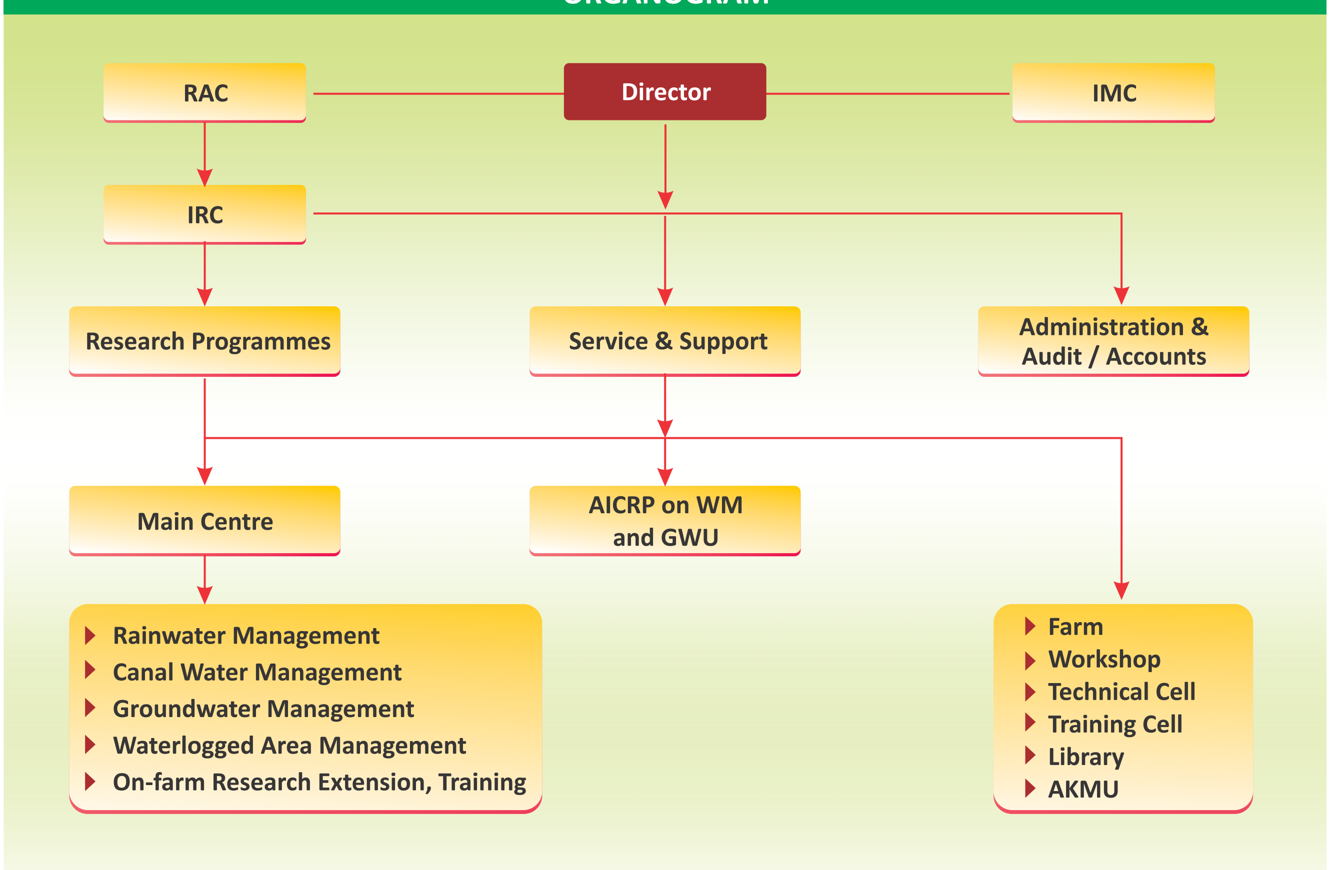
Summary of fund allocation, and expenditure during the year 2013-14 under Plan and Non Plan budget of the centre is presented at the end of this report (chapter 15).

Staff

At the end of March 2014, DWM had 80 sanctioned posts (including AICRP) out of which 57 are in position. The break up of the posts under different categories is given below:

Cadre	Sanctioned	In Position	Vacant
RMP	01	01	nil
Scientific	35	24	11
Administrative	16	13	03
Technical	17	13	04
Supporting	11	06	05
Total	80	57	23

ORGANOGRAM



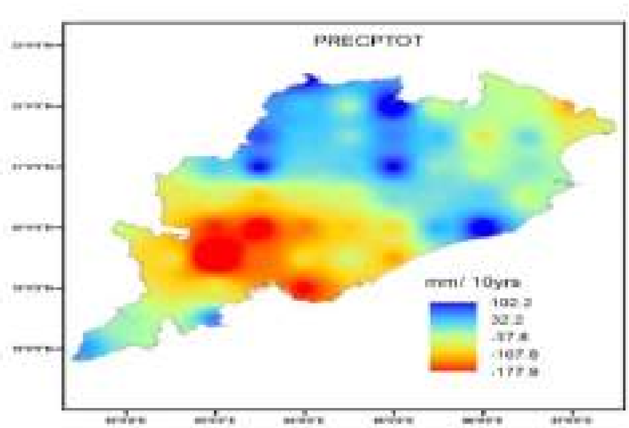
RESEARCH ACHIEVEMENTS

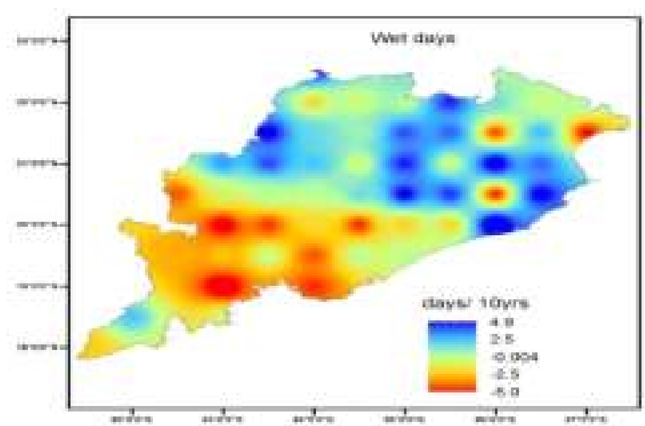
Rainwater Management

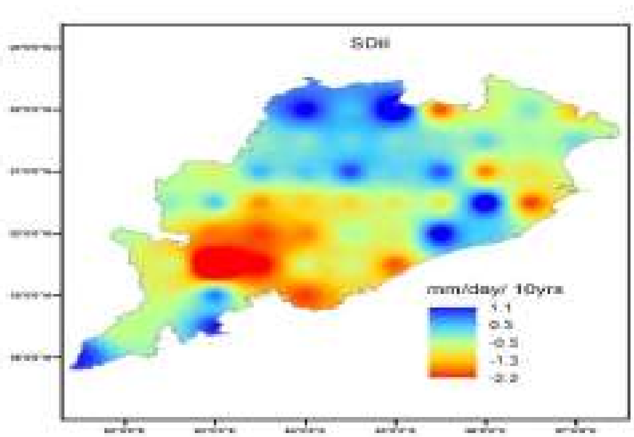
- Extreme Climatic Effects on Major Cropping Systems of Odisha
- Effect of Dry Spell Occurrence on Loss in Paddy Yield and Design of Water Harvesting Structures for its Mitigation
- Design and Development of Rubber Dams for Watersheds
- Performance Evaluation of Drip Irrigated Mango Under Deficit Irrigation
- Development of Water and Energy Efficient integrated Farming System model for the Rainfed Farmers
- Conservation Agricultural Practices in Rice Based Cropping System for Increasing Water and Nutrient Availability in a Rainfed Agro-ecosystem for Eastern India
- Water Budgeting in High-value Shrimp Monoculture and Carp Poly culture under Varying Intensification Levels
- Sustainable Rural Livelihood and Food Security to Rainfed Farmers of Odisha

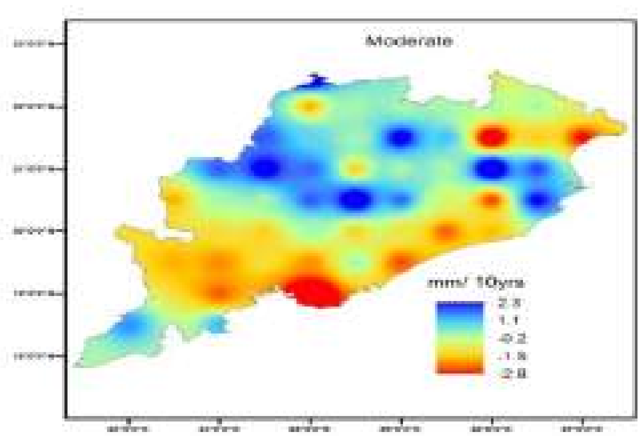
Project Title	:	**Extreme Climatic Effects on Major Cropping Systems of Odisha**
Project Code	:	DWM/12/154
Funding Agency	:	Institute
Project Personnel	:	D. K. Panda, K.G. Mandal, A. Mishra, A. K. Thakur, R. C. Srivastava, and A. Kumar

In tropical eastern part of India , Odisha state of late experienced most of the extreme climatic stresses. The extreme rainfall and temperature indices of Odisha were investigated as per definition of WMO Expert Team on Climate Change Detection Monitoring and Indices (ETCCDMI). Results indicated the occurrence of both highly positive and negative anomalous years since the 1990 suggesting an increased occurrence of both the floods and droughts in recent years. In particular, the temporal evolution of the extreme rainfall indices (SDII, RX1D, RX3D, R100, R95P and R99P) also indicated an increasing variability magnitude of the opposite anomalies in recent years. The noteworthy changes are the vulnerability of coastal and north-western region to the extreme rainfall events and the south Eastern Ghat to the moisture deficit stress. The wet day frequency and moderate rainfall amounts decreased in relatively larger parts of the state leading to decrease in total monsoon rainfall (PRECPTOT). The aridity intensity index (AII), a pertinent indicator of the moisture availability for crop production decreased in most parts of the state, particularly over the southern Eastern Ghats and parts of the coastal plain and northwestern strip, particularly during July and August, suggesting the emergence of moisture stress scenario.









Comparison of mean and extreme day and night temperatures in summer (MAM), monsoon (JJAS), and winter (DJF) indicated substantial spatial and seasonal changes for Odisha. Noteworthy is the decrease in the night time temperature (T_{min}), resulting to conspicuous increase in diurnal temperature range (DTR), in major parts of the state except the north and south ends. The mean and extreme day-time temperature (T_{max}, TX_X, TX_{90}) of the monsoon season deceased in recent years and might be due to light absorbing aerosols and cloudiness.

Project Title : **Effect of Dry Spell Occurrence on Loss in Paddy Yield and Design of Water Harvesting Structures for its Mitigation**
Project Code : DWM/11/153
Funding Agency : Institute
Project Personnel : S. Mohanty, D. K. Panda, A. Mishra, D.U. Patil and B.C. Sahoo

The different crop attributes of the rice crop were better under recommended dose of fertilizer compared to 80% of recommended dose (Table 1) and it was least under 60% recommended dose of fertilizer. Application of two irrigations improved plant height, panicles m^{-2}., filled grains.panicle^{-1}, grain weight and grain filling per cent in comparison to rainfed treatment. Application of two irrigations improved all these attributes.

Table 1 Crop attributes of rice as influenced by fertilizer dose and irrigation

Treatments	Plant height (cm)	Panicles m^{-2}	Filled grains panicle^{-1}	Grain weight (g. 1000 grain^{-1})	Grain filling (%)
Fertilizer dose ,100%	82.8	330.4	83.3	17.2	76.1
80%	82.0	308.7	77.9	16.8	74.5
60%	81.1	280.1	74.8	16.5	73.3
CD (p=0.05)	*0.79*	*15.2*	*3.72*	*0.33*	*0.68*
Irrigation, Rainfed	80.6	277.2	76.0	16.4	73.6
1 irrigation (PI)	81.9	309.1	78.8	16.9	74.6
2 irrigations (PI , FI)	83.4	332.9	81.1	17.3	75.7
CD (p=0.05)	*1.32*	*20.0*	*4.10*	*0.39*	*0.55*

Table 2 shows the yield and yield attributes of rice as influenced by fertilizer dose and irrigation. The grain yield, straw yield and dry biomass were highest under recommended dose of fertilizer and was lowest under 60% dose of fertilizer application. Regarding effect of irrigation, it was observed that two supplementary irrigations treatment was superior to one supplementary irrigation for mean yield and yield attributes.

Table 2 Yield and yield attributes of rice as influenced by fertilizer dose and irrigation

Treatments	Grain Yield, t ha^{-1}	Straw Yield , t ha^{-1}	Harvest Index	Dry biomass at maturity , t ha^{-1}
Fertilizer dose ,100%	4.43	6.69	0.398	10.55
80%	4.21	6.21	0.404	9.81
60%	3.70	5.76	0.391	8.89
CD (p=0.05)	*0.16*	*0.20*	*0.01*	*0.26*
Irrigation, Rainfed	3.79	6.40	0.392	9.08
1 irrigation (PI)	4.08	6.73	0.396	9.72
2 irrigations (PI & FI)	4.47	6.95	0.405	10.42
CD (p=0.05)	*0.13*	*0.25*	*0.01*	*0.30*

Calibration of the AquaCrop model was done using the crop yield and biomass data of the first year experiment. The parameters of the model were adjusted so that simulated plant biomass and yield almost matched with the observed plant biomass and yield. The validation of the model was done by using the yield and biomass data of the second year experiment of the project. The calibrated model was used to simulate the plant yield and biomass and compared with observed data. Figure 1 and 2 shows the scattered diagram for crop biomass and yield during the validation period. The values of coefficient of determination, mean error, mean absolute error and root mean squared error shows a reasonably good calibration and validation of the model.

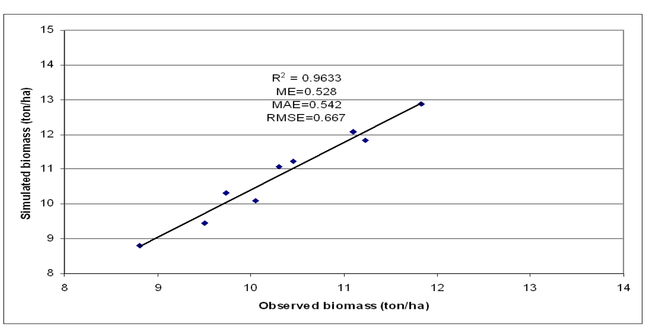


Fig. 1 Relation of simulated and observed crop biomass during validation period

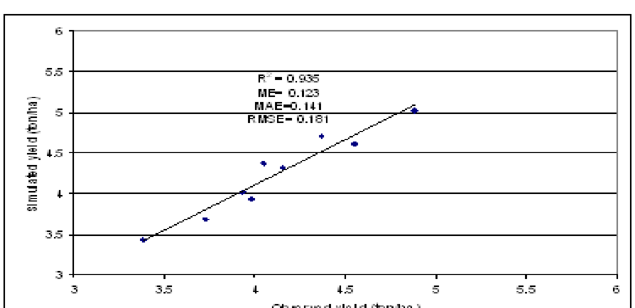


Fig. 2 Scatter diagram for simulated and observed crop yield during calibration period

Project Title	**: Design and Development of Rubber Dams for Watersheds**
Funding Agency	: NAIP, ICAR, New Delhi
Project Personnel	: S.K. Jena, A. Kumar, P.S. Brahmanand, A. Mishra and D.U. Patil

There was successful installation of five number of rubber check dams by DWM, Bhubaneswar at different watersheds such as Baghamari, Badapokharia, DWM Farm, Chandeshwar–1 and Chandeshwar-2 in Odisha. The installed rubber dams were successfully operated during monsoon for control of flood, soil erosion, sedimentation and utilization of stored water for irrigation during long dry spells and post monsoon season.

Rubber dam base structure was installed successfully at nine more locations (Pasauli and Siriwalgarh of Uttarakhand; Pyllun and Nongrah, Meghalaya; Sirsi, Hazaribagh, Jharkhand; Kanse, Maharashtra, Vansda, Gujarat; Sunabeda and Kausalyagang of Odisha) during the year and at Vansda, Navsari, Gujarat it was made operational after installing rubber sheets to it. The anchoring and inlet-outlet mechanism have been successfully installed at all these sites.

Rubber dam at Chandeswar

Rubber dam at Navsari, Gujarat

Reconnaissance survey for selection of 25 new sites in different agro-ecological and geo-hydrologic regions of India was done for installation of rubber dams. The following locations were selected based on technical feasibility, hydrological and socio-economic parameters.

1. Palampur-1 and Palampur-2 of Himachal Pradesh;
2. Bhatoli and Selakui of Uttarakhand;
3. Dapoli-1, Dapoli-2, and Dapoli-3 in Konkan region of Maharashtra;
4. Kanse-1, and Kanse-2 of Pune, Maharashtra;
5. Vansda-1, Vansda-2, and Navsari of Gujarat;
6. Jaleswar-1, Jaleswar-2, and Jaleswar-3 of Odisha coast;
7. Nandahandi, Jogiput, Semiliguda and Pottangi in the Eastern Ghat regions of Odisha,
8. Silala, Balkola and six other locations of Tamil Nadu; and
9. Khurda of Odisha.

Design, drawing and estimates of rubber dams for the above 26 sites were prepared. The anchoring material, inlet, outlet and other components of rubber dams were designed for each site. In the workshop of DWM, Bhubaneswar, one portable rubber dam has been developed for further testing.

The Chandeswar and Baghamari check dams are operated and maintained by farmers for paddy cultivation during *kharif* and pulses, oilseed and vegetable cultivation during *rabi* and summer season in the surrounding field. In the period of report various types of evaluations of rubber dams were done which mainly covers water availability analysis and crop productivity and other watershed parameters. The following observations were made. Water remained available in the upstream side of the rubber dam till 1st week of May 2013 located at Chandeswar-1 and 2, whereas all the nearby streams became dry by middle of March. At all the sites water stored up to the maximum capacity of the rubber dam since third week of June 2013 till March 2014. However water is still available for irrigation beyond March 2014 and expected to remain for another one to two months.

The water stored in the upstream side of the rubber dam was up to a stretch of 800 m to 1.7 km at various locations. The additional volume of water stored in the upstream side due to installation of rubber dam varies between 4800 m^3 to 10000 m^3 at any point of time during monsoon. In case this water is used for irrigation; it gets filled up by the water coming from the upper catchment during monsoon. The stored water in rubber dam irrigated 13 ha of rice fields during critical stages at Chandeswar-I and around 15 ha at Chandeswar-II. The rainfall occurred after south-west monsoon period during mid-October till end November has been stored in rubber dam and used by the farmers for *rabi* pulses and vegetables. The rubber dam at Badapokharia has been instrumental in augmenting groundwater recharge.

The impact of rubber dams on agricultural performance was studied. The productivity of rice in *kharif* season witnessed a jump by 26% due to assured irrigation during dry spells from rubber dam compared to pre installation period at Chandeswar. The rice yield increased from 4.14 t ha^{-1} during pre-installation period to 5.22 t ha^{-1} at post-installation period of rubber dam. The positive impact of rubber dam on productivity of summer vegetable crops such as brinjal (29%), watermelon (34%) and cowpea (22%) was analyzed (Table 3). The yield of brinjal increased from 4.8 t ha^{-1} during pre-installation stage to 6.19 t ha^{-1} during post installation of rubber dam. Similarly, the yield of watermelon and cowpea increased from 9.4 t/ha and 5.2 t ha^{-1} to 12.4 t ha^{-1} and 6.35 t ha^{-1} respectively during corresponding period due to additional available water after installation of rubber dam. The economic analysis indicated that the farmers could generate additional net returns up to ₹ 12000 per ha. The rainfall fluctuations during monsoon affected the rice yield in *kharif* season outside the command area of rubber dam. The flexible nature of rubber dam provided better resilience to rice crop under such scenario. The stored water in rubber dam could irrigate 13 ha of rice fields during critical stages at Chandeswar-I and around 15 ha at Chandeswar-II. The pod yield of green gram during *rabi* season of 2013 under rubber dam command area in Chandeswar was found to be significantly superior (35% increase on pod yield) to that of pre-installation period due to long duration of residual soil moisture. The rice-green gram cropping system under assured irrigation supply from rubber dam has the potential to enhance net returns of the farmers from the ₹ 12,400 (from sole rice cropping in pre-installation period) to ₹ 43,000 ha^{-1}.

Table 3 Yield of vegetable crops during summer season in rubber dam command area at Chandeswar

Crop	Yield (t ha^{-1})		Yield increase (%)
	Pre-installation stage	Post-installation stage	
Brinjal	4.80	6.19	29
Cowpea	5.20	6.35	22
Watermelon	9.40	12.60	34

The farmers were trained on improved water management practices and other crop management practices along with participatory irrigation management in the field. The biometric observations of rice and other vegetable have been recorded at regular intervals for assessing the impact of rubber dam on growth and productivity. World Bank team members visited the rubber dam installation sites on various occasion and interacted with farmers and filled questionnaires collecting information regarding impact of rubber dams on livelihood etc. The documents related to commercialization of technology for manufacturing of rubber composite was developed. Expression of interest and technical specification document was developed. This technology commercialization was included in the Agri-Business conclave held at NAIP, ICAR during 18-19 July 2013. The Memorandum of Understanding (MoU) among partners was signed on 17 February 2014 for commercialization of technology and for management of Intellectual Property Right (IPR) during post-NAIP period. The national bidding was done for Commercialization of "ICAR Flexi-Check dam" technology and bids were received and open in the bid opening meeting at CIRCOT, Mumbai on 28-03-2014. The pre-bid meeting was successfully done on 24th March 2014.

Project Title	:	**Performance Evaluation of Drip Irrigated Mango under Deficit Irrigation**
Project Code	:	DWM/11/151
Funding Agency	:	Institute
Project Personnel	:	S. Mohanty, P. Panigrahi, M. Raychaudhuri and Ashwani Kumar

The experiment on performance evaluation of drip irrigated mango trees under deficit irrigation was continued at the DWM research farm, Mendhasal, Bhubaneswar during the period April 2013 to March 2014. The treatments of the experiment were, (1) Full irrigation @ 100% Etc (FI), (2) RDI @ 80% ETc, (3) RDI @ 60% ETc, (4) RDI @ 40% ETc, (5) PRD @ 80% ETc, (6) PRD @ 60% ETc, and (7) PRD @ 40% ETc and (8) control, i.e. rainfed. Water was applied during the months of April and May excepting the periods when some rainfall occurred. After the end of monsoon season, irrigation was started from 15th December and continued thereafter. The irrigation was withheld from mid-January to mid-February to impose water stress on the trees, which is a pre-requisite for better flowering. The monthly irrigation applied under various treatments varied from 9 mm to 75 mm, with maximum amount in April and minimum in

February. The hydraulic performance of the drip system was studied from time to time and found satisfactory with emitter flow rate variation (Q_v) of 10%, co-efficient of variation (CV) of 9% and distribution uniformity (DU) of 92%.

Soil water variation

The mean monthly soil water content (SWC) observed at 30 cm interval within top 90 cm soil during April-June and November–March showed significantly higher SWC at full irrigation (FI, 100% ET_c) compared to other treatments. The SWC in top 30 cm soil was significantly higher than that in 30-60 cm and 60-90 cm soil depths. However, the soil water depletion at 60-90 cm soil depth was lower than that in 0-30 cm and 30-60 cm soil depths. The SWC consistently decreased from April to June and November to March in all the treatments more so under rainfed treatments. The SWC increased during November, due to residual soil moisture of the rainfall during July to October. The mean soil water fluctuation between two consecutive measurements during irrigation season under FI was observed higher than that under other treatments, suggesting highest evapotranspiration rate of the plants under FI.

Vegetative growth

Plant growth parameters (plant height, collar diameter and canopy volume) were measured half yearly (January-June and July-December) and showed increase in all the parameters. The maximum increase was noticed with fully-irrigated trees in both the periods (Table 4). The vegetative growths were higher in RDI treatments in comparison to corresponding PRD treatments. The growth parameters showed a decreasing trend with decrease in irrigation regimes under both RDI and PRD treatments. The magnitudes of the increase in plant growth were higher during July–December than that during January–June, due to adequate soil moisture through rainfall.

Table 4 Incremental vegetative growth parameters of mango trees under RDI and PRD treatments

Treatment	January–June			July–December		
	Plant height (m)	Collar diameter (mm)	Canopy volume (m^3)	Plant height (m)	Collar diameter (mm)	Canopy volume (m^3)
100% ET_c	0.34	14.8	9.82	0.49	21.2	9.71
80% RDI	0.29	11.6	8.09	0.44	20.5	8.74
60% RDI	0.27	9.7	7.83	0.38	16.3	8.22
40% RDI	0.21	8.1	5.66	0.36	12.2	7.43
80% PRD	0.25	10.5	7.23	0.41	16.5	8.06
60% PRD	0.24	9.2	6.55	0.36	14.4	7.54
40% PRD	0.20	7.7	4.37	0.33	11.7	6.42
Control	0.18	7.4	2.87	0.38	10.2	6.11
CD0.05	*0.01*	*NS*	*0.51*	*NS*	*NS*	*NS*

Fruit yield and quality

The yield parameters (fruit number, fruit weight and fruit yield), water use efficiency and fruit quality parameters (pulp content, TSS and acidity) in different treatments (Table 5) showed that higher number of fruits under FI treatments followed by RDI treatments at 80% Etc. However, the fruit weight was lesser in FI compared to that in 80% RDI, 60% RDI, 80% PRD and 60% PRD treatments. In PRD treatments, even though fruit numbers were lower, overall yield was better due to more fruit weight. Yield was highest in 80% PRD followed by full irrigation treatment. However, yield in the 60% PRD was statistically at par with full irrigation and 80% PRD treatment. There was 40% water saving and 84% improvement in water use efficiency in 60% PRD treatment in comparison to full irrigation treatment. The table shows that fruit quality is better in PRD treatments in comparison to full irrigation treatment and RDI treatments. The TSS values were highest and acidity values were lowest in 60% PRD treatment. However, in 40% PRD treatment, fruit quality was significantly inferior due to excess water stress.

Table 5 Incremental vegetative growth parameters of mango trees under RDI and PRD treatments

Treatment	Yield parameters			Water applied (m^3 tree^{-1})	WUE (kg m^{-3})	Quality parameters		
	Fruit number	Fruit weight (g)	Fruit yield (kg tree^{-1})			Pulp (%)	TSS (°Brix)	Acidity (%)
100% ETc	111	209.09	23.2	5.881	3.94	66.72	18.8	0.52
80% RDI	104	211.80	22.0	4.339	5.07	69.39	21.0	0.49
60% RDI	86	233.18	20.0	3.176	6.30	68.73	22.7	0.44
40% RDI	65	190.25	12.4	1.918	6.46	61.86	17.2	0.64
80% PRD	96	247.44	23.8	4.256	5.59	69.66	22.7	0.47
60% PRD	81	279.61	22.6	3.112	7.26	70.03	24.4	0.42
40% PRD	67	196.02	13.1	1.852	7.07	67.40	19.1	0.59
Control	61	167.45	10.2	--	--	62.20	15.0	0.61
CD0.05	*2.6*	*9.66*	*1.64*	--	--	*8.62*	*1.66*	*0.008*

Project Title : **Development of Water and Energy Efficient integrated Farming System model for the Rainfed Farmers**
Project Code : DWM/09/143
Funding Agency : Institute
Project Personnel : S.K. Rautaray, A. Mishra, R.K. Mohanty and M.S. Behera

On-Station Integrated Farming System Unit at DWM Farm, Deras

(a) Economics

The farming system unit consisted of 3408.44 m^2 with net return of ₹ 188341 ha^{-1}. Out of the seven components, pond with the bund resulted in highest net returns of ₹ 363750 ha^{-1} and was distinctly superior to other components involving crops alone. Among the crop components, highest net returns were accrued from pigeon pea grown on field bunds. This component was followed by bottle gourd (₹ 47852 ha^{-1}) and water melon (₹ 38728 ha^{-1}). Net return ha^{-1} increased to ₹ 188341 under Integrated Farming System as compared to traditional rice-fallow sequence (₹ 27982).

(b) Employment generation

A total of 173.6 man-days were generated from Integrated Farming System Unit. This is equivalent to 509.3 man-days ha^{-1} area. *Kharif* paddy grown alone generated 157.7 man-days ha^{-1}. Thus, adoption of Integrated Farming System generated 223% more employment as compared to rice-fallow sequence.

(c) Water productivity

Among the irrigated crops, bottle gourd showed highest net water productivity of ₹ 11.4 m^{-3} followed by water melon, okra and dry season field crops (Table 6). However, when integrated farming system as a unit is considered, the net water productivity was very high (₹ 53.7 m^{-3}). This was due to multiple use of water for various agro-enterprises, and due to crop production using rain water during *kharif* season.

Table 6 Returns from components and employment generation under energy efficient Integrated Farming System (area 3408.44 m^2)

Component	Area (m^2)	Employment in the unit (man-days)	Water use (mm)	Net water productivity (₹ m^{-3})	Gross Return from the unit	Net Return from the unit (₹)	Net Return (₹ ha^{-1})
Pond with bund	1456	94.36	305	-	113755	52962	363750
Rice	1879	29.6	0	-	10018	5258	27982
Field bund pigeon pea	73.44	0.9	0	-	510	406	55303
Okra	615	22.3	517	5.8	5658	1832	29790
Bottle gourd	200	5.3	420	11.4	2008	957	47852
Watermelon	200	5.2	420	9.2	1914	775	38728
Dry season crops	864	15.9	504	4.6	4569	2005	23205
Total	3408.44	173.56	2170	53.7	138432	64195	188341

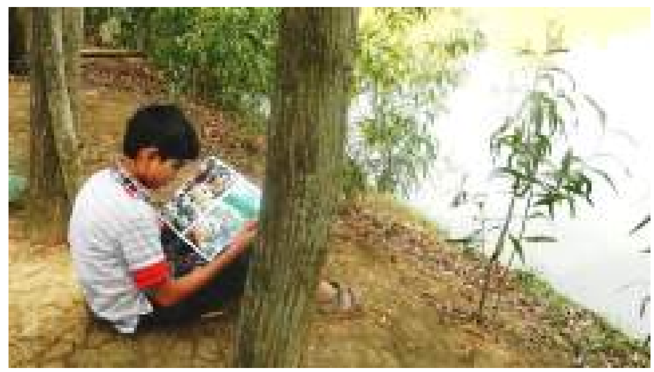
(d) Energy

The farming system had a net negative energy of -55.74GJ.ha^{-1}. This was due to the component of aquaculture in pond with the poultry in bund which resulted in net negative energy of -86.64 GJ ha^{-1}. All the crop components had positive net energy. Among the crop components, highest net energy was recorded in rice under INM followed by pigeon pea grown on field bunds. In contrast to income and employment generation, energy generation was negative under Integrated Farming System as compared to rice-fallow sequence (Table 7).

Table 7 Energy input output (GJha^{-1}) from components under energy efficient Integrated Farming System (Area 3408.44 m^2)

Component	Area (m^2)	Energy input from the unit	Energy output from the unit	Net energy from the unit	Net energy, GJ ha^{-1}
Pond with bund	1456	108.09	21.45	-86.64	-595.0
Rice	1879	1.44	27.26	25.82	137.4
Field bund	73.44	0.02	0.72	0.70	95.1
Okra	615	1.18	2.44	1.26	20.54
Bottle gourd	200	0.31	0.88	0.57	28.42
Watermelon	200	0.32	0.56	0.24	11.86
Dry season crops	864	0.84	3.147	2.307	26.68
Total	3408.44	112.2	56.46	-55.74	-275.0

Components of water and energy efficient farming, System at DWM Farm Deras.



Pond based unit farming System in a waterlogged site at Benakera, Satyabadi, Puri, Odisha

On-farm survey on integrated farming system in Odisha

Field survey was conducted in 51 farmers' field during 2012-13 (Table 8). Out of 51 farmers; 18 farmers were from coastal water logged areas of Puri, Bhadrak, Kendrapada and Cuttack districts, 16 from rainfed plateau areas of Dhenkanal, and Cuttack districts and 17 from irrigated areas in Balasore, Bhadrakh, Sambalpur, Khorda, Puri, and Kendrapada districts.

Table 8 Distribution of farming systems surveyed based on ecology and category of land holding

Ecology	Districts	No. of farming systems	Category of holding distribution			
			Marginal (< 1 ha)	Small (1-2 ha)	Semi-Medium (2-4 ha)	Medium (4-10 ha)
Coastal water logged areas	Puri, Kendrapada, Bhadrak, and Cuttack	18	5	7	2	4
Irrigated areas	Dhenkanal, Sambalpur and Cuttack	17	7	8	1	1
Rainfed plateau areas	Balasore, Bhadrakh, Sambalpur, Khorda, Puri, and Kendrapada	16	4	5	3	4
Total		51	16	20	6	9

Returns from Farming system components

a) Pond area

Pond size in coastal water logged areas ranged between 120 m^2 to 24000 m^2 with average of 3187 m^2. Average pond size was highest under waterlogged ecology followed by irrigated ecology (2345 m^2) and lowest under rainfed ecology (1079 m^2). Within coastal water logged ecology, marginal farmers had lowest pond size of 701.6 m^2. It increased to 2042.9 m^2 for small farmers and further increased to 7140 m^2 for Semi-medium category and declined to 5500 m^2 under medium category. Similar trend was observed for irrigated ecology. Under rainfed ecology, there was increase in pond size with increase in land holding category. Net returns from 1 ha pond area was highest under coastal water logged ecology (₹ 1,81,085) followed by irrigated ecology (₹ 1,20,712) and lowest amount of ₹84,566 under rainfed ecology.

b) Bund and upland area

Mean area of bund and upland was highest under rainfed ecology (2713 m^2) followed by waterlogged (1857 m^2) and lowest under irrigated ecology (1279 m^2). Mean area under bund and upland was lowest for marginal farmers (784.3 m^2) followed by 1537.6 m^2 for small farmers and highest of 3590.1 m^2 for semi-medium farmers. Net returns from 1 ha bund and upland area was highest under irrigated ecology (₹ 2,27,832) followed by coastal water logged ecology (₹ 1,63,409) and lowest amount of ₹1,08,801 under rainfed ecology.

c) Pond, bund and upland area

Net returns from 1 ha pond, bund and upland area was highest under coastal water logged ecology (₹ 1,71,912) followed by irrigated ecology (₹ 1,46,311) and lowest amount of ₹1,01,319 under rainfed ecology.

d) Rice

Area under rice was highest under rainfed ecology (19.17 ha) followed by coastal water logged ecology (14.04 ha) and lowest under irrigated ecology (10.63 ha). Net returns from 1 ha rice area was highest under irrigated ecology (₹ 21,030) followed by rainfed ecology (₹ 17,823) and lowest amount of ₹ 14,397 under coastal water logged ecology.

e) Farming system vis-à-vis rice fallow

Net returns from *kharif* rice – fallow sequence was ₹ 17,750 ha^{-1} (Mean of 51 farmers). This income was increased to ₹ 50680 ha^{-1} by land modification for pond based farming system. Net returns was highest under irrigated ecosystem (₹ 62,584 ha^{-1}) followed by waterlogged ecology (₹ 55,832 ha^{-1}) and lowest under rainfed ecology (₹ 33,624 ha^{-1}). Among the 4 categories of land holdings, Net returns under Farming system was ₹45,895 ha^{-1} for marginal famers. It increased to ₹ 53,989 ha^{-1} for small farmers and further increased to ₹ 58,667 ha^{-1} for semi-medium farmers. Lowest returns of ₹ 37,021 ha^{-1} was recorded with medium farmers with higher land holding (4-10 ha).

Project Title	:	**Conservation Agricultural Practices in Rice Based Cropping System for Increasing Water and Nutrient Availability in a Rainfed Agro-ecosystem for Eastern India**
Project Code	:	DWM/10/147
Funding Agency	:	Institute
Project Personnel	:	P. K. Panda, A. Mishra and S. K. Rautaray

The field trial was conducted in research farm of the institute at Mendhasal in split plot design with three replications. Four tillage practices *viz.* No-till (NT), Minimum tillage (MT), Conventional tillage with maize sown in flat bed (CT_1) and Conventional tillage with maize sown in raised bed (CT_2) were assigned to main plot treatments. Three nutrient managements such as100% recommended dose of NPK(F1), 50% recommended dose of NPK+50% N equivalent through FYM(F2) and 50% recommended dose of NPK+ 50 % N equivalent through green leaf manuring (GLM)- F3were allotted to sub plots. *Kharif* rice was grown with 60, 35 and 35 Kg of N, P_2O_5 and K_2O per hectare, respectively, and *rabi* maize crop with 120 Kg N, 60 Kg P_2O_5 and 40 Kg K_2O per hectare.

Among various tillage treatments, conventional tillage-CT2 registered higher rice yield (4.4 t ha^{-1}) over Minimum tillage (3.24 t ha^{-1}) and no till system (2.84 t ha^{-1}, Table 9). Both the conventional tillage i.e CT_1 and CT_2 were at par. Among nutrient management options, 100 % NPK registered significantly higher grain yield (4.2 t ha^{-1}) over F_3while at par with F_2. Both F_2 and F_3 were at par with each other. During rabi season, conventional tillage with maize sown in raised bed (CT_2), recorded significantly higher grain yield (4.72 t ha^{-1}) compared to CT_1, MT and NT. CT_1 and MT were at par with respect to grain yield of maize. CT_1 proved its superiority over NT. Among nutrient management options, F1 registered significantly higher grain yield (4.46 t ha^{-1}) over F2 and F3. Both F2 and F3 were at par with each other. With reference to soil organic carbon, NT registered significantly higher values over CT_1 and CT_2 and found to be at par with MT. Among nutrient management options, F2 registered significantly higher soil organic carbon compared to F1 and at par with F2. NT registered numerically higher content of available soil moisture after harvest of rice compared to CT and MT treatments (Fig. 3). Both F2 and F3 registered higher values of available soil moisture over F1.

Table 9 Rice and maize yield, organic carbon content and available soil moisture on volume basis (%) under conservational agriculture set up

Treatments	Rice yield (t ha^{-1})	Maize yield (t ha^{-1})	Organic carbon (%)	Available soil moisture v/v (%)
Main plots(M)				
NT-. No-till	2.84	3.20	0.55	15.94
MT- Minimum tillage	3.24	3.60	0.52	15.68
CT_1- Conventional tillage, maize sown in flat bed	4.20	3.86	0.48	15.28
CT_2- Conventional tillage maize sown in raised bed	4.40	4.72	0.47	15.16
CD(5%)	0.54	0.46	0.05	0.80
Sub plots(S)				
F1-100% NPK	4.2	4.46	0.45	15.81
F2-50%NPK+50% N through FYM	3.8	3.92	0.61	17.23
F3-50 %NPK+ 50 % N through	3.6	3.80	0.60	16.74
green leaf manuring(GLM) CD(5%)	0.42	0.42	0.12	1.02
Interaction(MXS)	NS	NS	NS	NS

No tillage with 100% NPK

Minimum tillage, 50 % NPK+ 50 % N as FYM

tillage, No 50 % NPK+ 50 % N as GLM

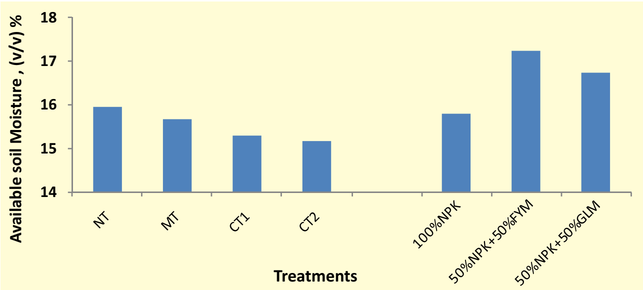


Fig. 3 Available soil moisture (%) on volume basis under different treatments of tillage and nutrient management

Project Title	: **Water Budgeting in High-value Shrimp Monoculture and Carp Poly culture under Varying Intensification Levels**
Project Code	: DWM/11/155
Funding Agency	: Institute
Project Personnel	: Rajeeb K. Mohanty, A. Kumar, D.K. Panda and D. U. Patil

An attempt is being made by DWM since 2012 to quantify the consumptive water use (CWU), total water use (TWU) or total crop water requirement and water productivity in commercially important carp polyculture, and shrimp monoculture of *Penaeus monodon* under varying intensity levels. The main objectives of this study are (1) To study the effect of different stocking densities on the consumptive and total water requirement of Indian major carps in poly culture and black tiger shrimp *P. monodon* in monoculture system, (2) To study the impact of varying intensification levels on water quality, sediment load, water productivity, growth and production performance of Indian major carps and *P. monodon* and (3) To develop protocols for best water management practices (BWMPs) for different levels of intensification.

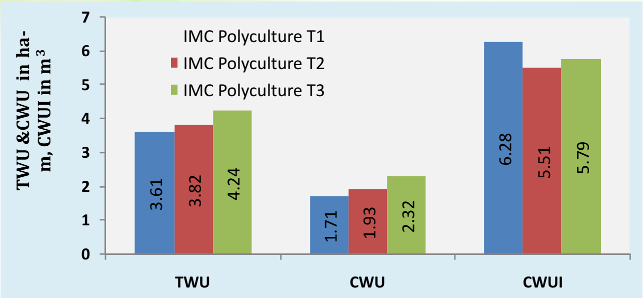


Fig. 4 Treatment-wise TWU, CWU and CWUI in carp polyculture under varying intensity levels

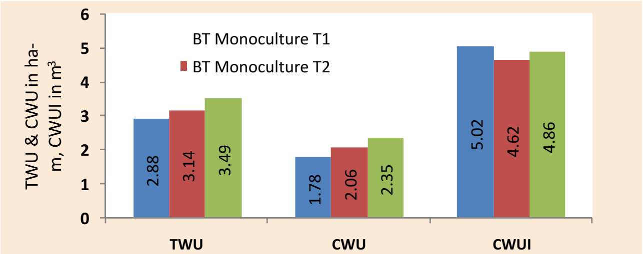


Fig. 5 Treatment-wise TWU, CWU and CWUI in black tiger *P. monodon* culture under varying intensity levels

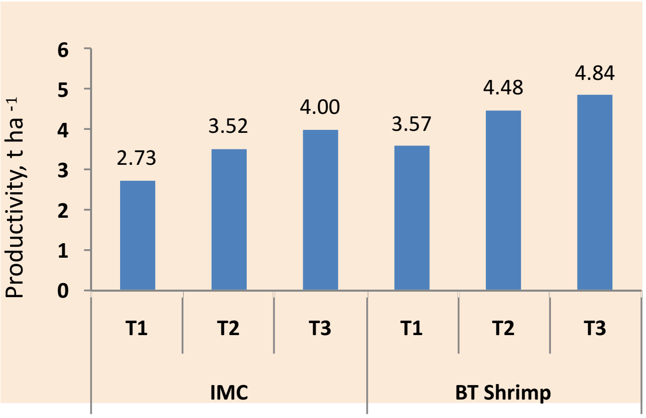


Fig. 6 Production performance of IMCs and P. monodon under varying intensity levels

Total water requirement and consumptive water use in carp polyculture and shrimp monoculture were quantified. Under different stocking density for carp polyculture, treatment-wise estimated total water use (TWU) was 3.61, 3.82 and 4.24 ha-m, while the computed consumptive water use index, CWUI (m3 kg^{-1} biomass) was 6.28, 5,51 and 5.79, in T_1 (6000 fingerlings ha^{-1}), T_2 (8000 fingerlings ha^{-1}) and T_3 (10000 fingerlings ha^{-1}), respectively (Fig. 4). Similarly, under different stocking density, treatment-wise estimated TWU was 2.88, 3.14 and 3.49 ha-m, while the computed CWUI was 5.02, 4.62 and 4.86 in T_1 (150000 PL ha^{-1}), T_2 (200000 PL ha^{-1}) and T_3 (250000 PL ha^{-1}), respectively in monoculture of *P. monodon* (Fig. 5). As density increased, TWU and CWU increased due to increased necessity of water replenishment. Density-dependent growth and yield performance takes place at higher intensity levels (Fig. 6), probably due to mutual competition for food & space that cause physiological stress, resulting in slow growth, size heterogeneity & weight distribution of fish/shrimp, which ultimately affects the water productivity (Fig. 7). Higher intensity level although substantially increase the harvestable biomass, also significantly affects production cost due to increase in the demand for more external inputs (feed, power, mechanical aeration, water, pumping cost, labor). Therefore, the desirable density that gives significantly higher yield, economic benefit (OV:CC) and NCWP was 8000 SD ha^{-1} and 200000 PL ha^{-1} in case of carp polyculture and *P. monodon* monoculture, respectively.

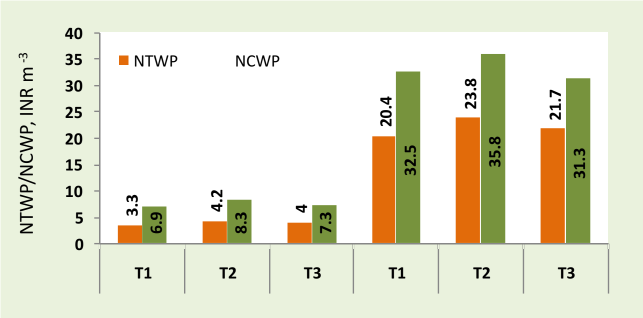


Fig. 7 Treatment-wise net total water productivity and net consumptive water productivity in carp polyculture and black tiger *P. monodon* culture under varying intensity levels

Project Title	:	**Sustainable Rural Livelihood and Food Security to Rainfed Farmers of Odisha**
Funding Agency	:	NAIP, ICAR, New Delhi
Project Personnel	:	S. Mohanty, K. G. Mandal, R. K. Mohanty and Ashwani Kumar

The study on livelihood of the rainfed farmers due to technological interventions was carried out in six study villages, i.e. Khallibandha, Nuagaon, Mandapala, Talagotha, Khamara and Kotapala villages in Dhenkanal Sadar block and Gunadei, Belpada, Kaunriapala, Mahadia, Pasa Singh and Podapada villages in Odapada block of Dhenkanal district. Multiple use of water in agriculture, on-dyke horticulture, vegetable cultivation, poultry, duckery, mushroom and fish culture was taken up in ten water harvesting structures under integrated farming system models. The pond area was used for fish culture and the bund area was used for on-dyke horticulture, whereas the upland area was used for vegetable cultivation. Some of the farmers had poultry, dairy and mushroom cultivation in the uplands. Banana, papaya, drum stick and arhar were mostly planted on the embankments around the pond as on-dyke horticulture. Vegetables like potato, brinjal, ladies finger, tomato, cabbage, cauliflower, cucumber, ridge gourd, cowpea, onion and chili were cultivated on uplands. The water in the water harvesting structures was utilized for supplementary irrigation to paddy crop in *kharif* season, irrigation of vegetables in post-monsoon season, fish culture and duckery.

View of IFS model inside

A fish fingerling production unit was developed in one of the integrated farming system model. A drip irrigation system was also installed in the integrated farming system model. The drip system was used for irrigating the vegetables as well as the papaya and banana plants on the embankment. The vegetables like tomato, ladies finger, brinjal, cabbage and cauliflower were irrigated by drip irrigation system.

Fish culture in pond

Poultry in upland area

On-dyke horticulture

Duckery in pond

Farmer groups were formed to carry out vegetable cultivation by lift irrigation in the post-monsoon season. Pumps were provided to the farmers for lifting irrigation water. Three farmer groups in the Khallibandha and Nuagaon villages were formed for water melon cultivation by river lift irrigation. In total 40 farmers were involved in three groups and 45 ha was put under cultivation. The water melon farmers were also encouraged for adopting drip irrigation. Facilitation was done so that farmers can avail subsidy on drip irrigation through the schemes of Department of Horticulture. An area of 4.5 acre of water melon was put under drip irrigation. The water melon production has increased significantly during the 5 year project period and now it is being exported to different states like West Bengal, Assam, Jharkhand and Chhattisgarh.

The economic analysis of the ten integrated farming system models indicated that the per hectare net income from pond area, bund area, upland area and paddy area varied in the range of ₹ 70,343/- to ₹ 1,42,025/-, ₹ 74,074/- to ₹ 3,19,444/- ₹ 41,333/- to ₹ 6,10,417/-, and ₹ 15,862/- to ₹ 25,375/- respectively. The net income/ ha was the lowest under paddy cultivation and was the highest in uplands especially where poultry was taken up as one of the components. The net income per ha from the bund area was higher than the pond area especially where intensive cultivation was done in the bund area. In one successful integrated farming system model, the net income per ha from the whole system without considering the fixed cost of the system was ₹ 3,36,089/-. Considering the fixed cost of the system, the net income per ha was ₹ 2,50,624/-.

The impact analysis of the technological interventions of the 10 farmers was done by doing a questionnaire survey and analyzing the data. The overall standard of living of farmers was compared based on their physical assets, social assets, financial assets, human assets and natural assets before and after adoption of technological interventions. Fig. 8 shows the average level of different types of assets of the 10 farmers before and after the technological interventions. Maximum improvement occurred in natural assets which were increased by 70% followed by physical assets with 24%. Social, human and financial assets gains were found in the range of 17-21%.

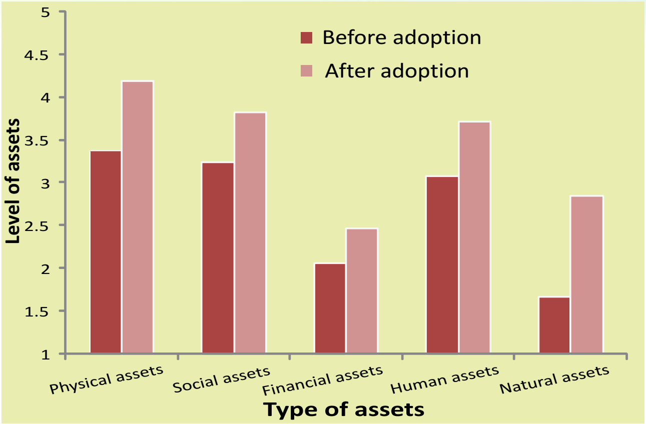


Fig. 8 Average level of different types of assets measuring livelihood of farmers

The change in overall standard of living of the 10 farmers is presented in Fig. 9. It is inferred from the figure that living standard of all farmers except two was below average level (score < 15) prior to adoption of technological packages. However, with the change of farming situation, adoption of technologies helped in bringing the living standard of all but one farm family at above average level (score >15). Standard of living of the farmers, who were engaged in more multiple use activities in the IFS model improved relatively better. Mean value of overall standard of living of all the 10 farmers derived through addition of the mean values of five assets, indicated that this has been increased from 13.47 to 18.01 (minimum and maximum possible value is 5 and 25, respectively).

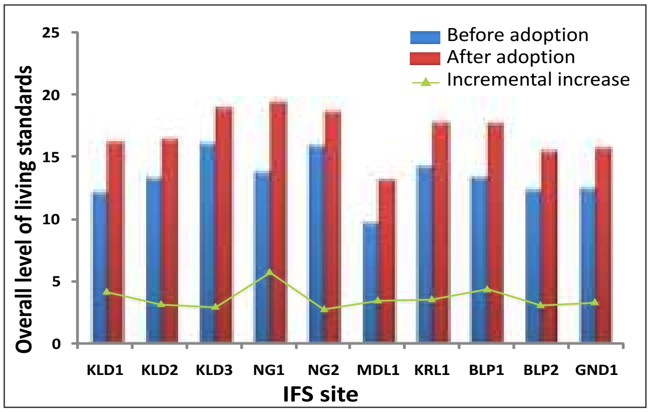


Fig. 9 Overall standards of living of selected farmers before and after adoption

A documentary film on "On-farm Water Management & Multi-Interprise System". A success story based on success story of NAIP Livelihood project was also prepared.

Canal Water Management

- Development of Decision Support System (DSS) for Irrigation Water Management in Hirakud Canal Command Area
- National Initiative for Climate Resilient Agriculture
- Improving Water Productivity under Canal Irrigation Command through Conservation of Surface and Ground Water using Tanks and Wells
- System of Rice Intensification (SRI): Studies on Water Management, Micronutrient Uptake and Crop Rotation
- Evaluating Deficit Irrigation under Drip System for Rice-based Cropping Sequence in Canal Command Area

Project Title	: **Development of Decision Support System (DSS) for Irrigation Water Management in Hirakud Canal Command Area**
Funding Agency	: ISRO, NRSA, Hyderabad
Project Personnel	: R.K. Panda, S. Mohanty and P.S. Brahmanand

A multi layered geo-spatial data base comprising of in-season satellite data; field water budget components study, canal hydraulic parameters like conveyance efficiency and field application efficiency were replicated during the period in the study area located in canal command area of Bargarh distributary under Hirakud canal command area for computation of crop /irrigation water requirements. In-season crop information using multi-date Resource Sat -1 and 2 (Sensors LISS IV, LISS III and AwiFS) during 1993-2013 with 7 cloud free satellite data were used for deriving paddy transplantation and its progress. There has been increasing trend in paddy coverage area between 58-80 % (Total CCA = 159076 ha). However, non paddy area coverage remained within 4.1-5.3 % (Fig. 10 and Fig. 11). Field scale water budget study during 2011-12 and 2012-13 in paddy fields located in upper, middle and lower reaches revealed that field evaporation, transpiration and deep percolation rates varied between 1.15 - 2.15, 3.0 - 4.55 and 1.0 - 2.35 mm day^{-1} respectively.

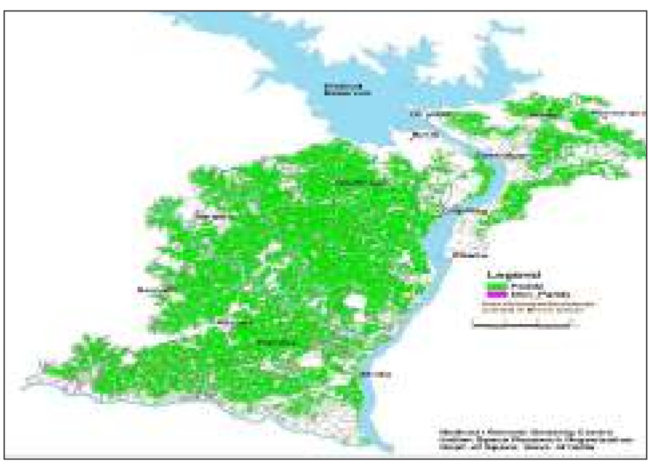
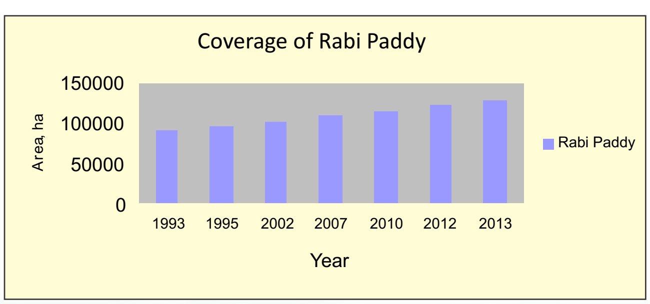


Fig. 10 Satellite data of 2012-13



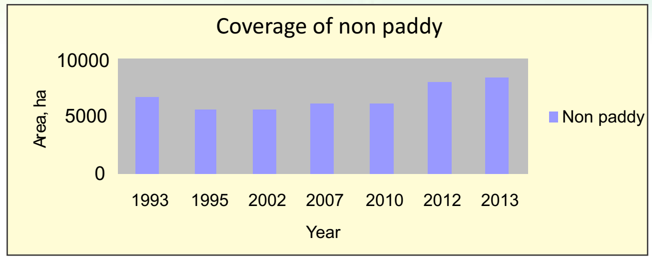


Fig. 11 Temporal crop coverage area

Canal hydraulics

Canal hydraulics like conveyance loss in lined and unlined canal sections and irrigation application efficiency in the commands of minor outlets were measured using pigmy type current meter and there was 84.8 % less conveyance loss in lined canal compared to unlined channels (Table 10). The irrigation application efficiency was between 23.95 –53.07% at five outlets in Malipali minor with CCA ranging between 25.6–79.4 ha, and ET_{crop} varied between 3.6–6.5 mm day^{-1} (Table 11).

Table 10 Canal Hydraulics

	Q_{in}, m^3/s^{-1}	Q_{out}, m^3/s^{-1}	$Q_s = Q_{in} - Q_{out}$, m^3/s^{-1} in 1 m length
Lined canal			
Bargarh	9.13	9.115	0.00015
Nuagarh	4.87	4.83	0.0004
Unlined canal			
Andhratikra	1.89	1.595	0.00295
Sanharatikra	1.775	1.665	0.0011
Kubedega	0.84	0.70	0.0014
Negitikra	0.775	0.595	0.0018

Table 11 Irrigation application efficiency

Outlet	Q(m^3/s^{-1})	CCA(ha)	Irr. appl. eff. (%)
O_{L1}	0.0089	43.2	36.14
O_{L2}	0.0042	25.7	28.71
O_{R3}	0.007	40.1	30.67
O_{R4}	0.024	79.4	53.07
O_{L5}	0.01	39.8	44.09

Leaf Area Index (LAI) of MTU 1001 paddy variety

The leaf area index of paddy crop increased from 1.28 at 21 days after transplanting (DAT) to 5.63 at 77 DAT after which it declined in head region. The similar trend was noticed in mid and tail regions where the highest leaf area index values of 5.32 and 5.05 respectively were observed at 77 DAT. Irrespective of the time period, the leaf area index of rice was found to be significantly superior at head region compared to mid and tail regions.

Assessment of water availability

Assessment of water availability at regional level in Bargarh distributary system having CCA of 12166 ha with total discharge of 9.393 cumec was made and interventions were developed for matching water supply with agricultural production system.

Methodology

The canal release was continuous for the cropping period (approximately 100 days) except the closure for minor maintenance for 3 days. The water availability at each minor/ sub-minors were calculated from their discharge rate. The crops grown in the command area were divided into 3 groups *viz.* heavy, medium and low water requiring crops (Table 12).

Table 12 Details of crop parameters used in the analysis

Crop Type	Crops	Water Requirement* (cm)	Net Return (₹ ha^{-1})
Heavy	Paddy, Sugarcane etc.	100	22500
Medium	G. Nut, Wheat, Vegetables etc.	50	25000
Low	Black gram, Green gram, Pea, Mustard etc.	30	15000

*The total water requirement for the entire cropping period

Deficit surplus analysis

The total crop water requirement for the command of each outlet (DO / minor / sub-minor) is calculated using the following expression:

$$WR_i = A^i_H \times D_H + A^i_M \times D_M + A^i_L \times D_L$$

where, WRi is the total water requirement for the command area of outlet 'i' (ha-cm), A^i_H, A^i_M and A^i_L are the area under heavy, medium and low duty crops in the command area of outlet 'i', respectively (ha), and D_H, D_M and D_L are the total depth of water required for the heavy, medium and low duty crops, respectively (cm).

The water available for each outlet is calculated considering the discharge and the duration of canal opening. The following formula was used.

$$WA_i = q_i \times 36 \times 24 \times N$$

where, WA_i is the total water available at outlet 'i' (ha-cm), qi is the discharge of outlet 'i' (cumec) and N is the number of operation of the canal.

The water available at each outlet is compared with its crop water requirement in the same command area and deficit surplus analysis is carried out. If $WR_i > WA_i$ then the outlet is operating under deficit condition, if $WR_i < WA_i$ then the outlet is operating under surplus condition and if $WR_i = WA_i$ then the outlet is operating under optimal condition.

Optimal allocation of crops

If an outlet is not operating under optimal condition, proper crop planning is required for the outlet. For optimal crop planning in the command area of the outlet, four frequently observed scenarios are considered. The scenarios and their methodology are presented below.

Scenario – I

Under this scenario, the main objective is to minimize the surplus water available at the outlet with the constraint that the total area under all the type of crops should be less than or equal to the designed curlturable command area of the outlet. Mathematically it is expressed as:

Objective: $\text{Min: } Z_i = WR_i - WA_i$

Constraints: $A^i_H + A^i_M + A^i_L \leqslant CCA^i$

$A^i_H, A^i_M, A^i_L \geqslant 0$

where, Z_i is the objective function, WR_i and WA_i are the water requirement in the command area and water available at the outlet 'i' respectively; A^i_H, A^i_M and A^i_L are the area under heavy, medium and low duty crops in the command area of outlet 'i' respectively; and CCA^i is the designed curlturable command area of the outlet 'i'.

Scenario – II

Under this scenario, the main objective is to utilize the maximum area for cultivation with the constraint of water availability for each outlet. Mathematically it is expressed as:

Objective: $\text{Max: } Z_i = A^i_H + A^i_M + A^i_L$

Constraints: $A^i_H \times D_H + A^i_M \times D_M + A^i_L \times D_L \leqslant WA_i$

$A^i_H + A^i_M + A^i_L \leqslant CCA^i$

$A^i_H, A^i_M, A^i_L \geqslant 0$

where, D_H, D_M and D_L are the total depth of water required for the heavy, medium and low duty crops respectively (cm); and the other terms are same as defined above.

However, it is assumed that the total cropped area Z_i may not exceed the culturable area available under the outlet 'i' i.e., CCA^i. Hence, the objective effectively becomes another constraint.

Scenario – III

Under this scenario, the main objective is to utilize the maximum area for cultivation with the constraints (1) water availability for each outlet should meet the demand, and (2) at least 1/3rd of the cropped area should be paddy (heavy duty crop) as per choice of the people. Mathematically it is expressed as:

Objective: $\text{Max: } Z_i = A^i_H + A^i_M + A^i_L$

Constraints:
$$A^i_H \times D_H + A^i_M \times D_M + A^i_L \times D_L \leqslant WA_i$$
$$A^i_H \geqslant CCA^i_A / 3$$
$$A^i_H + A^i_M + A^i_L \leqslant CCA^i$$
$$A^i_H, A^i_M, A^i_L \geqslant 0$$

where, the terms are same as defined above.

Similar to the Scenario II, it is assumed that the total cropped area Z_i may not exceed the culturable area available under the outlet 'i' i.e., CCA^i. Hence, the objective effectively becomes another constraint.

Scenario – IV

Under this scenario, the main objective is to maximize the net agricultural return from the command area of each outlet. The constraints here are, (1) water availability for each outlet should meet the demand, and (2) the total area under cultivation should be less than or equal to the available area. Mathematically it is expressed as:

Objective: $\text{Max: } Z_i = NR_H \times Ai_H + NR_M \times A^i_M + NR_L \times A^i_L$

Constraints:
$$A^i_H \times D_H + A^i_M \times D_M + A^i_L \times D_L \leqslant WA_i$$
$$A^i_H + A^i_M + A^i_L = CCA_i$$
$$A^i_H, A^i_M, A^i_L \geqslant 0$$

where, NR_H, NR_M and NR_L are the net return per hectare from heavy, medium and light duty crops respectively, and the other terms are same as defined above. All the scenarios were analyzed using Excel Solver.

Deficit surplus analysis

The analysis of data was carried by the above mentioned methodology. Deficit status (71569 ha-cm) was observed for all the minors/ sub-minors of the distributary system at the head reach. Water was surplus (12125 ha-cm) at most of the minors located in the middle reach; whereas, mixed status was observed for the outlets in the tail reach. However water deficit condition (32392 ha-cm) prevailed in the distributary system perhaps due to deficit condition of the outlets at the head reach.

Scenario – I

To maintain the optimum water use (with no surplus or deficit), about 66.5% of the total command area should be irrigated. However, there would be surplus water in the command area of Dekulba Minor even if the entire CCA cultivate heavy duty crops. This suggested that more water could be diverted to the Dekulba Sub-Minor or discharge in the Dekulba Minor could be reduced and the surplus water could flow to the Jamdol Minor to increase the cultivated area under the later. Under this scenario only 10026.75 ha of the total command area of 12166 ha would receive irrigation in rabi season with average rate of net return of ₹ 17,943/- per hectare of the irrigated area.

Scenario – II

Under his scenario results suggested that 100% of command area of the distributary can be irrigated, if the designed cropping pattern is followed. This would ensure more employment of agricultural labourers than the other scenarios. However, similar to the first scenario, the use of irrigation water is not optimal for the Dekulba Minor. Even though the total command area could be irrigated under this scenario, average rate of net return per hectare of the irrigated area would reduce (₹ 16,426) compared to the previous scenario.

Scenario – III

It was observed that this scenario would give more net return than that of the first scenario, with provision of irrigation for 99.7% of the CCA. However, because of the constraint of 1/3rd area under heavy duty crops, the average rate of net return per hectare of the irrigated area under this scenario would be less (₹ 16,365/-) than that of the second scenario.

Scenario – IV

The cropping patten under this scenario would give the maximum net agricultural return from the command area of the distributary with 100% land utilization and without any water deficit in any of the outlets. However, since no area is allocated for low duty crops like pulses and oilseeds, this scenario might not be practicable.

Therefore the cropping pattern obtained under Scenario–II may be adopted for the command area of the distributary for optimal land and water utilization, and generation of requisite employment. However, if the affinity of the farmers towards heavy duty crop cannot be avoided then Scenario – III could be adopted.

Project Title	:	**National Initiative for Climate Resilient Agriculture**
Funding Agency	:	NICRA, ICAR, New Delhi
Project Personnel	:	G. Kar, A. Kumar, P.S. Brahmanand, D.K. Panda, C. Mayilswamy, P.K. Singh and H.D. Rank

Monitoring ecosystem CO_2 emissions and sequestration, gross primary productivity, ecosystem respiration, net ecosystem exchange and energy balances over multiple cropping systems

Carbon dioxide (CO_2) exchange between the terrestrial ecosystems and the atmosphere is one of the major processes affecting atmospheric CO_2 concentration. In various ecosystems in the world long-term observations of CO_2 exchange have been made for assessing the role of terrestrial ecosystems in the present-day global CO_2 budget and to predict its changes in the future climatic scenario. The eddy covariance (EC) system can provide a measure of net ecosystem exchange (NEE), which can be partitioned into gross primary production (GPP) and ecosystem respiration (RE) using mathematical model and is useful for characterization of ecosystem carbon budgets. In this study ecosystem CO_2 emissions and sequestration, gross primary productivity, ecosystem respiration, net ecosystem exchange and energy balances were monitored using eddy covariance technique over multiple cropping systems [okra (April-June)-rice (July-November)-tomato (December-March)] at Deras research farm of DWM, Bhubaneswar.

The daily variation of NEE showed maximum net ecosystem exchange at 1130 hour and was highly influenced by leaf area index (LAI). In okra crop the NEE showed a negative value from secondary branching (32 DAS) to 10 days before last fruit picking (69 DAS) by more uptake of CO_2 due to photosynthetic assimilation than release of CO_2 through respiration from the canopy. The NEE reached its peak at maximum leaf area index stage (55 DAS) with the midday uptake (negative *NEE*, *i.e.* uptake of CO_2 due to photosynthetic assimilation) of –18.5 µmol CO_2 m^{-2} s^{-1} and night-time release (positive NEE, i.e. emission of CO_2 due to respiration in the absence of photosynthesis) of +4.55 µmol $CO_2 m^{-2} s^{-1}$ (Fig. 12).

Rice crop showed a daytime uptake and night-time release of CO_2 from the canopy. From the tillering stage the paddy field became the net CO_2 sink and diurnal variation of NEE became prominent. NEE reached its peak at boot leaf stage (76 DAS) with the midday uptake of –22.9 µmol CO_2 m^{-2} s^{-1} and night-time release of + 4.06 µmol CO_2 m^{-2} s^{-1} (Fig. 13). Maximum NEE and GPP by rice crop was found between 11.30 and 12.30 h. The crop also behaved as a net CO_2 emitter during the maturity period.

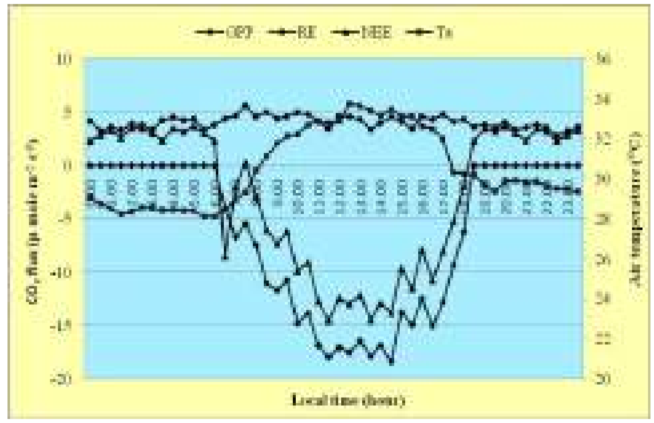


Fig. 12 Diurnal variation of gross primary productivity (GPP), respiration (RE), net ecosystem exchange (NEE), air temperature (Ta) of Okra at maximum leaf area stage

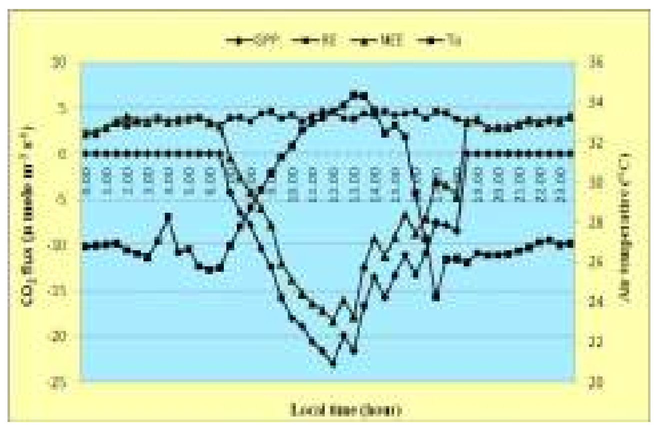


Fig. 13 Diurnal variation of gross primary productivity (GPP), respiration (RE), net ecosystem exchange (NEE), air temperature (Ta) of rice at boot leaf stage of rice

The seasonal and diurnal variation of surface energy fluxes over okra and rice crop stand (maximum leaf area stage in case of okra and boot leaf stage in case of rice) were measured (Fig. 14 & 15). Maximum net radiation (R_n), amount of energy available over the crop was measured at 11.30-12.30 h. The latent heat flux (LE) which is the most important component of energy balance for irrigation management was largely dependent on development of leaf area index (LAI) and soil moisture content and showed peak when LAI was maximum. The mid day latent heat flux rate (on clear days) varied from 432 W m^{-2} in okra at maximum leaf area stage to 465 W m^{-2} in rice at boot leaf stage.

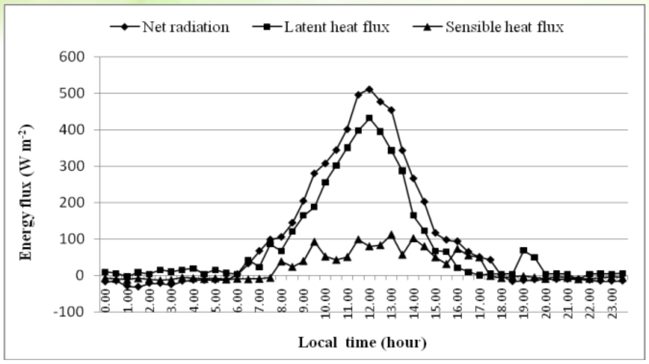


Fig. 14 Diurnal variation of energy fluxes over okra crop at maximum leaf area index stage

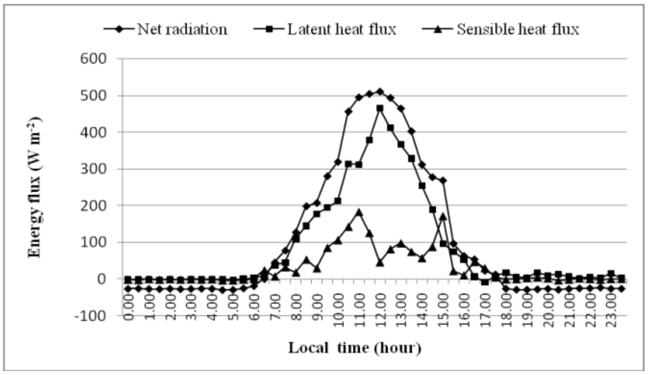


Fig. 15 Diurnal variation of energy fluxes over boot leaf stage in case of rice

Multiple use of created water resources for higher water productivity

Pond based farming systems (crops, on-dyke horticulture, fisheries) were developed in created water resources in three canal commands in Kendrapara district to enhance water productivity and to mitigate dry spells. Water productivity of the area enhanced from ₹ 1.1-1.42 m^{-3} through sole rice to ₹ 6.35-7.95 m^{-3} through pond based farming. Due to assured available water cropping intensity in the pond command area increased by 2 to 2.5 times with net return between ₹ 48,645 to ₹ 66,170 from the pond based farming area.

Estimation of recovery rate, characterization of command area, cropping system under the dug well command areas and improving water use efficiency and productivity through drip irrigation in vegetable crops.

A 1.5 hp (horse power) pump with a discharge rate of 6 lps (liter per second) at 3600 rpm (revolution per minute) with 12 m suction head was used for the pumping purpose. Water level indicator was used to monitor the drawdown in the dug well with the time. For the analysis of pumping test data Neuman's straight line method was used to determine the hydraulic parameters of an unconfined aquifer by straight-line fits to early, intermediate, and late time drawdown data. Drawdown and time was plotted using semilog graph paper with time in logarithmic scale (Fig. 16 & 17). From the late-segment of the curve, the transmissivity and specific yield of the aquifer (Table 13 & 14) was determined by using following formulas

$$T = \frac{2.3Q}{4\pi\Delta s'}$$

$$S_y = \frac{2.25T\, t_{0y}}{r^2}$$

Where, T = transmissivity, Q = discharge rate, Δs' = difference in draw down, S_y = specific yield, r = radius of well.

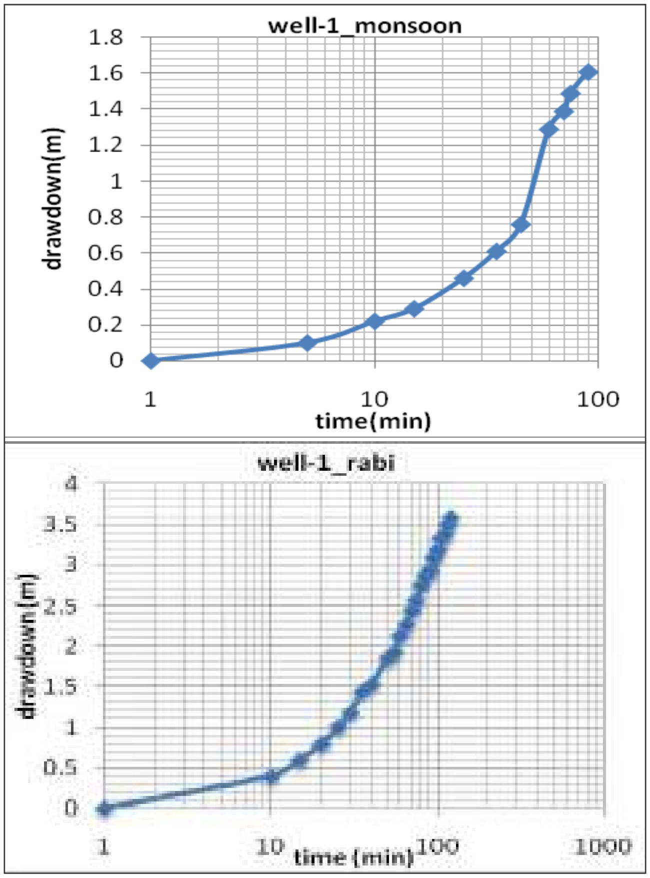


Fig. 16 Drawdown with time of well 1 in monsoon and *rabi* season

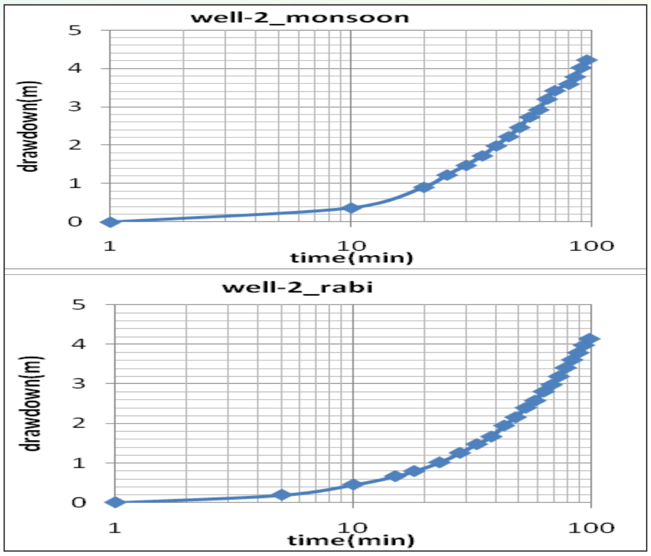


Fig. 17 Drawdown with time of well 2 in monsoon and *rabi*

Table 13 Transmissivity, specific yield and storativity of the aquifer of different wells of monsoon season

Well no	Transmissivity ($m^2\ min^{-1}$)	Specific yield	Storativity
1	54.74	1.275	0.08 1
2	22.81	0.673	0.085
3	17.12	0.664	0.250
4	20.28	0.315	0.031

Table 14 Transmissivity, specific yield and storativity of the aquifer in *rabi*

Well no	Transmissivity ($m^2\ min^{-1}$)	Specific yield	Storativity
1	49.77	1.622	0.077
2	27.37	0.977	0.087
3	13.69	0.637	0.200
4	22.81	0.567	0.020

Table 15 Total water available (aquifer storage + well storage) in single pumping

Well no	Avg. storativity	Water available from aquifer storage (in a single pumping) (S*I*2πRh)(m^3)			Water available in the well in a single pumping (πR^2h)			Total water available (aquifer storage + well storage)		
		Kharif	Rabi	Kharif (m^3)	Rabi (m^3)	Summer (m^3)	Summer	Kharif (m^3)	Rabi (m^3)	Summer (m^3)
1	0.079	0.752	0.544	66.939	56.953	44.962	0.339	67.690	57.497	45.301
2	0.086	0.833	0.614	67.541	58.008	49.954	0.456	68.374	58.623	50.410
3	0.225	0.515	0.012	32.838	5.002	19.641	0.184	33.353	5.014	19.825
4	0.0255	0.268	0.175	70.386	56.840	43.737	0.104	70.654	57.015	43.841

The total water available from the well and the aquifer in a single pumping with an average values of 59.98 m^3, 44.52 m^3 and 39.83 m^3 in the three seasons, *kharif*, *rabi* and summer respectively, were adequate satisfying the water requirement of the various vegetable crop grown in the study site (Table 15). Analysis of the recovery test data was carried out to find out the recovery rate of the wells (Table 16) as well as the time to regain its original position before pumping (Table 17).

Table 16 Recovery rate of the well water to its static water level

Well no.	Discharge rate(lps)	Static water level(m)	Time of pumping(min)	Drawdown(m)	Recovery rate(m hr^{-1})
1	6	4.84	105	1.61	1.8
2	6	1.37	95	4.23	0.30
3	6	4.48	165	0.98	0.39
4	6	2.75	130	4.55	0.26
5	6	0.65	180	0.45	1.8

Table 17 Computed time of regaining static water level

well no	Recovery rate (m hr^{-1})	Wetted height (h=L -S)(m)			Time for regaining static water level (hrs)		
		Kharif	*Rabi*	*Summer*	*Kharif*	*Rabi*	*Summer*
1	1.80	7.11	6.05	4.77	3.9	3.4	2.7
2	0.30	7.17	6.16	5.30	23.9	20.5	17.7
3	0.39	3.49	0.53	2.09	8.9	1.4	5.3
4	0.26	7.47	6.03	4.64	28.7	23.2	17.9
5	1.80	6.78	5.73	3.92	3.8	3.2	2.2

The average aquifer properties calculated using pumping test data namely transmissivity, specific yield and storativity of 114 m^2 min^{-1}, 0.077 and 0.096 respectively showed that the aquifer may serve as a sustainable source to meet the irrigation requirement of the study area. The 26-63% saving in water and 12-44% increase in yield was also observed in different crops after installation of drip irrigation system (Table 18).

Table 18 Saving in water and increase in yield due to installation of drip irrigation system

Crop	Saving in water (%)	Increase in yield (%)
Sunflower	52	-
Maize	53	12
Chilli	53	15
Cauliflower	63	27
Potato	39	38
Tomato	26	42
Cabbage	41	56
B. gourd	53	36.5
Brinjal	44	30
Banana	47	44

Development and evaluation of location specific groundwater recharge structures in different agro-ecological zones

Location specific groundwater recharge techniques suitable for geo-hydrological conditions was developed and tested for recharge rate and area of influence. Dry Stone Masonry Pond, Single Wall Masonry Structure, Cement Masonry Structure were constructed at Kherad, Som, Karget, Shisvi villages of Udaipur district, Rajasthan. To assess groundwater recharge through rainwater harvesting structures, daily monitoring of surface water level was carried out through the installation of gauge in the pond. The water table of the identified well situated in the downstream side of the structures were measured on daily basis. The overall storage capacity of water harvesting structures constructed at Shishvi and Masonry Check Dam at Karget Karget were 4235 and 3985 m^3, respectively. The average recharge rates were 7.92 and 8.32 cm day^{-1} at Shishvi and Karget, respectively.

The water harvesting cum groundwater recharge structures were developed and evaluated at Dhari and Kodinar farms of Junagarh Agricultural University, Gujarat. The recharged water to aquifer from these ponds storage (storage capacity 9604 m^3) was 13415 m^3. The total harvested rainwater (runoff) during the monsson of 2012 was 13572 m^3. The recharged groundwater from the pond storage can be helpful for the life saving irrigation of 5 cm depth to the crops in the area of 26.83 ha in case of dry spell during the monsoon. If no dry spells occur during monsoon, the recharged groundwater can be helpful during winter season to irrigate additional area of 3.35 ha of crop having 40 cm seasonal irrigation requirements.

The total harvested water storage was 4478 m^3 through runoff in another 4 ponds at JAU farm Dhari and out of that 4297 m^3 was available for groundwater recharge. The recharged groundwater due to pond storage can be helpful for the life saving irrigation of 4 cm depth to the crops in the area of 10.74 ha in case of dry spell during the monsoon. Otherwise, it can be utilized to cover additional area of one hectare of winter crop having seasonal irrigation water requirements of 40 cm. Construction of another recharge structure of designed capacity of 31700 m^3 is under progress at JAU farm, Mahuva which is located in coastal belt of Gujarat.

Project Title	:	**Improving Water Productivity under Canal Irrigation Command through Conservation of Surface and Ground Water using Tanks and Wells**
Funding Agency	:	INCID, MOWR, New Delhi
Project Personnel	:	K.G. Mandal, S. Ghosh, R.K. Mohanty, M. Raychaudhuri and Ashwani Kumar

The canal command and the study area

Kuanria Medium Irrigation Project (KIP; 20°21' N latitude and 84°51' E longitude) at Daspalla block (571.57 km^2 area) Nayagarh district of Odisha has reservoir is 124 km^2 and cultivable command area 3780 ha. The right and left distributaries are 18.2 and 16.5 km long .There are total of 32 sub-minors and 5 minors distributed over the entire command area.

Pond-based integrated system under Khamarsahi sub-minor

The rain/ runoff water storage tank was made in the field of a beneficiary farmer, Sh. Sudarsan Das of village Paikabaguarani under Khamarsahi sub-minor in the right distributaries of KIP under WUA 8 jurisdiction. The capacity and total command area of the constructed pond were 1630 m^3 and 2.43 ha including the pond area. Fish (rohu, catla and mrigala) was reared in the pond. Primary crop rice (varieties were 'Swarna', 'Priya' and 'CR-1018') was grown during *kharif* season in the pond command area. Paddy yield ranged from 3829 to 3952 kg ha^{-1} under the pond command, and 3162 to 3396 kg ha^{-1} in the non-command. During *rabi* season, greengram, blackgram and chickpea was grown with residual soil moisture. One supplementary irrigation was given from the pond. In the non-command area, greengram and blackgram was grown with residual soil moisture only. The crop yield of greengram, blackgram and chickpea was 453, 494 and 741 kg ha^{-1}, under the pond command, whereas yield of greengram and blackgram, in the non-command area were 371 and 395 kg ha^{-1} respectively. The fish yield of 2.88 t ha^{-1} was obtained in 210 days.

Pond-based integrated system under Madhyakhanda sub-minor

The rain/ runoff water storage tank was constructed in the field of a beneficiary farmer, Sh. Banabihari Muduli of village Dendabhuin under Madhyakhanda sub-minor in the right distributaries of KIP under WUA 9. The capacity and total command area of the constructed pond were 1630 m3 and 2.43 ha including the pond area. Fish (rohu, catla and mrigala) rearing was done in the pond. Rice was the primary crop during *kharif* season and varieties were

Brinjal intercropped with maize in the tank and well command in Madhyakhanda sub-minor

'Swarna', 'Pooja' and 'CR-1009'. Paddy yield ranged from 3293 to 3890 kg ha^{-1} under the pond command and 2779 to 3520 kg ha^{-1} in the non-command area. During *rabi* season, crop yield of green gram and pigeonpea was 401 and 371 kg ha^{-1}, under the pond command, whereas yield of green gram in the non-command area was 371 kg ha^{-1} . The yield of fish was 2.71 t ha^{-1} in 210 days.

Bitter gourd cultivation in the tank and open well command in Madhyakhanda sub-minor

Pond-based integrated system under Lunisara sub-minor

The rain/ runoff water storage tank was constructed in the field, near the main roadside, of a beneficiary farmer, Sh. Hadia Nayak of village Soroda under Lunisara sub-minor in the right distributaries of KIP under WUA 10. Fish (rohu, catla and mrigala) was reared in the pond. Rice was the primary crop during *kharif* season in the pond command area. Paddy yield was 3211 kg ha^{-1} under the pond command, and average of 3335 kg ha^{-1} in the non-command. The fish yield was 2.83 t ha^{-1} and was obtained in 210 days.

Pond-based integrated system under Soroda sub-minor-II

The rain/ runoff water storage tank was constructed in the field, near roadside, of a beneficiary farmer, Sh. Bhagirathi Nayak of village Subalaya under Soroda sub-minor-II in the right distributaries of KIP in WUA 10. The capacity and total command area of the constructed pond were 1630 m^3 and 2.02 ha including the pond area. Fish was reared in the pond. Rice was the primary crop during *kharif* season. Rice varieties 'Swarna', 'Pooja' and 'CR-1009' were in the pond grown command area. Paddy yield ranged from 3088 to 3458 kg ha^{-1} in pond command, and 3088 to 3149 kg ha^{-1} in the non-command. The crop yield of greengram was 346 kg ha^{-1} under the pond command. The fish (rohu, catla and mrigala) yield of 2.46 t ha^{-1} was obtained in about 210 days.

The other four rain/ runoff water storage tanks and open wells were constructed in four different sites/ sub-minors. These ponds were made in the beneficiary farmer's (Mrs. Jyotsnamai Nanda) field in the village Kunjabanagarh with Mangalpur sub-minor in the left distributary of KIP under WUA 2; in a beneficiary farmer's (Sh. Banamali Mishra) field in the village Malisahi with Khairapankalsahi sub-minor in the left distributary of KIP under WUA 4; in a beneficiary farmer's (Sh. Balakrushna Pradhan) field in the village Dwargaon with Madhyakhanda (2) sub-minor in the left distributary of KIP under WUA 5; and in a beneficiary farmer's (Mrs. Itishree Mishra) field in the village Dendabhuin with Odasar sub-minor in the right distributary of KIP under WUA 6. On an average, the trend was similar to the other four as described earlier.

New crop of sweet corn has been introduced in the pond-command under Mangalpur sub-minor

Fish harvested (rohu, catla and mrigala) from constructed water storage tank under Sorada sub-minor II

Conjunctive use of groundwater and pond water was made possible for irrigation to okra in Madhyamkhanda (2) sub-minor

Fish culture and studies on pond water quality, production and performance index and fish water productivity

Low input-based medium-duration fish culture was undertaken. Fish fingerlings of Indian major carps i.e., IMCs (Catla catla, Labeo rohita and C. mrigala) were stocked @ 5,000 ha^{-1} with a stocking composition of 30:30:40 (MBW- 18.0, 14.5 & 12.0 g for catla, rohu and mrigala, respectively) in each pond of 1630 m^3 (Table 19). The mean minimum and maximum values of various water quality parameters in the ponds during the rearing period were: water temperature 27.4 - 35.3 °C; pH 6.8-8.8; dissolved oxygen 4.4 - 6.9 ppm; total alkalinity 81 - 123 ppm; dissolved organic matter 2.6 - 4.6 ppm; nitrite –N 0.006 - 0.07 ppm; nitrate-N 0.06 - 0.5 ppm; ammonia 0.01 - 0.33 ppm; transparency 33+4; and total suspended solid 160 - 358 ppm. TSS and DO concentration showed a decreasing trend with the advancement of rearing period while, gradual increase in nitrite, nitrate, ammonia were attributed by increased level of metabolites and organic matter. At any given point of time, other water quality parameters and plankton did not register any specific trend. After 210 days of rearing, fish yield was 2.46-2.88 t ha^{-1}. Species-wise production-size index ranged between 540.7-609.6, 241.1-279.2, and 338.6-382.4 for *Catla catla*, *Labeo rohita* and *C. mrigala* respectively. Similarly, the species-wise performance index ranged between 274.2-303.5, 196.7-210.9, and 200.1-209.4 for *Catla catla, Labeo rohita* and *C. mrigala* respectively, indicating the normal growth performance of the cultured species. Pond-wise gross water productivity (₹ m^{-3}) ranged between 6.47-7.79 while the net water productivity (₹ m^{-3}) ranged between 4.6-5.72.

Table 19 Production and performance indices of IMCs in pond-based farming system

Pond in the sub-minor	Species	Initial MBW (g)	Final MBW (g)	PSI / PI	Productivity (t ha^{-1} $210d^{-1}$)	AFCR/FE%	GWP (₹ m^{-3})	NWP (₹ m^{-3})
Khamarsahi sub-minor	Catla	18.0	553.2	540.7 / 274.2	2.88	1.37 /50.3	7.79	5.72
	Rohu	14.5	476.5	241.1 / 196.7				
	Mrigala	12.0	498.5	338.6 / 200.1				
Madhyakhanda sub-minor	Catla	18.0	570.0	606.2 / 303.5	2.71	1.15 /70.3	7.32	5.35
	Rohu	14.5	485.5	279.2 / 210.9				
	Mrigala	12.0	470.0	382.4 / 206.5				
Lunisara sub-minor	Catla	18.0	558.5	609.6 / 302.0	2.83	1.29 /64.2	7.07	5.03
	Rohu	14.5	480.5	260.7 / 204.4				
	Mrigala	12.0	485.5	356.2 / 202.2				
Soroda sub-minor-II	Catla	18.0	562.0	609.0 / 282.2	2.46	1.41 /59.6	6.47	4.60
	Rohu	14.5	482.5	246.1 / 200.9				
	Mrigala	12.0	490.0	372.7/ 209.4				

PSI- production-size index, PI- performance index, AFCR- apparent feed conversion ratio, FE- feeding efficiency, Fish sold @ ₹ 80 kg^{-1}, GWP- gross water productivity, NWP- net water productivity

The chemical quality parameters of pond and groundwater in Kuanria command area is presented in Table 20. It indicated that mean values of each parameter was within the permissible limits for irrigation purpose as per the FAO guidelines, hence were found suitable for irrigation.

Table 20 Chemical quality of pond water and groundwater in the Kuanria canal commands in Daspalla, Nayagarh

Quality parameters	Pond water		Groundwater	
	Mean (±s.d.)	Range	Mean (±s.d.)	Range
pH	7.68 (±0.35)	7.26-8.18	6.47 (±0.38)	6.08-6.84
EC (µS cm^{-1})	506 (±185)	267-640	497 (±183)	388-771
TDS (mg l^{-1})	248 (±91)	131-314	243 (±90)	190-378
Na (me l^{-1})	2.66 (±1.18)	1.21-3.78	1.56 (±0.60)	1.17-2.46
K (me l^{-1})	0.34 (±0.16)	0.21-0.55	0.38 (±0.06)	0.02-1.37
P (ppm)	2.40 (±1.18)	0.70-4.20	1.43 (±0.15)	0.50-3.10
Ca (me l^{-1})	0.98 (±0.21)	0.70-1.30	1.60 (±0.60)	1.20-2.50
Mg (me l^{-1})	0.73 (±0.24)	0.50-1.10	1.33 (±0.82)	0.30-2.30
NH_4-N (mg l^{-1})	14.0 (±4.43)	10.5-21.0	23.6 (±1.0)	10.5-35.0
NO_3-N (mg l^{-1})	20.42 (±6.79)	14.00-31.5	43.0 (±3.5)	38.5-46.0
Cl (me l^{-1})	2.03 (±1.12)	0.70-3.25	1.57 (±0.66)	0.60-2.12
HCO_3 (me l^{-1})	9.33 (±2.73)	6.00-13.00	9.5 (±0.5)	5.0-15.0

s.d. is standard deviation

Development of appropriate cropping systems and assessment of economic benefit of pond-based integrated farming in the canal command

Rice-fallow is a predominant cropping system in the command area; rice is grown during *kharif* season due to almost sufficient rainfall during monsoon period. However, due to drought like situation once in three years, paddy crop also suffers from moisture stress. Due to our intervention by construction of rain/ runoff water storage tanks and open wells, better cropping systems were followed in the intervened area by the trained and beneficiary farmers. Due to pond-based integrated system, appropriate cropping system was rice + (fish in pond)-green gram, rice + (fish in pond) –black gram and rice + (fish in pond) -chickpea compared to rice-fallow, rice-green gram and rice-black gram in the Khamarsahi sub-minor; rice + (fish in pond) +pigeonpea (on dyke) –green gram and rice + (fish in pond) + pigeonpea (on-dyke)- pigeonpea (on dyke) compared to rice-fallow and rice-green gram only in Madhyakhanda sub-minor; rice+(fish in pond) –green gram compared to rice-fallow cropping system in Lunisara sub-minor; and rice+(fish in pond) –green gram compared to rice-fallow cropping system in Soroda sub-minor under the KIP command in the study area. The economic assessment of pond-based integrated farming showed that cost of cultivation, including the cost for *kharif* crop, fish culture and *rabi* crops, ranged from ₹ 1,19,772 to ₹ 1,24,230 and the benefit was ₹ 1,37,210 to ₹ 1,74,012 due to the pond-based interventions.

Project Title	: **System of Rice Intensification (SRI): Studies on Water Management, Micronutrient Uptake and Crop Rotation**
Project Code	: DWM/12/156
Funding Agency	: Institute
Project Personnel	: A.K. Thakur, K.G. Mandal, S. Raychaudhuri and A. Kumar

Rice experiment during *kharif*

A field experiment was conducted during the 2013 *kharif* season at the DWM Research Farm to evaluate the effect of rice cultivation systems on growth, physiology and grain yield. The systems of rice cultivation comprised SRI method and conventional transplanting method (TP) with two different nutrient managements (organic and integrated nutrient management (INM)). Experimental treatments were, a.SRI-Organic; b. SRI-INM; c. TP-Organic; d. TP-INM

Morphology, grain yield and yield-contributing characteristics

At harvest. SRI plants were 11% taller than conventionally TP plants (Table 21). Organically-grown plants were shorter than the plants grown with chemical fertilizers in both the methods. SRI hills had nearly double the number of tillers and panicles than TP hills. The number of tillers per unit area was greater under TP method compared to SRI method mainly due to the greater number of hills per unit area under TP. The number of tillers per unit area was also more when grown with chemical fertilizers than with organic treatments. However, the number of panicles per unit area was significantly higher in SRI plots than TP. These results showed that in SRI method the percentage of tillers that formed panicles (effective tillers) were significantly higher (13%) than conventional method.

Table 21 Effect of rice cultivation systems on plant height, tillering and panicle development

Cultivation system	Plant height (cm)	Tiller No. hill^{-1}	Panicle No. hill^{-1}	Tiller No. m^{-2}	Panicle No. m^{-2}	Effective tillering (%)
SRI-Organic	86.9	16.9	15.0	422.1	374.5	88.72
SRI-INM	91.9	18.4	16.5	461.2	412.3	89.40
TP-Organic	78.3	9.0	7.2	451.1	358.1	79.38
TP-INM	83.2	10.0	7.9	502.1	392.8	78.23
LSD 0.05	2.1	1.4	1.2	24.7	19.8	2.19

The average panicle length in SRI (21.0 cm) was significantly higher than panicles in TP (16.1 cm). The longer SRI panicles carried nearly 18% more number of grains compared to panicles obtained from TP (Table 22). Highest grain yield was obtained in SRI with inorganic fertilization. As compared to TP-INM grain yield under SRI-INM enhanced by 43%. Under organic fertilization under SRI showed 31% higher grain yield than TP. The enhancement in grain yield under SRI was mainly due to significant improvement in number of spikelet per panicle, grain filling percentage and 1000-grain weight. The harvest index in SRI method also showed significant improvement compared to TP, mainly due to increase in grain yield (Table 22).

Table 22 Effect of rice cultivation systems on grain yield, yield contributing characters, straw weight and harvest index

Cultivation system	Ave. panicle length (cm)	Spikelet number Panicle^{-1}	Filled spikelet (%)	1000-grain weight (g)	Straw dry weight (t ha^{-1})	Grain yield (t ha^{-1})	Harvest Index
SRI-Organic	20.4	122	78.4	24.2	4.84	4.99	0.51
SRI-INM	21.6	132	76.7	24.0	6.47	6.02	0.48
TP-Organic	16.4	98	68.9	23.1	4.91	3.97	0.45
TP-INM	15.8	113	66.9	23.3	5.66	4.19	0.43
LSD 0.05	0.5	9	2.2	0.4	0.27	0.19	0.02

Black gram with different planting pattern during *rabi*

Another field experiment was conducted during *rabi* season to evaluate the effect of rice cultivation methods (SRI vs TP with two different nutrient managements) on performance of *rabi* pulse crop with three types of planting pattern, broadcasting (with plant density of 50-55 m^{-2}), line sowing with 30 cm row to row distance (plant density of 30-35 m^{-2}) and square sowing (maintaining same plant-plant and line-line distances) with 20 x 20-cm spacing (planting density of 25 m^{-2}). Black gram (Vigna mungo L. var. Ujala) was grown in the same field where rice was cultivated during kharif season following two cultivation methods (SRI vs TP) with two different nutrient managements (organic vs. INM). No additional nutrients were provided for the pulse crop.

Effect on yield and yield components

Improved morphological features and root growth under square planting of black gram resulted into significant improvement in number of pods, seeds per plant and grain weight (Table 23), which ultimately led to higher grain yield. Organic application during *kharif* rice also added advantage in terms of grain yield and yield contributing parameters compared with INM. Square sowing significantly improved number of pods plant-1 (97% than broadcasting and 60% than line sowing), seeds number pod-1 (48% than broadcasting and 26% than line sowing) and bolder grains. Overall, these parameters led 73% and 70% more yield under square planting than broadcasting and line sowing method (Fig. 18). In SRI plots there was 11% more yield compared with conventional transplanted rice plots, may be due to more availability of remnant nutrients in SRI plots.

Table 23 Effect of rice cultivation system and planting pattern in black gram (*Vigna mungo*) on No of pods $plant^{-1}$, No of seeds pod^{-1}, and 1000-seeds weight (g).

Rice Cultivation system	No. of pods $plant^{-1}$				No. of seeds pod^{-1}				1000-seeds weight (g)			
	Broad.	Line	Square	Av.	Broad.	Line	Square	Av.	Broad.	Line	Square	Av.
SRI-Organic	13.8	14.6	27.6	18.7	4.0	4.6	6.4	5.0	25.0	29.2	29.8	28.0
SRI-INM	10.8	15.0	22.6	16.1	3.6	4.6	5.8	4.7	24.4	27.4	30.2	27.3
TP-Organic	13.6	16.4	23.6	17.9	4.0	4.2	5.4	4.5	23.2	26.4	29.2	26.3
TP-INM	11.0	14.6	23.2	16.3	3.8	5.0	5.6	4.8	23.8	26.0	28.6	26.1
Av.	12.3	15.2	24.3		3.9	4.6	5.8		24.1	27.3	29.5	
	R	P	R x P		R	P	R x P		R	P	R x P	
LSD 0.05	1.17	1.44	2.89		0.2	0.3	0.6		1.7	1.3	2.5	

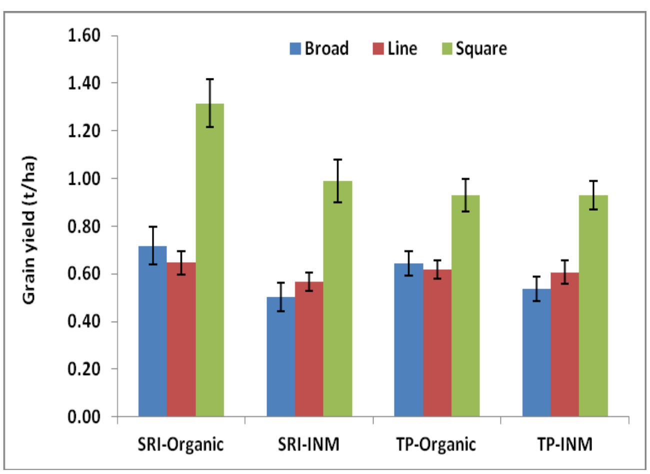


Fig. 18 Effect of rice cultivation system and planting pattern in black gram (*Vigna mungo L.*) on grain yield. Bars indicated mean ±SE (n = 5)

Project Title : **Evaluating Deficit Irrigation under Drip System for Rice-based Cropping Sequence in Canal Command Area**

Project Code : DWM/12/158

Funding Agency : Institute

Project Personnel : P. Panigrahi, R. K. Panda, A. K. Thakur, S. K. Rautaray and S. Raychaudhuri

This project was initiated at the DWM Research farm, Mendhasal, Bhubaneswar. The project aims to compare the effect of deficit irrigation (DI) under drip system in rice-capsicum-baby corn and rice-rice-baby corn cropping sequences. The response of rice to supplemental irrigation during stress period through drip system at 75% ET_c, 100% ET_c and 125% ET_c were compared with to that under surface irrigation and rain-fed treatments in *kharif* period at 2 lateral layouts: lateral to lateral distance of 1.0 m and 1.4 m. The response of capsicum to drip irrigation at 50% ET_c, 75% ET_c and irrigation at 50% ET_c except flowering and fruiting stage (FFS) with lateral layouts of lateral distance of 1.0 m and 1.4 m were evaluated.

Drip irrigation in rice

Soil Samples were collected from experimental field and it's physical and chemical properties were determined. The texture of soil is sandy loam (45% sand, 24% silt and 31% clay) with bulk density of 1.44 g cm^{-3}. The field capacity and permanent wilting point were 0.17-0.31 cm3.cm^{-3} and 0.05-0.12 cm3 cm^{-3}, respectively with mean pH of 5.91. The experimental soil was acidic in nature.

The hydraulic performance of the drip system was studied from time to time and found satisfactory with emitter flow rate variation (Q_v) of 8%, co-efficient of variation (CV) of 7% and distribution uniformity (DU) of 92%. Water was applied to *kharif* rice after one or two days of drying of standing water in field. The monthly irrigation applied under various treatments varied from 107 mm to 179 mm under different drip irrigation treatment and 248 mm under surface irrigation. The vegetative growth and yield parameters of rice under different irrigation treatments and lateral layout are given in Table 24.

Table 24 Vegetative growth, yield and IWUE of *kharif* rice under drip and surface irrigation methods

Treatments		Plant height (cm)	EBT till^{-1}	Grain per panicle	1000 grain weight (g)	grain yield (t ha^{-1})	straw yield (t ha^{-1})	water applied (mm)	IWUE (t ha-mm^{-1})
DI_{75}	L_1	92.1	11.2	61.3	22.7	3.92	4.87	107	0.005
	L_2	91.7	11.0	60.9	22.4	3.87	4.69	107	0.004
DI_{100}	L_1	93.2	11.8	61.7	22.9	4.27	5.13	143	0.006
	L_2	92.8	11.4	61.4	22.7	4.01	5.04	143	0.004
DI_{125}	L_1	95.1	12.1	62.1	23.0	4.39	5.46	179	0.005
	L_2	94.6	11.8	61.8	22.8	4.19	5.21	179	0.004
SI		95.6	12.7	62.4	23.2	4.48	5.83	248	0.004
Rainfed		93.2	11.4	59.8	22.6	3.40	5.11	--	---
$CD_{0.05}$	I	4.1	2.7	11.5	3.6	0.7	0.3	21	---
	L	3.7	1.8	6.4	2.9	0.8	0.5	16	---
	IxL	4.6	3.1	9.8	4.7	0.5	0.8	22	

DI_{75}: Drip irrigation at 75% ET_c, DI_{100}: Drip irrigation at 100% ET_c, DI_{125}: Drip irrigation at 125% Et_c,
SI: Surface irrigation, L_1: 1.0 m lateral distance; L_2: 1.4 m lateral distance

After *kharif* rice, capsicum was transplanted in the same field and different irrigation regimes (at 50% ET_c, 75% ET_c, 50% ET_c except FFS and 100% ET_c) were imposed with two lateral layout (1.0 m and 1.4 m lateral to lateral distance) under drip system. The maximum vegetative growth (plant height, canopy soread and number of branches were) observed with 100% ET_c. The maximum fruit yield (15.4 t ha^{-1}) was recorded with fully-irrigated (100% ET_c) plants at lower later to later distance (1.0 m) which was statistically at par with that at 75% ET_c and 1.0 m lateral to lateral distance. However, the water use efficiency under the later treatment was 49% higher than that with 100% ET_c.

Groundwater Management

- Groundwater Recharge Guidelines for Agro-Ecological Region No. 8. with Hard Rock Geology
- Development of Technological Options for Comprehensive Water Resource Management in Non-exploration Zone (CRZ III) of Coastal Odisha
- Geo-referenced Soil Information System for Land Use Planning and Monitoring Soil and Land Quality for Agriculture
- Impact of Wastewater Use on Soil Properties and its Prospect of Utilization in Crop Production
- Suitability of the Available Poor Quality Water Resources for Agriculture under Different Agro-climatic Region
- Design and Development of Small Filters for Reducing Contaminants in Poor Quality Water at Farmers' Level for Safe Irrigation in Periurban Areas
- Decision support system for enhancing water productivity of irrigated rice-wheat cropping system
- Design and evaluation of a portable drum based drip irrigation system

Project Title	: **Groundwater Recharge Guidelines for Agro-Ecological Region No. 8. with Hard Rock Geology**
Project Code	: **DWM/11/150**
Funding Agency	: Institute
Project Personnel	: M.J. Kaledhonkar, R.R. Sethi, Ashwani Kumar and R.C. Srivastava

Study was conducted in Walayar sub basin of Parambikulam and Aliyar river basin (Agro-Ecological Region No. 8), located in Coimbatore district of Tamil Nadu. The basin is dominated by hard rock geology and decline of groundwater table is major problem. Hence in order to maintain groundwater table depth, additional groundwater recharge required for the basin was calculated through modelling approach. Analysis of meteorological data for frequency and severity of extreme droughts events were carried out for rain gauge stations (North and south Pollachi, Negamam) located within the sub basin. Probability curves were prepared by Weibull formula. Results suggest that Pollachi station may experience 30 and 20 % deficit drought in every 7 and 4 years, respectively. However, Negamam Rain Gauge Station experience 30 and 20 % deficit drought in every 5 and 4 years, respectively. Therefore, Negamam is more prone to severe drought compared to Pollachi station. The rain event with 20, 30 and 40% less rainfall than mean value will represent approximately 15-17 cm, 23-25 cm and 31-34 cm of water deficits in Walayar sub basin and probability of exceedence for corresponding annual rainfall amounts will be 74-77, 80-85 and 91-92%.

Lumped groundwater model

A lumped groundwater model with the basic principle of water budget was used to estimate the groundwater table behavior of the study area. The model was calibrated with the data of observation wells from period from 2005 to 2008. Rise in groundwater level was noticed which confirmed the reduction in net pumping during the calibration period. Net groundwater draft was 0.1506, 0.1444 and 0.1284m for Pollachi North, Pollachi South and Negaman respectively. Results of calibration and validation of the model at six observation wells showed that lumped model was able to predict changes water table reasonably to a good extent. Ability of lumped model in simulating ground water table level was tested by RMSE (Root Mean Square Error), RMSE-Observation standard deviation ratio (RSR) and NSE (Nash Sutcliffe efficiency). Results of tests are given in Table 25.

Table 25 Testing of simulated results

Year	RMSE	STDev	RSR	Error (%)	NSE
Calibration Period					
1999	2.8	50.3	0.056	5.6	94.4
2000	3.2	49.4	0.064	6.4	93.6
2001	4.4	50.3	0.087	8.7	91.3
2002	3.9	52.9	0.073	7.3	92.7
2003	3.2	52.7	0.061	6.1	93.9
2004	4.4	53.5	0.083	8.3	91.7
Validation Period					
2006	2.7	50.5	0.053	5.3	94.7
2007	3.3	51.1	0.065	6.5	93.5
2008	3.0	49.9	0.061	6.1	93.9

Determination of additional recharge required to manage water deficits

Frequency of extreme drought events might increase under climate change scenario with resultant depletion of groundwater level. Recurring drought would further worsen the scenario. Therefore, modelling was attempted for moderate drought events (20 and 30% less than average rainfall amount) and persisted for 7 years in sequence. Two possibilities, as mentioned below, considered for modelling to simulate water table conditions.

i) Rainfall amount equal to 80% of average rainfall for 7 years

ii) Rainfall amount equal to 70% of average rainfall for 7 years

Depletion of groundwater storage due to persistent droughts was worked out and the same was considered as additional recharge requirement besides natural recharge so that current groundwater could be met and groundwater storage could be restored.

Verification of modeling results with field data

In Pollachi region, 12 years out of 21 years were having less rainfall than average amount (i.e. 862 mm) but out of 12 years 8 were less than 800 mm. In Kinathukadavu region, 8 years out of 21 years were having less rainfall than average amount (*i.e.* 777 mm). Thus water table data of all observation wells could be used to estimate the additional groundwater recharge. The same could be used for verification of modelling results (Table 26).

Table 26 Additional groundwater recharge for Pollachi 6 and Kinathukadavu 15 on basis of simulations (1988-2008)

	Pollachi		Kinathukadavu			
	PG6 (m)	PG14 (m)	PG1 (m)	PG3(m)	PG4 (m)	PG15(m)
Maximum	309.8	251.6	379.8	355.2	387.1	326.6
Minimum	294.3	243.3	371.8	340.9	378.2	313.2
Difference	15.5	8.3	8.0	14.4	8.9	13.4
Sp. Yield	0.025	0.025	0.025	0.025	0.025	0.025
Addl. recharge	0.39	0.2	0.20	0.36	0.22	0.34

The observed additional groundwater recharge varied from 21-39 cm in Pollachi region and 20-36 cm for Kinathukadavu region (Table 27).

Table 27 Comparison of observed and simulated additional recharge.

Location	Additional recharge (cm)	
	Observed	Simulated
Pollachi 6	21 to 39	21- 24
Kinathukadavu 15	20 to 36	26- 29

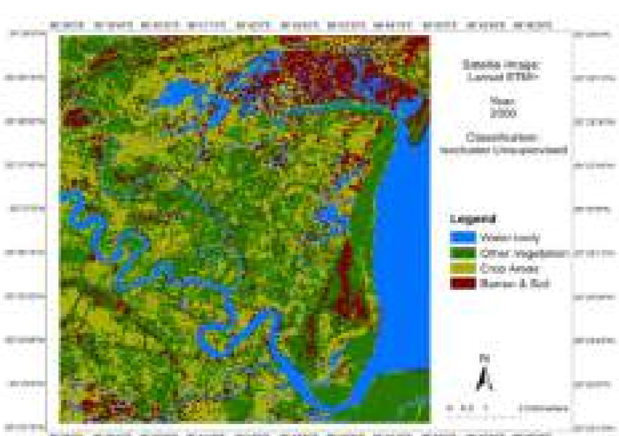
The additional groundwater recharge on basis of simulation varied from 21-24 cm in Pollachi region and 26 -29 cm for Kinathukadavu region. It showed agreement between observed and simulated values of additional recharge but observed values towards upper limits were higher. It might be because of real occurrence of severe droughts in 21 years period compared to simulation of period of 7 years in which only moderate drought (20 and 30% less than average rainfall amount) was assumed for simulations.

Project Title : **Development of Technological Options for Comprehensive Water Resource Management in Non-exploration Zone (CRZ III) of Coastal Odisha**
Project Code : DWM/12/164
Funding Agency : Institute
Project Personnel : Ranu Rani Sethi, R.C. Srivastava, Jugal Tripathy, M.Das, P.S.B. Anand and A. Kumar

The study was conducted in Mahakalapada block of Kendrapara district of Odisha. The area is situated at latitude of 20.400 to 20.500 N and longitude of 86.450 to 86.750E respectively. The altitude is only 0-3m above mean sea level along the coast line. Mean annual rainfall (1994-2013) of the study area is 1409.58mm, out of which about 1237 mm (87.73%) is received during monsoon season (June-October). The maximum and minimum temperature varies up to 38.6^{0}C in May and 11.2^{0}C in January. Groundwater table depth varied between 1.2m to 3.5 m during February to May, and water level remains 0.5 to 1m above the ground surface during monsoon and post monsoon season. For comprehensive water resource planning, assessment of water resources was carried out by rainfall and change in land use/land cover analysis.

Change detection analysis

The Landsat ETM+ satellite images of 2000 and 2006 were used to classify land use/land cover maps and change detection study. Iso cluster unsupervised classification was employed to generate land cover maps. Post classified images were observed to detect the changes. Fig. 18 showed the post classified Landsat ETM+ images for both the years. Major land cover types were agricultural areas, land with other vegetation, water bodies and soil/barren land (Table 28). There was increase of 2.81% agricultural areas in the year 2006 with reference to the year 2000. Similar trend in increase (8.01%) in land with other vegetation was observed in 2006. The reason was due to the effect of super cyclone in coastal areas during the year 1999, which damaged almost 90% of the agricultural and other crops. However, gradually over the period of time, there was increase in cropped area in the coastal areas, as reflected in the image analysis (Fig. 19). During 2006 there was increase in crop coverage for most of the coastal Odisha. But water bodies and soil/barren land areas, decreased by 6.54 % and 4.27% respectively during period of 6 years (2000 – 2006) suggesting effect of water stagnation during 1999 super cyclone year that affected the cropped area in 2000.



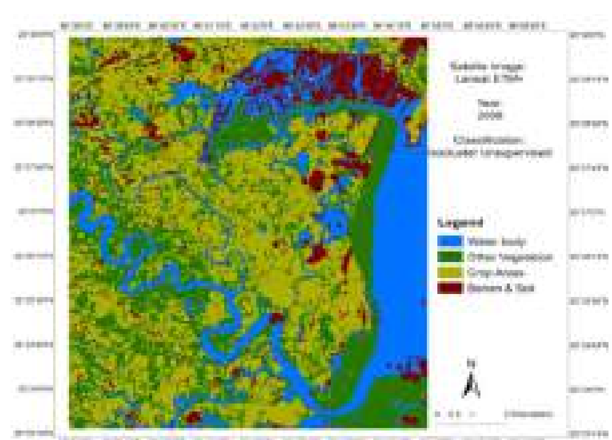


Fig. 19 Post Classified images (left) and (right) for the years 2000 and 2006 respectively

Table 28 Land Cover Changes in and around Suniti Village (from the classified images for the year 2000 & 2006)

Land Cover Types	2000		2006		Total Changes	Change
	ha	%	ha	%	(ha)	(%)
Agricultural Areas	2553.84	18.12	2660.40	20.93	106.56	2.81
Land with other vegetation	4361.04	30.95	4951.08	38.96	590.04	8.01
Water Areas	5239.80	37.19	3894.12	30.65	1345.68	6.54
Soil & Barren Areas	1932.12	13.71	1199.52	9.44	732.6	4.27

Spatial analysis of water quality

Twenty water samples (10 from creek and 10 from bore wells) were collected from the study area during October 2013 (post monsoon) and March 2014 (Pre monsoon) and spatial distribution of the same was analysed using krigging procedure. The pH for borewell was comparatively higher than the surface water (Creek). But electrical conductivity, was higher in surface irrigation sources which may be due to link with the sea and some external factors. Spatial variation shown in Figures 20 and 21 depicts the continuous increase in pH and EC of water samples from inland sites towards the sea coast due to influence of sea. In Fig 19 (left), it was observed that pH at C4 site decreased from 7.43 to 6.78, which may be due to influence of other sub distributaries of fresh water resources at this point. Again there was increase in pH in C5. Beyond the distance of 11.32 km from sea coast, pH remained almost neutral (close to 7) in surface water sources. In Fig. 19 (right), there was gradual increase in pH of water in borewells (hand pump operated). Similar trend was observed in electrical conductivity of water from both the sources (Fig. 20). The rate of change in variation of pH and EC for the creeks from the study area was found to be 0.185 and 1.745 dS.m^{-1} per kilometer, respectively and that for the borewells were 0.0682 and 0.778 dS.m^{-1} per km respectively moving away from sea.

In case of post monsoon (October 2013) water samples, pH varied between 7.14 to 8.42 and 7.29 to 8.46 in creek and borewells respectively. But electrical conductivity in creek did not follow any trend and varied within 1 to 10.3 dS.m^{-1}. The reason could be due to its location and connection with many small creeks with different salinity level. In bore well, there was decrease in salinity towards inland. Further, the variation of pH and EC in surface water was comparatively larger than that of tube wells, which tapped water from the deeper aquifer. Both for surface and sub surface water resources, saline water intrusion is the major concern for coastal areas warranting appropriate technological options addressing both irrigation and drainage issues in the coastal areas for improving the water management scenarios in agriculture.

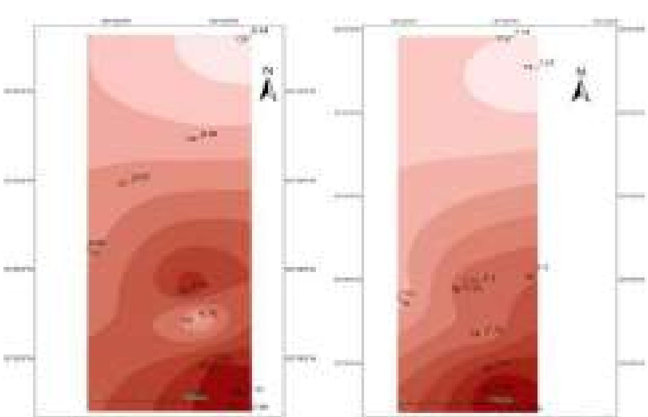


Fig. 20 Variation of pH in creek (left) and bore wells (right) during March 2014

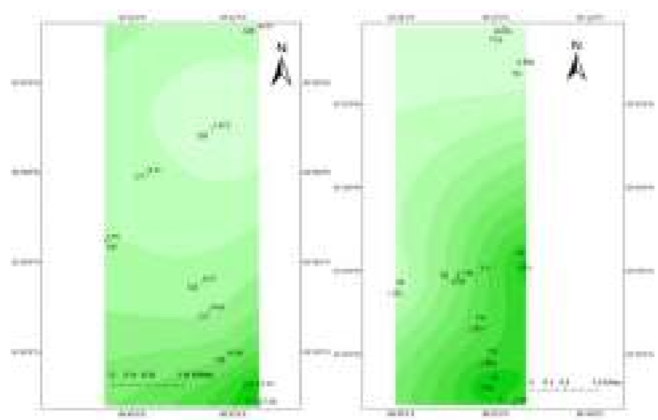


Fig. 21 Variation of EC (dS.m-1) in creek (left) and bore wells (right) during March 2014

Project Title : **Geo-referenced Soil Information System for Land Use Planning and Monitoring Soil and Land Quality for Agriculture**

Funding Agency : NAIP, ICAR, New Delhi

Project Personnel : M. Raychaudhuri, K. G. Mandal and G. Kar

In the reporting year, soil physical quality of the Indo-Gangetic Plains (IGP) and Black Soil Regions (BSR) of India under paddy-wheat and cotton-based cropping system respectively with different management practices were assessed. The pedo-transfer functions (PTFs) were derived to determine Ks based on physical and chemical properties and soil physical quality index was developed. These will helpful to understand soil hydraulic behaviour and formulating appropriate water management strategies for sustainable crop production.

Indo-Gangetic Plains (IGP)

In IGP fourteen benchmark geo-referenced sample sites were selected from arid, semiarid, sub humid and humid/Perhumid bio climates with mean annual rainfall of <550 mm, 550-1000 mm, 1000-1600 mm and 1600 to 2000mm/>2000 mm respectively covering seven states namely Rajasthan, Punjab, Uttarakhand, Uttar Pradesh, Bihar, West Bengal and Tripura and eleven (2.1, 4.1, 9.2, 4.3, 9.1, 12.3, 13.1, 18.5, 16.2, 15.3, 17.2) agro-ecological sub-regions (AESR). The texture of the soils varied from sandy clay loam to loamy, with few soils having sandy or clayey texture prevailing under arid and humid bio-climates, respectively. The soil reaction is in general, acidic to neutral in humid/perhumid region; slightly acidic to slightly alkaline in sub-humid environment; slightly alkaline to strongly alkaline in semiarid environment and strongly alkaline in arid environment. The saturated hydraulic conductivity (K_s) varied from negligible in Zarifaviran soils to 8.39 cm h^{-1} in Fatehpur soils. Majority of the soils had K_s 0-1 cm h^{-1} covering Bihar,

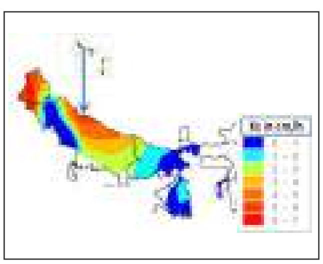


Fig. 22 Distribution of saturated hydraulic conductivity (K_s) in the IGP soils

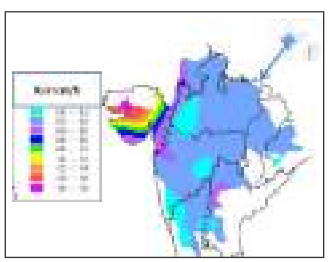


Fig. 23 Distribution of saturated hydraulic conductivity (K_s) in the BSR soils

West Bengal and Uttar Pradesh (Fig. 22). It had been observed that the K_s increased significantly with increase in sand (r = 0.63**) and SOC content (r = 0.25**) and decreased significantly with increase in silt (r = -0.52**), clay (r = -0.53**), FC (r = -0.40**), PWP (r = -0.38**), $CaCO_3$ (r = -0.22**) and exchangeable sodium percentage ESP (r = -0.33**) content in the soil. Higher ESP content was observed in soil control section (SCS) of Natrustalfs (>25 - 100) and lower in Haplustalfs (< 15) and the results are well supported. The results depict that apart from particle size distribution organic carbon content, $CaCO_3$ and ESP content in the soil contributed well towards K_s of IGP soils.

Pedo-transfer functions through multiple regression models were developed for determining K_s A significant relationship with sand and SOC content was observed when only physical properties alongwith carbon were used as inputs. Significance level was increased when chemical properties like $CaCO_3$ content, ESP and Ca/Mg ratio were added in the regression model (Table 29). Pedo-transfer functions through multiple regression equations were developed for K_s by incorporating physical parameters *viz.*, sand, silt, clay and BD and chemical properties like pH, OC, $CaCO_3$ content, EMP, ESP, BS, clay CEC and Ca/Mg. A significant model with sand content and BD was obtained when only physical properties were used as inputs. Significance level was increased when chemical properties like $CaCO_3$ content and ESP were added in the regression model as inputs to determine K_s. Further better model was obtained when clay CEC (%) and BS (%) were included as input parameters. The R^2 value improved to 0.6224 with inclusion of chemical parameters and K_s could be more precisely expressed in terms of clay (%) clay CEC (%) BS (%) ESP (%), EMP (%), $CaCO_3$ and Ca/Mg (Table 29). This is because the presence of pedogenic $CaCO_3$ and exchangeable sodium content highly influences the soil hydrological behaviour. Soils with ESP > 15 % exhibit large swelling and shrinkage with wetting and drying and also disperses completely in the presence of water.

Table 29 Pedotransfer functions for K_s of the IGP and BSR soils

		R^2	N	MSE
IGP	K_s = -1.06 + 0.055 sand(%) -0.074 $CaCO_3$ (%) - 0.011 Ca/Mg	0.58	133	1.55
BSR	K_s (cm/h) = - 0.134 – 0.00631clay (%) + 0.008 clay CEC (%) + 0.0039 BS (%) - 0.0146 ESP (%) -0.0124 EMP (%) + 0.037 $CaCO_3$ (%) – 0.045Ca/Mg	0.62	194	0.029

In Black Soil Region (BSR) eighteen benchmark geo-referenced sample sites were selected from arid, semiarid, sub humid dry and sub humid moist bio climates with mean amount rainfall of <550 mm, 550-1000 mm, 1000-1200 mm and 1200 to 1600 mm respectively covering six states *viz.*, Maharashtra, Gujarat Madhya Pradesh , Andhra Pradesh, Karnataka and Tamil Nadu and eighteen (6.1, 5.1, 8.1, 3.0, 6.4, 7.1, 5.1, 8.3, 8.2, 4.4, 7.2, 6.2, 6.3, 5.2, 10.3, 10.2, 10.1, 7.3) agro-ecological sub-regions (AESR).

The soils are clayey, and clay and silt constitutes >50% of the total particles The soils are, in general, neutral to slightly alkaline and strongly alkaline when they occur in semi-arid and arid environments (<900 mm mean annual rainfall). The pH and $CaCO_3$ generally increase as the rainfall decreases from sub-humid to arid climates.

The saturated hydraulic conductivity (K_s) varied from 0.027 cm h^{-1} in Vasmat soils to 6.521 cm h^{-1} in Sokhda soils. Majority of the soils of this region has K_s <0.25 cm/h covering Maharashtra, Karnataka and Tamil Nadu (Fig. 23). The K_s increased significantly with increase in sand (r = 0.25**), clay, CEC (r = 0.27**) and $CaCO_3$ (r = 0.46**) content and decreased significantly with increase in clay (r = -0.21**), ESP (r = -0.16*), EMP (r = -0.22*) content in the soil and also with BD (r = -0.17*) of the soil. The results depict that apart from particle size distribution K_s of these soils is also governed by $CaCO_3$, ESP, and EMP content in the soil and the compactness of the soil too. More compact the soil less is the K_s.

Soil Physical Quality

Soil physical quality governs the hydrological behaviour of soil and depends on textural and structural porosity. It has been observed that BSR soils with higher clay content have higher textural porosity that occurs between the primary mineral particles, whereas IGP soils have higher structural porosity comprising microcracks, cracks, bio-pores, and macrostructures produced by tillage. The surface (Fig. 24) and subsurface (Fig. 25) soils of IGP were found sensitive to management factors such as tillage, compaction and cropping due to high structural porosity whereas the surface (Fig. 26) and subsurface soils (Fig. 27) of BSR were little affected by soil management practices because of high textural porosity. The slope, S of the water retention curve at the inflection point is mostly due to micro-structural porosity that governs directly many of the principal soil physical properties. Soil with only textural or structural porosity is compacted or loose and shows poor physical quality. Therefore, the presence of considerable amount of structural and textural pores and a corresponding large value of S are essential for good soil quality.

In IGP soils incorporation of organic matter as one of the management practices destroyed the structural porosity (i.e., pores which are larger than that which corresponds with the inflection point) whereas there are simultaneous gains in textural porosity (sizes smaller than that which corresponds with the inflection point) which in turn improved the soil physical quality. In BSR soils textural pores dominated and the management practices adopted had little effect on improving the structural porosity of the soils. Incorporation of coarse materials like sand, crop residues etc are recommended for improving the

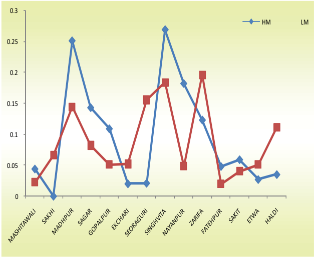


Fig. 24 Soil physical quality (S) of the IGP surface soils

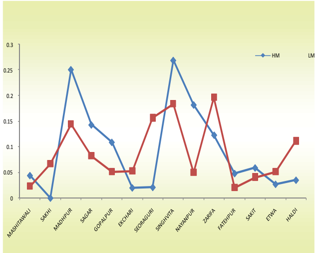


Fig. 25 Soil physical quality (S) of the IGP sub surface soils

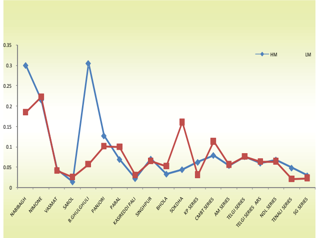


Fig. 26 Soil physical quality (S) of BSR surface soils

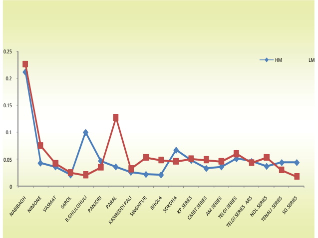


Fig. 27 Soil physical quality (S) of BSR subsurface soils

Project Title	:	**Impact of Wastewater Use on Soil Properties and its Prospect of Utilization in Crop Production**
Project Code	:	DWM/11/152
Funding Agency	:	Institute
Project Personnel	:	Madhumita Das, O. P. Verma, A. K. Nayak and R. R. Sethi

Response of soil organic carbon and its fractions under wastewater treatments

Four different types of soils, red and laterite, red and yellow, coarse and fine textured alluvial were incubated at a temperature 27-38°C with normal water (W), the effluent of COS Board Paper mill (PM), Jagatpur, Cuttack, United Breweries (UB) Ltd., Khurda and Sakthi Sugar distillery (DE), Dhenkanal, at soil moisture content of 100% (F) and 60% (F60) of field capacity. The organic carbon, humus, humic acid, fulvic acid and microbial carbon contents of soil samples were measured at 13, 30 and 48 days intervals. The soil organic carbon (SOC) showed a decreasing trend with time, while humus formation as organic carbon concentration showed maximum after 48 days of incubation. The SOC was higher at 100% field capacity (F) than that of 60% FC but varied with nature of wastewater and types of soil. SOC increased with the application of wastewaters from all three sources. Maximum with distillery waste water followed by paper mill and breweries. The soil humus concentration however decreased with the incubation period duration from 13 to 48 days reaching lowest at 48 days. The soil humus concentration was lowest under normal water treatment at 48 days and 1.9-4.2 times higher under red and laterite soils, 4.7- .94 times under red and yellow soils, 5.06 -7.45 times under alluvial coarse and 1.22-2.8 times under alluvial fine textured soils with three above different effluent treatments.

The soil microbial carbon improved by 0.56-5.11, 0.63-1.96, 1.0-2.97 and 0.58-1.36 times in red and laterite, red and yellow, coarse and fine textured alluvial soil types respectively over its respective normal water treatment values. The impact of breweries and paper mill effluents was relatively more in red and laterite, and red and yellow soils, while effect of distillery spent wash was maximum in alluvial soil. The application of breweries, paper mill and distillery wastewaters in four different soil types was found useful to improve soil organic carbon and its fractions

Influence of soil types on leachate properties during leaching with paper mill effluent and water

Paper mill effluent (PME), collected from COS Board, Jagatpur, Cuttack had neutral (pH7.0), low saline (EC,1.32 dS m^{-1}), with excess amount of Ca (154.71 mg L^{-1}), Mg (53.28 mg L^{-1}), Cl (779.9 mg L^{-1}), HCO_3 (91.5 mg L^{-1}), SO_4 (88.5 mg L^{-1}), and contained moderate to low content of NO_3, organic carbon, Zn, Cu, Fe and Mn. The paper mill effluent was allowed to pass through four different soil types at constant head method up to the level of equilibrium. The PME bathed soil columns were then leached with normal water till it stabilized with leachate parameters. There was no Cd and Pb detected in collected PME sample.

Data pertaining to the important components of leachates collected at different intervals from varied soil types reveal (Fig. 28) that based on pH and EC, the equilibrium was attained after 145 to 195 minutes of leaching with PME, which further got stabilized after 80 to 120 minutes of leaching with normal water. It subsequently indicates that recharge of soils with various ions during the progress of leaching with PME usually get discharged under normal water washing. In regards of parameter wise comparison of leachate qualities, a 7% increase in pH and 18% enrichment in HCO_3 content with normal water over its corresponding PME leached leachate was obtained under neutral coarse textured alluvial soil type. These subsequently reflect the suitability of Paper Mill Effluent of COS Board, Jagatpur, Cuttack, as alternate irrigation source for red and laterite, red and yellow and alluvial soil types.

Water quality appraisal around the industrial estate, and perspective of use in agriculture

Groundwater samples are collected from nineteen different places covering four villages in and around the Sakthi Sugars Limited, Haripur, Dhenkanal District in Odisha during pre-monsoon period and analyzed for sixteen water quality parameters. Parameter to parameter wise comparison revealed that 57.89% waters were impaired by pH, each 10.53% were not preferred by Cl and Mn contents and 78.95% were not desirable for use in irrigation by Ca/Mg (Table 30). Use of descriptive statistics revealed that Mn was highly varied followed by Cu, Fe and other parameters. Among all the water quality parameters, lowest variation (CV 10.23%) was observed in pH. Simple correlation (r) among the parameters, reflected that pH was significantly related with Na (0.70, 0.01P) and Ca (0.57, 0.01P); and EC with Na (0.77, 0.01P), Cl (0.71, 0.01P) and SO_4 (0.68, 0.01P); and Fe with Mn (0.51, 0.01P). Simple and multiple regressions among the correlated parameters revealed that by estimating EC and pH, the Na, Ca, Mg, Cl and SO_4 contents of the samples can be determined.

pH = 5.39 + 0.58(Na) + 0.041(Ca) + 0.073(Mg), R^2 = 0.70; EC=0.19 + 0.12(Na) + 0.18(Cl) + 0.013(SO4), R^2= 0.66; EC=0.23+0.56(Na), R^2 = 0.57; EC=0.44+0.27(Cl), R^2= 0.51; EC=0.36+0.03(SO_4), R^2 = 0.46; Na=0.38 + 0.44 (Ca), R^2 = 0.64

Integrating the results of descriptive statistics, and susceptibility of the parameter to cross the threshold limit, pH, EC and Mn were found as indicating parameters for periodical monitoring of water quality for irrigation purpose, and by estimating them the whole range of water quality can be generated.

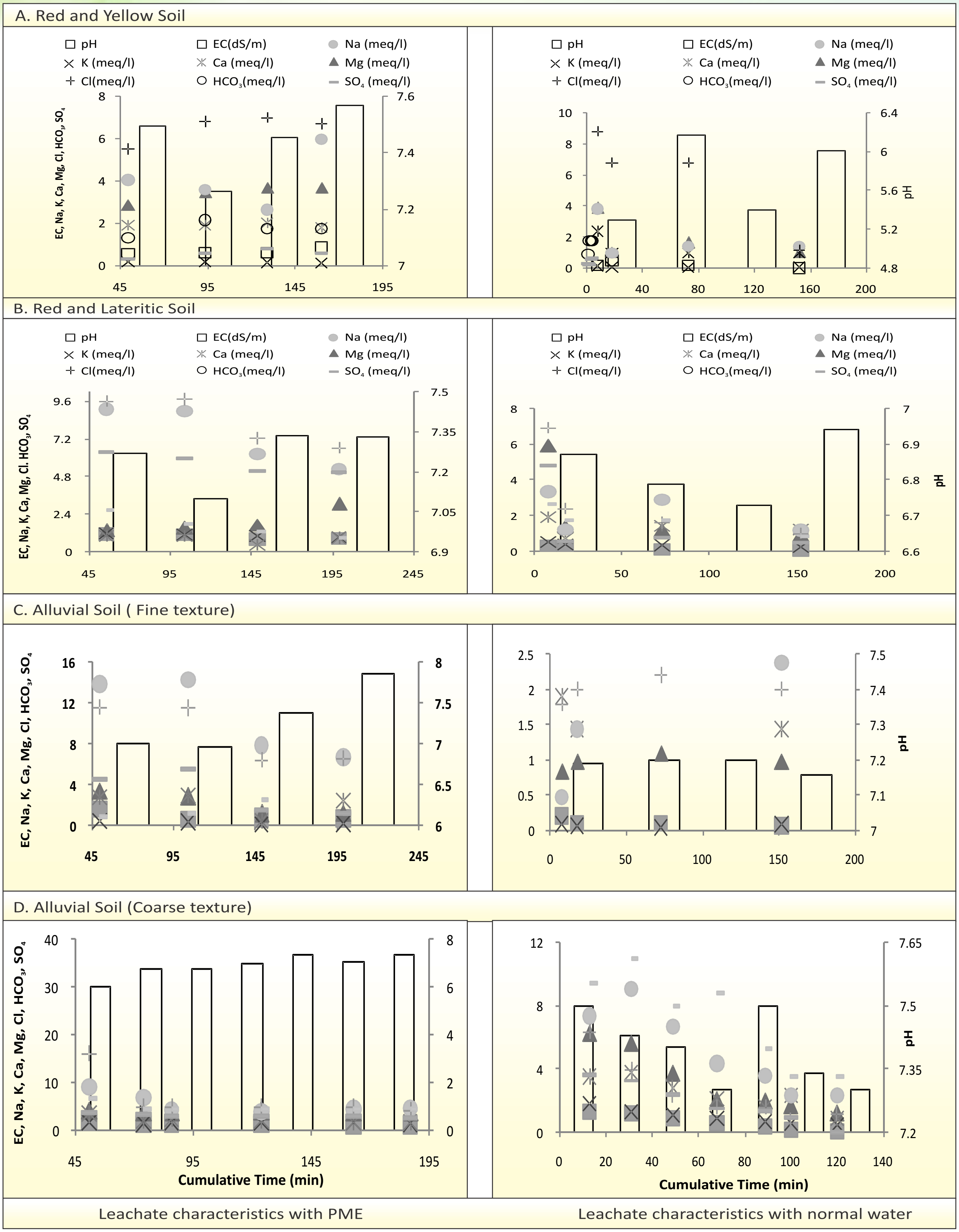


Fig. 28 Variation of leachate characteristics with time under different soil types

Table 30 Variability measures of water quality parameters (CV % in descending order)

Parameters	Largest	Smallest	Mean	Standard deviation	CV (%)
		High variability (CV, $\geq$ 200%)			
Cu mg L^{-1}	0.0008	Trace	0.0001	0.0002	211.18
Mn mg L^{-1}	1.043	Trace	0.112	0.239	214.16
		Moderate variability (CV, 100 - 200%)			
K me L^{-1}	0.43	Trace	0.11	0.12	103.98
Zn mg L^{-1}	0.64	Trace	0.14	0.16	110.53
Fe mg L^{-1}	0.2	Trace	0.04	0.06	176.09
Ca/Mg	7	0.09	1.18	1.64	139.39
		Low variability (CV, <100%)			
pH	7.97	5.44	6.36	0.65	10.24
EC dS m^{-1}	1.92	0.24	0.86	0.50	57.64
Na me L^{-1}	2.44	0.3	1.11	0.68	61.49
Ca me L^{-1}	3.96	0.22	1.66	0.95	57.30
Mg me L^{-1}	12	0.22	2.88	2.59	90.04
Cl me L^{-1}	5.2	0.2	1.58	1.31	83.26
SO_4 mg L^{-1}	50	5	17.24	11.51	66.80
HCO_3 me L^{-1}	3	0.2	1.02	0.85	83.29
SAR	0.93	0	0.68	0.23	33.02
Cl/SO_4	11.34	0.26	3.87	3.04	78.55

Project Title : **Suitability of the Available Poor Quality Water Resources for Agriculture under Different Agro-climatic Region**
Project Code : WTCER/08/135
Funding Agency : Institute
Project Personnel : M. Raychaudhuri, Ashwani Kumar, S. Raychaudhuri, S. K. Jena and R. C. Srivastava

Development of a water quality index (WQI) for potable and irrigation purpose using chemical parameters based on Indian and FAO Standards was attempted. The WQI developed was validated with the groundwater quality data of Rushikuliya Command area obtained from Central Ground Water Board, Bhubaneswar.

Water Quality of Rushikuliya Canal Command Area for Irrigation and Potable Use

Rushikulya Canal Command is situated in the Ganjam district of Odisha comprising of four numbers of Anicuts (Sorismuli on Badanadi river, Madhaborida on Mahanadi river, Padma on the Padma river; and Janivilli on the Rushikulya river) and two medium sized reservoirs (Bhanjanagar reservoir on Borigam nala and Sorada reservoir on the Padma river). For Irrigation, the numerous distributaries, minors and sub-minors of Rushikulya Irrigation System plays a vital part. In addition, number of Minor Irrigation schemes are also in operation in for of check weirs, ponds, tanks etc, which are also extensively utilized.

The water quality data of ground water from the Rushikulya command area were monitored from the established monitoring wells, exploratory wells and surface water body as well was obtained from Central Ground Water Board (CGWB). These samples were collected both during the pre-monsoon season (2005) for a comprehensive comparison and to document any distinct seasonal changes in ground water quality. The samples collected were subjected to analysis for their pH, Electrical Conductivity (E.C.), Carbonate (CO_3^{--}), Bi-carbonate (HCO_3^{--}), Chloride (Cl^-), Sulphate (SO_4^{--}), Nitrate (NO_3^-), Phosphate (PO_4^{--}), Fluoride (F^-), Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^+) and Potassium (K^+). For the present study only the water samples collected from the dug wells (phreatic aquifers have been considered). The depth of these dug wells are in the range of 6 – 12 metres below the ground level.

For estimating WQI, 10 to 15 parameters were considered viz., pH, total hardness, calcium, magnesium, bicarbonate, chloride, nitrate, sulphate, total dissolved solids, sodium, potassium and fluorides. The chemical analyses of the groundwater and the percent compliance with the FAO guidelines/Indian Standards were estimated. For computing WQI three steps were followed. In the first step, each of the parameters were assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes as well as per cent deviation from the standards. A deviation of 0-20, 21-40, 41-60, 61-80 and 81-100 % were assigned weight of 5, 4, 3, 2, 1 respectively. In the second step, the relative weight (W_i) was computed and in the third step, a quality rating scale (qi) for each parameter was assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the FAO/BIS and the result multiplied by 100. For computing the WQI, the SI is first determined for each chemical parameter, which is then summed up to determine the WQI.

For irrigation purpose, the computed WQI values were classified into four categories based on the restrictions *viz.*, none, slight, moderate and severe with WQI ranging as <150, 151-300, 301-450 and > 450 respectively. For potable use the computed WQI values were classified into four categories *viz.*, good, poor, very poor and unsuitable with WQI ranging as <100, 101-200, 201-300 and > 300 respectively.

Groundwater Quality for Irrigation Use

WQI was determined following three steps as described above. In the first step, weight was assigned to each parameter (wi) according to its relative importance in the overall quality of water for drinking purposes as well as per cent deviation from the FAO standards. The maximum weight of 5 was assigned to the parameter K due to its importance in water quality assessment as well as 80 % or more than 80 % of the samples are beyond the permissible limit. The pH, carbonate, bicarbonate, chloride, sulphate, phosphate and fluoride were given the minimum weight of 1 as >= 80 % of the samples are within the permissible limit for irrigation purpose. The second step was followed and relative weight was assigned accordingly. The computed WQI ranges from 31.74 at Narayanpur to 5596.4 at Nimina. Majority of the samples (39.4 %) were of good quality followed by severe restrictions (30.3 %) with WQI ranging from 458.3 to 5596.4. The high value of WQI at these locations was found to be mainly from the high salinity and potassium content in the groundwater due to sea water intrusion.

Groundwater Quality for Potable Use

WQI was determined following three steps as described above. In the first step, weight was assigned to each parameter (wi) according to its relative importance in the overall quality of water for drinking purposes as well as per cent deviation from the standards. The maximum weight of 4 has been assigned to the parameter TDS, alkalinity and total hardness due to its importance in water quality assessme nt as well as 60 % or more than 60% of the samples are beyond the permissible limit. The pH, sulphate and fluoride is given the minimum weight of 1 as >= 80 % of the samples have the pH within the permissible limit and of no harm for potable use. The second step was followed and relative weight was assigned accordingly. The WQI computed as per the methodology ranges from 17.2 at Jatrasuni to 430.4 at Surala (Fig. 29). Majority of the samples (45.5 %) are of poor quality with WQI ranging from 100.9 to 196.3 (Fig. 30). The higher WQI at these locations was due to high hardness, alkalinity, magnesium and nitrate content in the groundwater.

It may be concluded from the study that WQI can be used to predict the suitability of water quality for irrigation and domestic purpose based on their respective standards .The methodology can also be incorporated easily in the algorithms of decision support system.

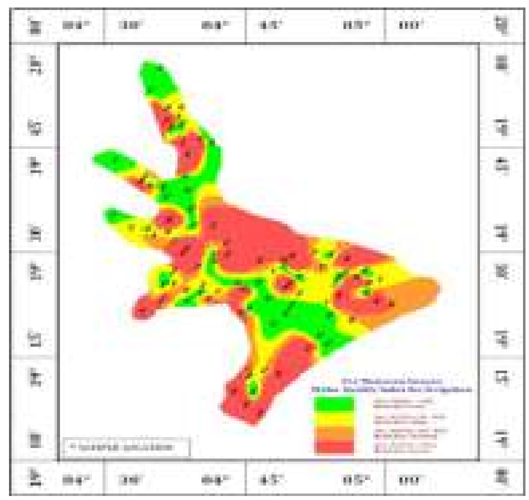


Fig. 29 Variation in irrigation water quality of Rushikuliya command area based on FAO guidelines

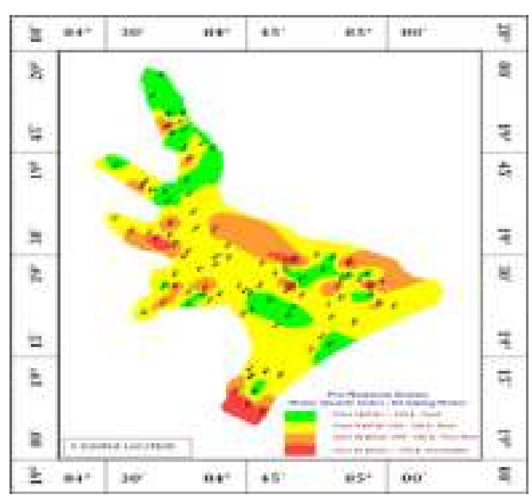


Fig. 30 Variation in drinking water quality of Rushikuliya command area based on BIS guidelines

Project Title	:	**Design and Development of Small Filters for Reducing Contaminants in Poor Quality Water at Farmers' Level for Safe Irrigation in Periurban Areas**
Project Code	:	DWM/12/161
Funding Agency	:	Institute
Project Personnel	:	M. Raychaudhuri, R. C. Srivastava, S. Raychaudhuri and Ashwani Kumar

The objective of the project was to devise a filter useful for reducing undesirable/ unwanted/ toxic contaminants present in the wastewater (domestic and municipal) for its safe use in irrigation by the small scale holders.

Selection of Filter Materials

Some locally available, inexpensive coarser materials like, gravels, sand, coconut and jute fibres were tried to design and develop small filters for reducing contaminants in poor quality water. Column study conducted using these coarse materials revealed that combination of gravels, quartz sand particles (< 2 mm) and jute fibre was found the best in reducing the sediments and total microbial load including Total Coliform and E. Coli counts (Fig. 31.).

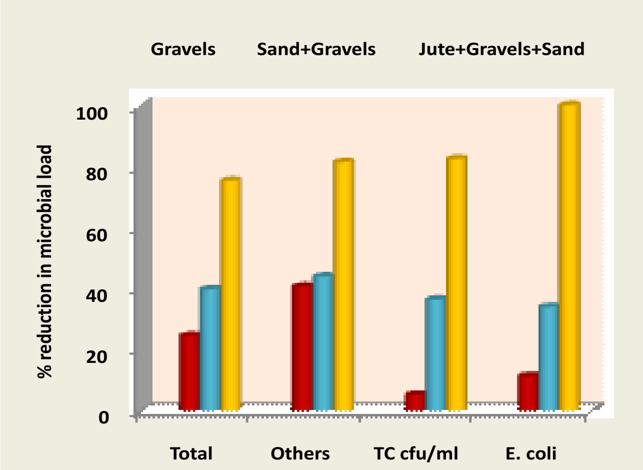


Fig. 31 Percent reduction in microbial load by filter components

Removal of Cd using Coconut Shell Charcoal

Wastewaters contain heavy metals that are transmitted to human through soil and crop assimilation. Cadmium is one of the abundantly available heavy metal in wastewater. Cd contamination is observed in wastewater ranging from 0.1-0.18 ppm which is beyond the permissible limit as recommended for irrigation use by FAO. An attempt has been made to remove Cd from aqueous solution using coconut shell charcoal (CSC). Coconut shells are abundantly available especially in the coastal region and 1 m t of CSC can be produced from 3.1 m t of coconut shell each year.

CSC was prepared anaerobically and was made alkaline by increasing the pH to increase its adsorption efficiency. Batch test was carried out with varying concentration of Cd (0.1 to 1 ppm) to determine the efficiency of coconut shell charcoal (CSC) and Alkaline charcoal (AC) to remove Cadmium. Models were developed on Cd adsorption by CSC and AC using the Langmuir and Freundlich Isotherm Expressions.

Experimental data obtained from batch test were fitted into Freundlich and Langmuir adsorption isotherm (Fig. 32 - Fig. 35). The linearised form of Freundlich and Langmuir equations are described as follows:

$$C_e/Q_e = 1/ab + C_e/a \qquad \text{(I)}$$

$$\text{Log}Q_e = \log K_f + 1/n \log C_e \qquad \text{(II)}$$

where Q_e represents the amount of adsorption adsorbed at equilibrium (mg/g), C_e is equilibrium concentration (mg/l), a is the maximum surface density or adsorption capacity and has same limit with Q_e and b (l/mg) can be related to the equilibrium constant or bonding energy, K_f and n are Freundlich constants. The intercept and slope obtained by plotting log Q_e versus log C_e. The slope of the straight line represents (1/n), while log K_f is the interception of the line on the Y-axis.

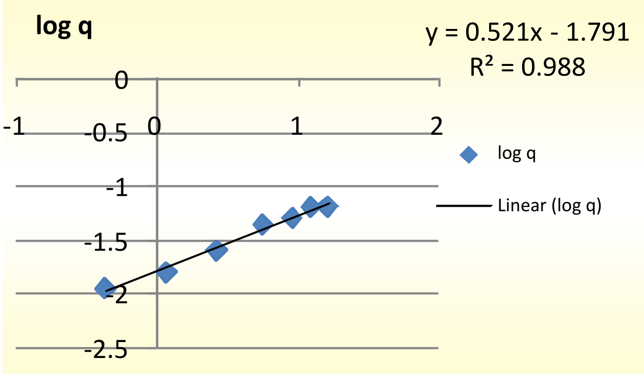


Fig. 32 Freundlich adsorption isotherm for Cd on CSC

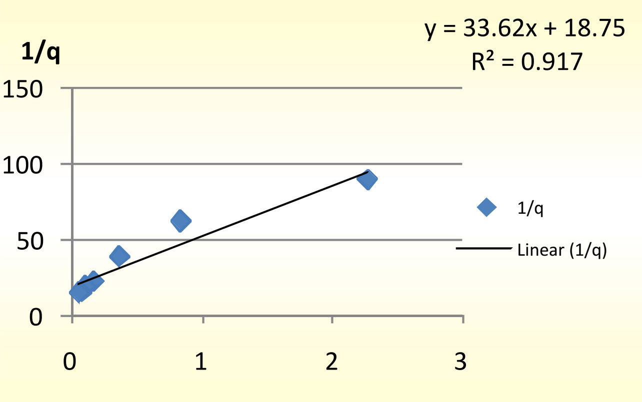


Fig. 33 Langmuir adsorption isotherm for Cd on CSC

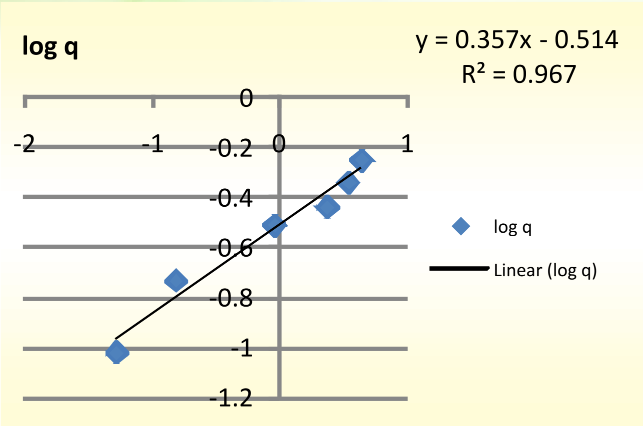


Fig. 34 Freundlich adsorption isotherm for Cd on alkaline CSC

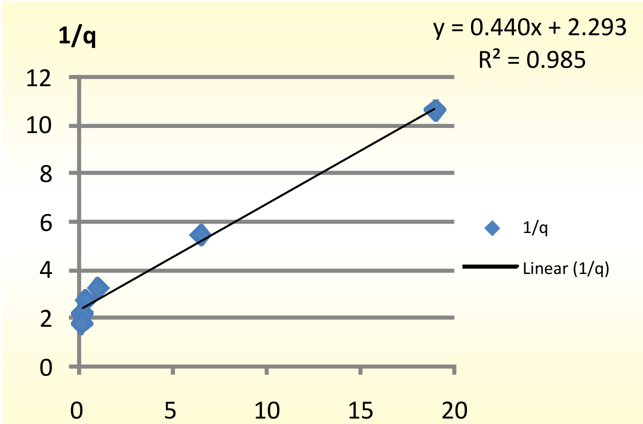


Fig. 35 Langmuir adsorption isotherm for Cd on CSC

The linearization of both equations with the experimental data revealed that both Freundlich and Langmuir adsorption fitted well with the experimental data which is depicted from the R^2 obtained for the Langmuir equation as 0.917, 0.985 and the R^2 obtained from the Freundlich equation as 0.988, 0.967 for CSC and alkaline CSC respectively. The Langmuir adsorption equation is valid for monolayer sorption on a surface with finite number of identical sites. Based on this equation the constant 'a' was the adsorption on CSC and alkaline CSC to form a monolayer. The adsorption capacity of Cd on CSC and alkaline CSC were 0.03 and 2.27 mg g^{-1} respectively (Table 31). The empirical constant b in the equation deuotes the affinity of the binding sites. The 'b' obtained for Cd on CSC and alkaline CSC was 1.78 and 0.192, respectively (Table 31). The adsorption capacity of CSC was increased by increasing its pH. This is because the surface charge of the adsorbent was modified by charging the pH from 8.64 to 10.89. Increase in pH increases the negative charge of carbon surface, which in turn increased the cation exchange capacity of CSC. At the same time the force of electrostatic attraction were weakened because of the increasing fraction of Cd $(OH)^+$ with the rise in pH. But this effect may be insignificant compared with those positive effects. The increase in K_f, which is the measure of adsorption capacity, with rise in pH is quite encouraging compared to the values. The K_f for CSC is 0.0162 mg g^{-1} while for alkaline CSC the K_f increased to 0.3062 mg g^{-1} (Table 32). All these results indicated that the process is endothermic. It has been observed that the adsorption capacity increased with increase in alkalinity duo to increase in surface charge of the charcoal. In both the cases the n calculated from Freundlich equation are higher than 1 and increased with increase in pH. The situation n>1 is most common and may be due to a distribution of surface sites or any factor that causes a decrease in adsorbent adsorbate interaction with increasing surface density.

Table 31 Langmuir adsorption isotherm for Cd on CSC and alkaline CSC

Carbon source	Langmuir Model	a (mg g^{-1})	b (l/g)	R^2
CSC	$C_e/Q_e = 33.62\ C_e + 18.75$	0.030	1.78	0.917
Alkaline CSC	$C_e/Qe = 0.440\ C_e + 2.293$	2.27	0.192	0.985

Table 32 Freundlich adsorption isotherm for Cd on CSC and alkaline CSC

Carbon source	Freundlich Model	K_f (mg g^{-1})	n	R^2
CSC	$LogQ_e = 0.521\ logC_e - 1.791$	0.0162	1.92	0.988
Alkaline CSC	$LogQ_e = 0.357logC_e - 0.514$	0.3062	2.80	0.967

It may be concluded from the study that gravels, quartz sand particles (< 2 mm) and jute fibre in combination can reduce the sediment and microbial load and the readily available coconut shell burnt to form charcoal can remove Cd from wastewater economically.

Project Title	:	**Decision support system for enhancing water productivity of irrigated rice-wheat cropping system**
Funding Agency	:	NFBSFARA, ICAR, New Delhi
Project Personnel	:	Ranu Rani Sethi, M. J. Kaledhonkar and K. G.Mandal

The objective of the projects was to develop the Water Productivity Decision Support System for Agro-Technology transfer (WPDSSAT-RW) for sustainable production in irrigated rice-wheat cropping system. During the reported period followings works has been carried out.

Delineation of Rice areas for the State of Punjab

Rice area in the state of Punjab was delineated using Remote Sensing (Enhanced Thematic Mapper + of Landsat 7) and GIS tools. The dominant feature class in all the districts is agricultural area mainly covered by rice was identified and its area was calculated and compared with rice area reported by the state Govt. There was good match between satellite image analysis and Govt. of Punjab records. Map prepared delineating the rice area coverage in the state of Punjab is shown in Fig. 36.

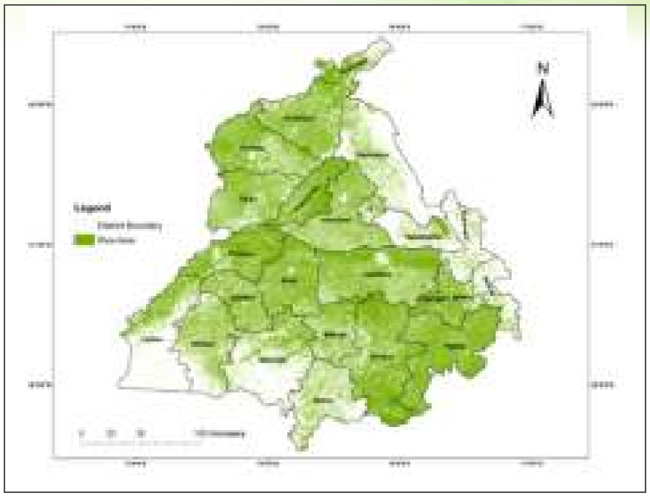


Fig. 36 Spatial distribution of rice area in state of Punjab during year 2000

The total area estimated by remote sensing analysis (2626.2 thousand hectare) was in agreement with area reported by Govt. of Punjab (2611 thousand hectare). However, there were variations in areas of individual districts. The supervised classification of remote sensing data gave spatial distribution of rice area in the state of Punjab and gave reasonably good estimate of rice area.

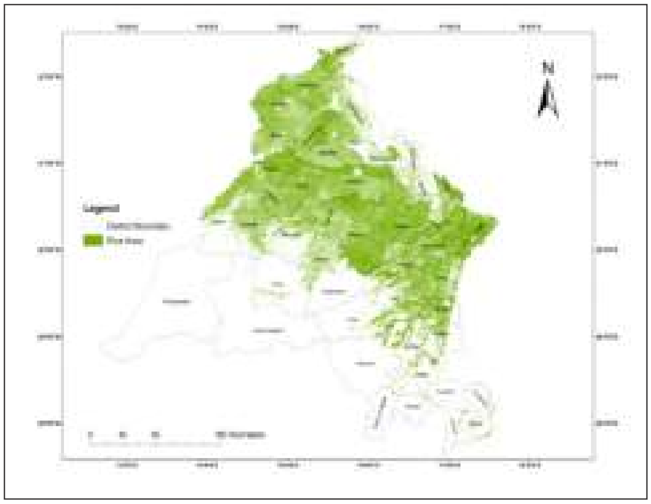


Fig. 37 Delineation of rice area under ACR-VI

Delineation of Rice areas for Agro-Climatic Region (ACR) VI

The rice area (3.6 million ha) under under ACR-VI, comprising Punjab, Haryana and two districts of Rajasthan (Sri Ganganagar and Hanumangarh) is shown in Fig. 37. Out of total rice area, 2.6 and 1.05 million ha is covered in Punjab and Haryana respectively. However very limited area is under rice cultivation in Rajasthan. This result was confirmed from the reports of AICRP (WM) centers located in Sriganganagar of Rajasthan.

Fig. 38 Major cropping pattern in ACR-VI

Delineation of major cropping system

District wise cropping pattern was prepared from the based on the cropping system map of Punjab developed by SAC (ISRO), Ahmedabad. Fig 38 showed the major cropping pattern in ACR-VI. Out of total geographical area of 11.4 million ha in ACR-VI, 5.8 million ha (50.87%) area is under rice-wheat cropping system, which is covered in the states of Punjab and Haryana.

Delineation of dominating soil group in ACR-VI

Soil map for ACR-VI has been prepared from Harmonized World Soil database web site. Major soil group and soil texture class has been delineated for the study area. Major portion of the area is under calcisol CL. Broader soil group showed the dominance of loamy soil in ACR-VI. It represented the major cropping system of rice-wheat is under loamy soil. Rainfall data were obtained from statistical abstract of Punjab, 2008-2009.

Project Title	:	**Design and evaluation of a portable drum based drip irrigation system**
Funding Agency	:	Institute
Project Personnel	:	R.C. Srivastava and D.U. Patil

A Portable Small Tank Based Drip Irrigation System was designed and evaluated with aim 1. to design a system by which water in small quantity (100 litres) could be transported from a water resource to field in a normal terrain; 2. Designing a drip system to work with a pressure of 50 -75 cm head, and 3. Evaluation of the efficacy of the system.

The total study consisted of two parts: first to design a system (Fig. 39) to transport water from site of resource to the field and secondly to apply it efficiently to minimize the amount of water required. For this the idea came from seeing people rolling gas cylinder to transport them from trucks to buildings just by pushing it. Another scene was transport of water in buckets on small trolleys from public taps or tankers to home. It was thought to combine both and create a system where a water tank can be rolled on wheels. To do so, a cylindrical water tank of 100 litre was taken and two old jeep tyres were fitted on both sides (Fig. 40). This gave the tank a free rolling on these two tyres.

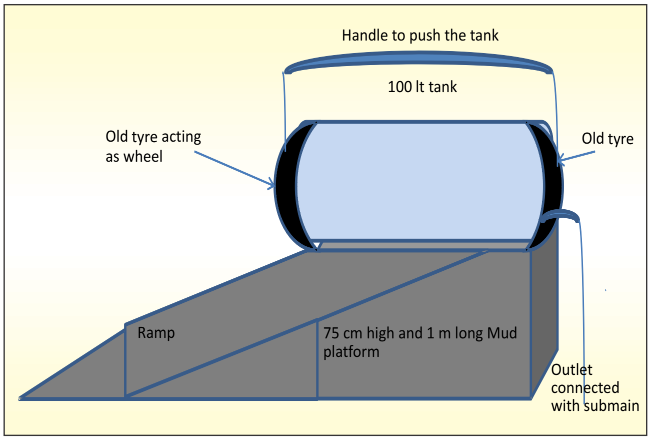


Fig. 39 Gravity fed drip system for sub marginal farmers

A 'U' shaped handle was attached on both sides for pushing the wheels as it is in lawn mower. To fully integrate the handle with tyres, a cross of MS flat was fitted on tyres alongwith a shaft and ball bearing. This reduced the effort in carrying the tank. Tests were carried out to push it on rough surfaces and it was found that it with full capacity water of 100 litres can be pushed on uneven surface with normal effort.

Fig. 40 Prototype (built from scrap of institute workshop) of rolling water tank on 25 cm high ramp at testing area

The tank had an inlet opening covered with a cap. The outlet lateral was connected in the cap so that no additional hole has to be made in body of tank reducing chances of leakage. The diameter of the tank was 45 cm and thus the average head available with the tank alone lying would be about 20 cm. Thus it was proposed to put the tank on an elevated platform to add up the head available. To evaluate the drip system, a 50mm diameter sub main pipe of 5 m length was used and the laterals were fitted at spacing of 2 m each. In all three laterals of 15 m each were fitted. While two laterals were fitted with microtube of 50 cm length at a spacing of 100 cm, the third one was fitted with button drippers of 2 lph. To estimate the optimum height of platform, 3 platforms of 25, 50 and 75 cm along with ramp to facilitate pushing of tank to platform were fabricated. The tank was filled with water from tap about 50 m away, rolled to site and was connected to submain through a 12 mm diameter lateral. The discharge from microtube and button drippers was measured by collecting water in mugs for 5 minutes.

The evaluation of the system showed that system can be operated even with 25 cm high ramp, However for better results using 50 cm high ramp will be desirable, which had highest uniformity coefficient of 94.20. The discharge with 2 mm dia microtube was higher (10 lph) which will reduce with smaller dia microtube. Further for reduced discharge, the microtube can be connected to the designed emitter.

Waterlogged Area Management

- Assessment and Development of Water Resources for Diversified Agriculture in Waterlogged High Rainfall Area
- Eco-efficient Agricultural Practices for Enhancing Nutrient Use Efficiency of Rice (*Oryza sativa*) under Waterlogged Ecosystem
- Identification of Suitable Crops for Wastewater Irrigation
- Delineation of Waterlogged Areas in Eastern India and Formulating Strategies for Fitting in Suitable Crops and Aquaculture through Harnessing Agro-biodiversity for Enhancing Water Productivity
- Development of Agriculture Water Management Portal (AWMP)
- Global Yield Gap and Water Productivity Atlas (GYGA)

Project Title	: **Assessment and Development of Water Resources for Diversified Agriculture in Waterlogged High Rainfall Area**
Project Code	: DWM/09/140
Funding Agency	: Institute
Project Personnel	: R. K. Panda and G. Kar

The on-farm water resources management plan of 41 ha alongwith feasible crop plan was developed for the study area in Pattamundai block of Kendrapara district, Odisha, which is frequently affected by the surface waterlogged condition. The depth-duration-frequency relationship was developed using Gringorten's plotting position approach and the drainage coefficient was computed as 75.2 and 162 mm/day for 2-years and 5-years return period, respectively. Considering 2-year return period, the design discharge was found to be 0.35 $m^3 s^{-1}$ and the proposed cross section for the irrigation cum drainage channel of length 675 m was computed.

Design strategy for water harvesting structures

Previous study of minor irrigation system in Odisha through secondary storage, efficient delivery and multiple use, reported that assuming about 50% main reservoir capacity water will be available for irrigating dry season crops . Fixing the 1st priority level of the objective function as maximization of net seasonal benefit and 2nd priority level as maximization of cropped area, the optimal surface area for auxiliary storage reservoir as the percentage of the command area was found 17.40% and 10.92%, respectively. Therefore in the present study it was assumed that 15% pondage area of the command area of 41 ha i.e. 6.2 ha was under farm ponds.

Optimized crop model

A multi objective optimized crop model using Goal programming technique was developed with two objective functions namely; maximization of profit and maximization of production for the study area. The farmers' affinity for selection of crops and the constraints like availability of water and fertilizer was considered. The model was studied under two water availability scenarios of 75 and 85 % of net irrigation water (Table 33 and Table 34). Estimation of total water availability and effective rainfall were computed using USDA SCS-CN procedure and FAO approach, respectively. Reference evapo-transiparion ET0 was computed using Hargreaves approach and accordingly ET_c was computed. Thus the net irrigation requirement (NIR) of crop was estimated using the equation:

$NIR = ET_c + PERC - ER$, where, PERC is the continuous percolation losses

Considering the above procedure, the multi–objective goal programming using winQSB software was run for obtaining optimal solution (Table 35). In scenario 1, water availability was higher (75% probability, 17346 ha-mm) compared to scenario 2 (85% probability, 13877 ha-mm) and *kharif* paddy, *rabi* tomato and rabi brinjal were allocated with maximum profit and production. In scenario 2, only paddy in *kharif* season and tomato in *rabi* were found in the solution. Thus optimal crop area allocation with 75 % water availability was found feasible.

Table 33 Crop-wise net water availability at 75 % probability level

Crops	K_c	ET_o mm	ET_{crop} mm	Effective rainfall, mm	Percolation mm	NIR mm
Kharif Rice (July-October)	1.15	79.4	91.31	203.48	69.1	-43.07
	1.23	73.2	90.04	173.72	69.0	-14.68
	1.14	90.6	103.28	148.12	66.9	22.06
	1.02	98.3	100.27	27.56	69.0	141.71
Total			384.89	552.88	274.0	106.02
Rabi Rice (January-April)	1.0	168.9	168.9	0	0	168.9
	1.1	135.5	149.1	0	0	149.1
	0.9	160.0	144	0	0	144.0
	0.9	166.0	149.4	23.9	0	125.5
Total			611.3	23.9	0	587.47

Crops	K_c	ET_o mm	ET_{crop} mm	Effective rainfall, mm	Percolation mm	NIR mm
Rabi Tomato (December-March)	0.5	126.2	63.1	0	0	63.1
	0.6	168.95	101.37	0	0	101.37
	1	135.52	135.52	0	0	135.52
	0.5	159.65	79.83	0	0	79.83
Total			379.82			380
Rabi Brinjal (December-April)	0.85	126.2	107.27	0	0	107.27
	0.9	165.95	152.1	0	0	152.1
	1.0	135.52	135.52	0	0	135.52
	0.95	159.65	151.67	0	0	151.67
	0.7	108.3	75.81	0	0	75.81
Total			622.32	0	0	622

Table 34 Crop-wise net water availability at 85 % probability level

Crops	K_c	ET_o mm	ET_{crop} mm	Effective rainfall, mm	Percolation mm	NIR, mm
Kharif Rice (July-October)	1.15	74.1	85.2	193	69.1	-38.7
	1.23	72.5	89.2	164.44	69.0	-6.24
	1.14	75.9	86.5	146.04	66.9	7.36
	1.02	82.5	84.2	22.34	69.0	130.86
Total			345.07	525.82	274.0	93.25
Rabi Rice (January-April)	1.0	160.3	160.3	0	0	160.3
	1.1	113.7	125.07	0	0	125.07
	0.9	150..7	135.63	0	0	135.63
	0.9	151.8	136.62	7.76	0	128.86
Total			557.62	7.76	0	549.86
Rabi Tomato (December-March)	0.5	109.7	54.85	0	0	54.85
	0.6	160.3	96.18	0	0	96.18
	1	113.7	113.7	0	0	113.7
	0.5	75.35	75.35	0	0	75.35
Total			340.08	0	0	340.0
Rabi Brinjal (December-April)	0.85	109.7	93.25	0	0	93.25
	0.9	160.3	144.27	0	0	144.27
	1.0	113.7	113.7	0	0	113.7
	0.95	150.7	143.17	0	0	143.17
	0.7	151.8	106.26	0	0	106.26
Total			600.64	0	0	601

Table 35 Optimal crop area

Crop Name/ Decision Variable	Area (ha) Allocation	Unit Profit (Rs ha^{-1})	Total Contribution (₹)
Water availability at 75% Probability of estimated runoff			
Kharif Paddy	20	25000	5,00,000
Rabi Paddy	0	30000	-
Tomato	24.1	80,500	19,40,316
Brinjal	5.9	86,100	5,07,705
Water availability at 85% Probability of estimated runoff			
Kharif Paddy	25.7	25000	6,43,117
Rabi Paddy	0	30000	-
Tomato	24.3	80,500	19,54,162
Brinjal	0	86,100	-

Impact of surface drainage system on paddy yield

The pre-intervention survey of the farmers in four beneficiary villages adjacent to the study area namely; Amber, Baipada, Jigarana and Naladholia under Khadianta Gram Panchayat was made to ascertain the existing socio-economic condition by interviewing fifty-nine key farmers. About 89.8% of the farmers were marginal (with less than 2.5 acres holdings) and small (2.5 to 5.0 acres) categories. Similarly, 74.6 % farmers were under BPL category. Execution of the field drainage system during 2007-08 by CAD&WM modulated the waterlogged situation in the crop field and the farmers cultivated paddy crop during 2008-12 *kharif* seasons with yield between 2.3 - 3.1 t ha^{-1} compared to 1.2 t ha^{-1} under pre-drainage scenario. Further, a waterlogged tolerant paddy variety Swarna sub-1was introduced during 2010-11 and 2011-12 crop seasons and the average yield was 4.65 t ha^{-1}.

Hydrologic impact of field drain and the renovated structures

It was observed that the field drain successfully modulated the submergence in the nearby paddy field. As a result, on 8th October 2010 when a peak rainfall event of 152 mm occurred in the study area, there has been a reduction of 49 cm depth of submergence in paddy crop field (Fig. 41) compared to field drain where the depth of water was 109 cm.

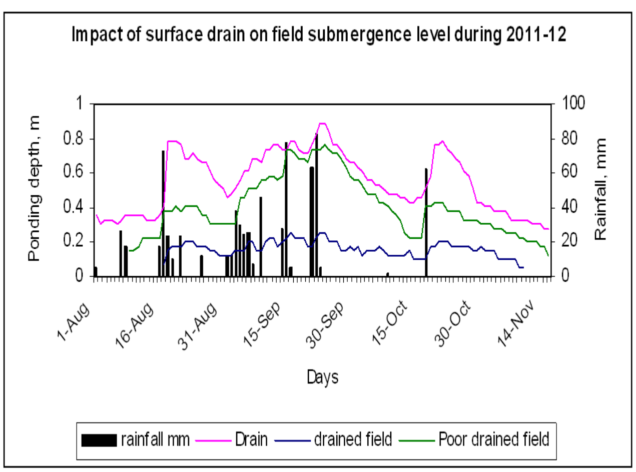


Fig. 41 Spatial submergence in field drain and drained paddy field

The renovation work of the minors increased in flow rate with the range of 0.2-0.45 m^{3}sec^{-1} during 29th –46th weeks, where as prior flow rate was almost negligible. Similarly, week-wise temporal water availability measured in a farm pond during the year 2012 revealed water fluctuation between 0.5 -3.2 m during 23rd - 31st weeks, which indicated availability of adequate water for growing *rabi* crops. The impact of 39 renovated farm ponds of size ranging between 1200-6000 m^2 covering 6.2 % area of the command area of 300 ha revealed encouraging results during *rabi* season with varied successes.

Project Title	:	**Eco-efficient Agricultural Practices for Enhancing Nutrient Use Efficiency of Rice (*Oryza sativa*) under Waterlogged Ecosystem**
Project Code	:	DWM/12/163
Funding Agency	:	Institute
Project Personnel	:	P.S. Brahmanand, S.Roy Chowdhury, S. Ghosh and A. Kumar

Field experiment was conducted in *kharif* season in the farmers' fields in village Balisahi of Pipli block of Puri district of Odisha to study the performance of rice under different nutrient treatments in waterlogged ecosystem. Split-split plot design was adopted with two depth of waterlogging (M1:10-25 cm; M2: 25-50 cm) as main plot treatments, two method of fertilizer application (S1:Broadcasting; S2: Band placement) as sub plot treatments of and five sub sub-plot treatments of type of N fertilizer (SS1: Control; SS2: N@60 kg ha^{-1} through urea; SS3 : N@60 kg ha^{-1} through Dicyanodiamide (DCD); SS4: N@60 kg ha^{-1} through Neem coated urea (NCU) and SS5: N@60 kg ha^{-1} through DWM bioformulation) with three replications. DWM bio-formulation was prepared with combination of leaf extracts of *Pongamia pinnata, Azadirachta indica* and other plant species which have property of slowing down the rate of release of nitrogen. The main objective of the study was to find out the effect of different nutrient treatments on productivity and nitrogen use efficiency of rice under waterlogged condition.

The growth parameters such as plant height, tiller number, leaf area index and dry matter accumulation were higher at lower submergence level, band placement and N@60 kg ha^{-1} through DCD. There was concomitant increase in yield attributes such as panicle number and filled grain per panicle through superior grain yield with these treatments. Significantly superior grain yield (3.8 t ha^{-1}) was noticed under shallow submergence (10-25 cm) compared to intermediate level of submergence (25-50 cm, 3.51 t ha^{-1}; Fig. 42) and band placement of N @ 60 kg ha^{-1} was found to be significantly superior in terms of grain yield (3.82 t ha^{-1}) compared to broadcasted of nitrogen fertilizer treatment (3.49 t ha^{-1}, Fig. 43). Similarly, Nitrogen @ 60 kg ha^{-1} applied through Dicyanodiamide (DCD) has resulted in superior grain yield of rice (4.1 t ha^{-1}) compared to NCU and DWM bio-formulation (Fig. 44). Highest nitrogen use efficiency of 26.5 kg grain. kg N^{-1} applied was also noticed with N @ 60 kg ha^{-1} through area + DCD (Fig. 45). However, the treatment with DWM bio-formulation also improved grain yield and nitrogen use efficiency compared to control and NCU application.

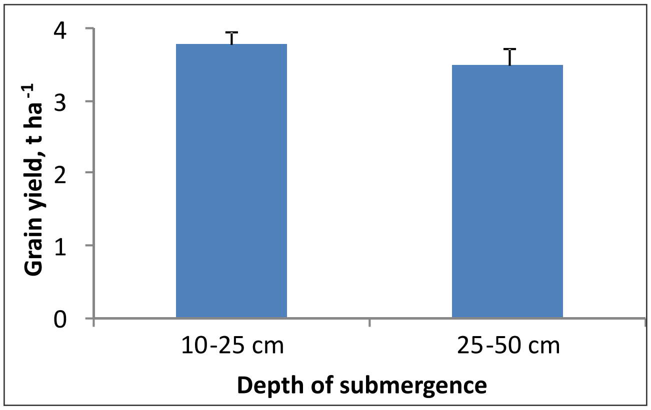


Fig. 42 Grain yield (t ha^{-1}) of rice as influenced by level of submergence

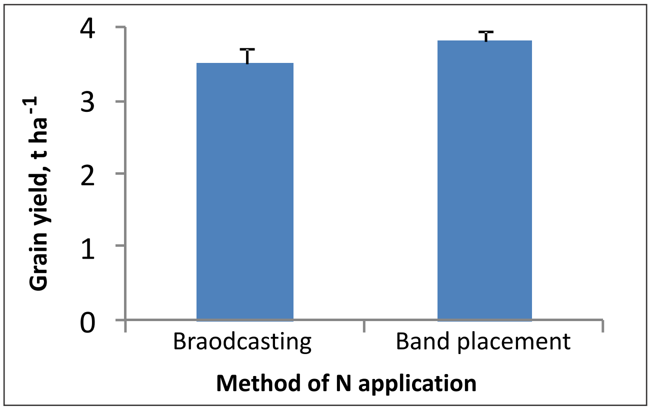


Fig. 43 Grain yield (t ha^{-1}) of rice as influenced by method of application of N fertilizer

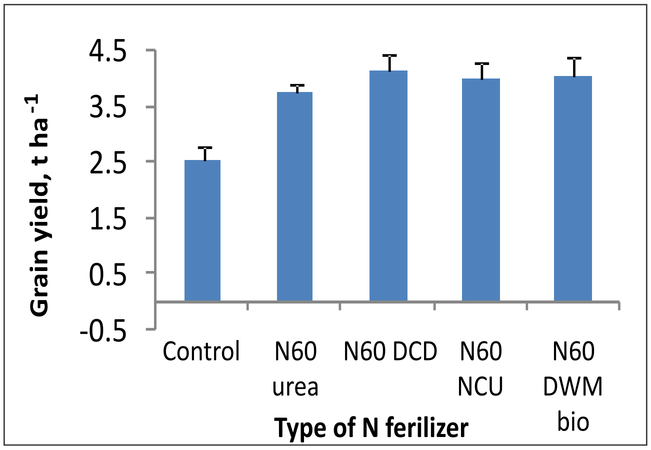


Fig. 44 Grain yield (t ha^{-1}) of rice as influenced by type of N fertilizer

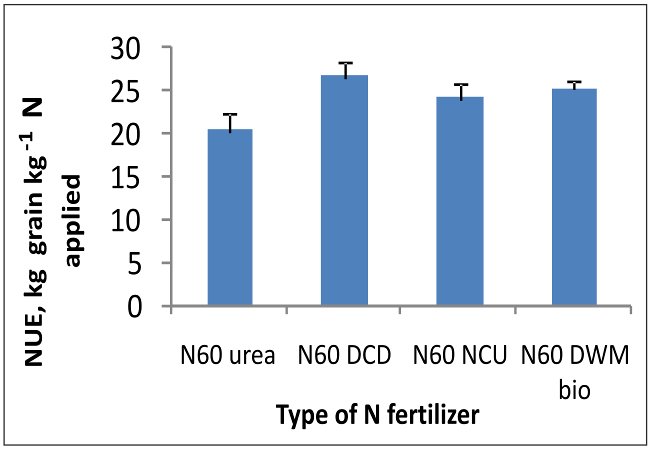


Fig. 45 Nitrogen use efficiency (kg grain kg^{-1} N applied) of rice as influenced by type of N fertilizer

View of experimental rice field at Balisahi village, Puri district during *kharif*, 2013

Project Title	:	**Identification of Suitable Crops for Wastewater Irrigation**
Project Code	:	DWM/12/159
Funding Agency	:	Institute
Project Personnel	:	S. Raychaudhuri, M. Raychaudhuri, S.K. Rautaray and S. Roy Chowdhury

Studies on transfer factors of heavy metals to identify crops having lower accumulation of metals

Heavy metal accumulation of in parts of ladies finger, pumpkin, ridge gourd, bitter gourd, *Amaranthus*, cucumber, malabar climbing and paddy was studied in pot culture experiment. Plants were grown in earthen pots with three replications. Each pot was filled with 3kg soil collected from wastewater irrigated fields at Joypurpatna, having pH 5.7, organic C 0.54%. The pots were irrigated with a synthetic sewage having metal concentrations of 0.5 mg kg^{-1} Cd, 0.5 mg kg^{-1} Cr and 5 mg kg^{-1} Pb. The plants were harvested at 60 days along with roots and were analyzed for Cd, Cr and Pb. The transfer factor (TF) was calculated for each plant. Highest TF was observed with *Amaranthus* red followed by tomato, water melon, malabar climbing, bitter gourd, ladies finger and ridge gourd. The concentration of Cr was more than Cd and Pb in most plants. Higher accumulations of metals were observed in leaf tissues than in fruit parts (Fig. 46).

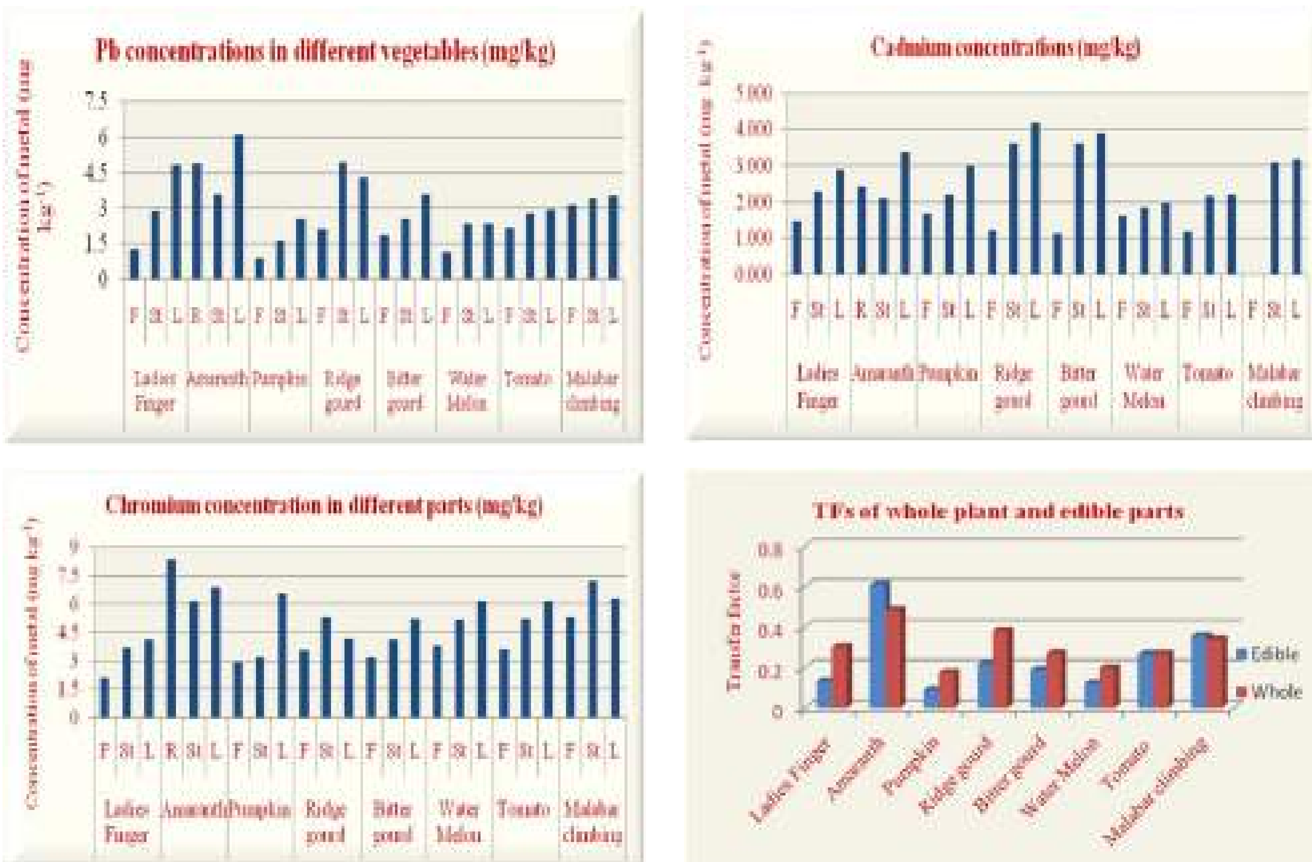


Fig.46 Heavy metal accumulation by different plants and transfer factors

Studies on graded levels of heavy metals in vegetables

Field experiment was conducted at Deras experimental farm with graded level of Cd on six vegetable crops *viz.* okra, tomato, ridge gourd, french bean, radish and Amaranthus. The experiment was laid out in split plot with vegetables in main plots and graded doses of Cd (0, 3, 6 and 9 ppm levels) in sub plots. The growth parameters and photosynthesis rate and yield were recorded. Amaranthus gave maximum yield of 24.7 t ha^{-1} (fresh) at 3 ppm Cd level and was higher than that at 0 level of Cd addition. At 6 ppm level decrease in yield (24 t ha^{-1}) was observed with Amaranthus. However, the differences were insignificant. The yields of all other vegetables were at par in both the 0 and 3 ppm Cd level whereas at 6 and 9 ppm decrease in yields in ridge gourd was observed (Fig. 47).

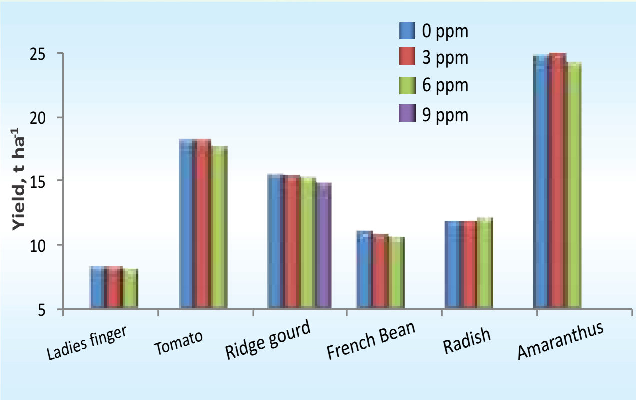


Fig. 47 Vegetable yield at different concentration of Cd

The net photosynthetic activities were measured at 30 and 60 days after planting to ascertain the impact of Cd on photosynthetic CO_2 uptake of vegetable plants. The net photosynthetic rates decreased with higher doses of Cd both at 30 and 60 days after planting (Fig. 48)

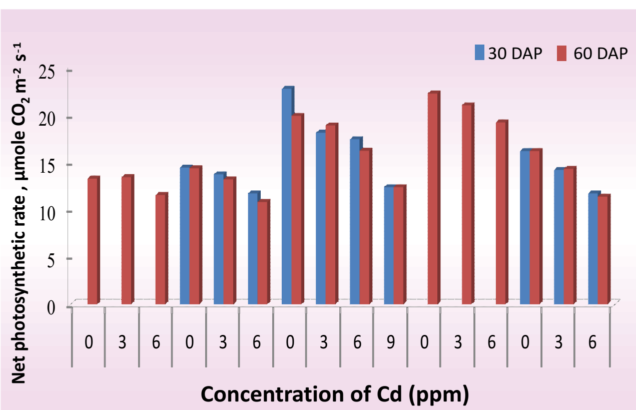


Fig. 48 Effect of graded level of Cd on net photosynthetic rate of vegetables (µmol CO_2 m^{-2} s^{-1})

Periodic analyses for Mass balance of heavy metal in paddy-vegetable and paddy-paddy systems

Periodic analyses of soil and crop samples from six identified sites in farmer's field at Joypurpatna were done between winter (January) 2013 and winter (January) 2014 along with the analyses of irrigation water for budgeting heavy metals *viz.* Cd, Cr and Pb. The soils were analysed for pH, EC, organic Carbon and heavy metals *viz.* Cd, Cr and Pb. The uptake of heavy metals in crops grown and addition of metals through wastewater were determined. The heavy metal uptake in rice was 11 percent higher in Rabi seasons than that in *kharif* (17, 40 and 12 g per ha for Cd, Cr and Pb respectively). Levels of Cd, Cr and Pb in soil at different seasons are given in Fig. 49.

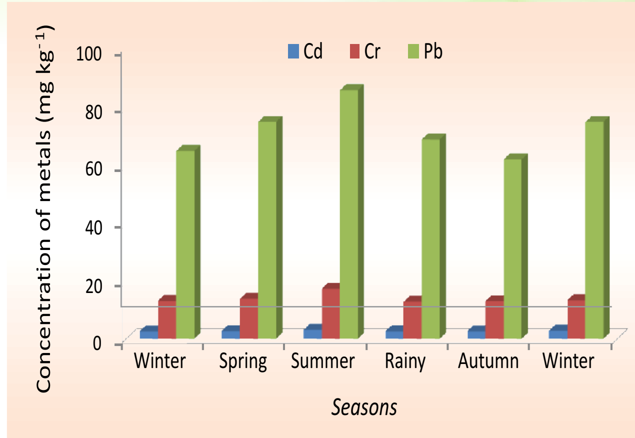


Fig. 49 Changes in heavy metal concentrations in wastewater irrigated fields in different seasons

Studies on Die off period of pathogens

To ascertain the persistence of microbial pathogens on vegetable crops after wastewater irrigation, an experiment was conducted in farmers field at Joypurpatna. Vegetable samples *viz.* okra, tomato, amaranthus, Malabar climbing, bitter gourd, ridge gourd and cucumber were collected at 0, 3, 5, 7 and 10 days after irrigation. The microbial load viz, total coliforms (TC), E coli and other bacteria (OB) were enumerated as indicator organisms in the laboratory and expressed as log cfu per gram of vegetables in figures below. The initial load of TC, E coli and OB were lowest (3.02. 1.80 and 3.50 log cfu per g) in okra on the day of irrigation (0 days) and highest in bitter gourd, ridge gourd. Probably, the rough surface and crevices in ridge gourd might have been congenial for higher retention of microorganisms. At 7 and 10 days after irrigation mean, reduction of 1.92 and 2.53 log cfu of E coli were found in vegetables (Fig. 50).

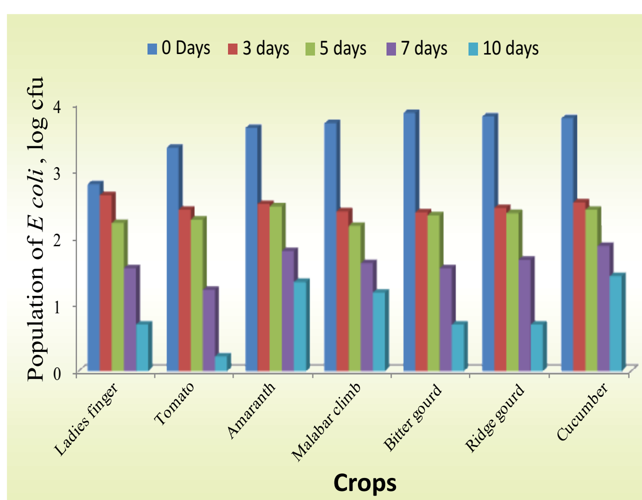


Fig. 50 Pathogens in vegetable at different days after wastewater irrigation (log cfu g^{-1})

Project Title	:	**Delineation of Waterlogged Areas in Eastern India and Formulating Strategies for Fitting in Suitable Crops and Aquaculture through Harnessing Agro-biodiversity for Enhancing Water Productivity**
Project Code	:	DWM/12/162
Funding Agency	:	Institute
Project Personnel	:	S. Roy Chowdhury, P.S. Brahmanand, A.K. Nayak, R.K.Mohanty and Ashwani Kumar

The delineation of waterlogged areas in Odisha was carried out through assessment of the district wise status of waterlogged areas with the help of LISS III data (1:50,000 scale) for the period 2005-2006. The data were collected from Orissa Space Application Center (ORSAC), Bhubaneswar. To improve the accuracy of delineation, LISS III data of three season, namely *kharif* (monsoon), *rabi* (winter) and *zaid* (summer) for the period 2005-06 were considered following on-screen visual interpretation approach. Accordingly 17 different types of water bodies and waterlogged areas were characterized using ARC GIS software. The different types of water bodies/waterlogged areas classified were 1. Canal drained lined, 2. Canal drain-unlined, 3. Lakes/ponds dry 4. Lakes/ponds dry, rabi-extent, 5. Lakes/ponds dry, kharif-extent 6. Lakes/ponds dry, zaid -extent, 7. Lakes/ponds perennial 8. Reservoir / tanks dry 9. Reservoir / tanks dry, rabi-extent, 10. Reservoir / tanks dry, kharif-extent, 11. Reservoir / tanks dry, zaid -extent, 12. Reservoir / tanks perennial 13. River stream dry 14. River stream perennial, 15. Wetland coastal natural, 16. Wetland inland manmade, and 17. Wetland inland natural. In addition there is manmade waterlogged areas as well (Fig. 51). In these different classes of waterlogged areas and or water bodies, the perennial river or streams flow throughout the year whereas perennial lakes and ponds are those areas which maintain water for a season or throughout the year and generally are not subjected to extreme fluctuation in level of water. The perennial reservoir / tanks normally show spread of water at least in one season in a year (NRSA NRC LULC 50K).

Among waterlogged prone districts of Odisha, Jagatsinghpur district showed 10884.42 ha perennially under rivers and streams, and 548.98 ha under lakes and ponds with a total of 11433.4 ha under perennial water bodies. This was followed by Kendrapara district where 11229.41 ha perennially under rivers and streams, and 162.34 ha under lakes and ponds with total 11391.75 ha area was under perennial water bodies. The Baleswar district had perennially 6350.86 ha area under rivers and streams and 253.53 ha area under lakes and ponds and 91.76 ha under reservoir/tanks with total 6696.15 ha as perennial water bodies. In Bhadrak district 4747.67 ha area was perennially under rivers and streams and 286.24 ha was under lakes and ponds with total 5033.91 ha of perennial water bodies. The Puri had 6237.13 ha perennially under rivers and streams, and 204.92 ha under lakes and ponds. The Khurda district showed 1729.07 ha area was under perennial water bodies. The Ganjam district had perennially 4075.77 ha area under rivers and streams and 4530.07 ha area under lakes and ponds and 3818.04 ha under reservoir and tanks. In Sambalpur district which is dominated by Mahanadi river basin and Hirakud command, about 9563.29 ha area was perennially under rivers and streams, lakes and ponds and reservoir and tanks as perennial water bodies. The Kalahandi district showed 8118.80 ha area perennially under rivers and streams, and 3015.10 ha under lakes and ponds with total 11133.9 ha area perennially under waterlogged condition. The Bolangir district showed 8310.64 ha area perennially under rivers and streams, 5446.12 ha under lakes and ponds and 3.83 ha under perennial reservoir and tanks. Koraput district had perennially 4832.63 ha area under rivers and streams and 266.56 ha area under lakes and ponds and 117.05 ha under reservoir and tanks with total 5216.24 ha as perennial water bodies.

Kendrapara district had highest area 11229.41 ha perennially under rivers and streams, followed by Jagatsinghpur district i.e. 10884.42 ha. The Ganjam district has highest 8348.11 ha area perennially under lakes, ponds, reservoir and tanks followed by Bolangir district with 5449.95 ha area under similar category. The Baleswar and Kendrapara district had shown man made waterlogged area of 569.98 and 169.97 ha respectively. Three of such manmade waterlogged area was delineated and were identified for cropping system study and intervention. They were in Haldipada block in Baleswar district, Taribatpur village (N 21°45.872'/ E 87°11.248') of Jaleswar block of Baleswar district and Jambhirai village (located at N 21°33.124'/ E 87°11.108') in Baliapal block in Baleswar district. Soil samples were collected from three locations i.e. Haldipada block in Baleswar district, Taribatpur village located at N21°45.872'/ E87°11.248' of Jaleswar block of Baleswar district and Jambhirai village located at N21°33.124'/ E87°11.108' in Baliapal block in Baleswar district.

Table 36 presents physical properties of the soils at three sites. Soils are light in texture i.e. silt loam, sandy loam and loamy sand at Haldipada, Taribatpur and Jambhirai sites respectively. Bulk density of sol at Taribatpur and Jambhirai found 1.64 and 1.53 g.cm^{-3} respectively which were higher than normal soil i.e. 1.33 g cm^{-3}, and might be due to higher proportion of and particles whereas at Haldipada, it was found to be lower i.e. 1.28 g cm^{-3}. The chemical properties of the soils are presented in table 37. The soils of three sites were slightly acidic (6.10 to 6.22) in reaction and electrical conductivity was also very low (Table 37). Organic carbon content of the soils are low (0.27 to 0.37%). Available N content were also low (115-196 kg ha^{-1}) and could be due to low organic carbon content and nitrate loss through leaching from surface soil. Available P status of the soil are also low (<15 kg ha^{-1}) and might be due to acidic nature of the soil. The available potassium content are in medium range (168.37 to 189.69 kg ha^{-1}), suggesting loss of labile K from soil profile due to waterlogged condition and leaching.

Table 36 Physical properties of soil at three experimental sites

Sites	Soil depth (cm)	Particle size analysis (%)				Textural class	Bulk density ($g.cm^{-3}$)
		Coarse sand	Fine sand	Silt	Clay		
Haldipada	0-15	22.16	14.49	60.37	2.98	Silt loam	1.28
Taribatpur	0-15	28.61	40.22	28.78	2.39	Sandy loam	1.64
Jambhirai	0-15	32.62	40.51	21.14	5.73	Loamy sand	1.53

Table 37 Physico-chemical properties of soil at three experimental sites

Sites	Soil depth (cm)	pH	EC dS/m	Organic Carbon (%)	Available N ($kg.ha^{-1}$)	Available P ($kg.ha^{-1}$)	Available K ($kg.ha^{-1}$)
Haldipada	0-15	6.22	0.02	0.37	196	<15	170.23
Taribatpur	0-15	6.2	0.02	0.35	149	<15	189.69
Jambhirai	0-15	6.10	0.04	0.27	115	<15	168.37

In the post monsoon period after Phailine cyclone, which occurred on second week of October, the water level decreased from 124 cm above ground situation in October 2013 to 52cm in November and gradually subsided to -64 cm in the month of February, 2014 at Taribatpur near Chalanti lake in Jaleswar block of Baleswar district.

The water quality parameters for aquaculture intervention were also done at Taribatpur village (Table 38). The recorded mean minimum and maximum values of various water quality parameters prevailed in the pond were indicative of its suitability to carry out freshwater aquaculture. At any given point of time, other water quality parameters and plankton did not register any specific trend.

Table 38 Pond water quality parameters at Taribatpur (Farmer- Narayan Dhal) during 2013-14

PARAMETERS	
Water quality parameters	
Water pH	7.66 ± 0.12
Dissolved Oxygen (ppm)	5.9 ± 0.6
Temperature (^0C)	29.8 ± 0.3
Total alkalinity (ppm)	111 ± 9
Dissolved Organic Matter (ppm)	5.1 ± 0.2
Total Suspended Solids (ppm)	192 ± 11
NH_4^+ water (ppm)	0.6 ± 0.01
Total plankton (units l^{-1})	$6.8x10^4 \pm 1.3x10^3$
Nitrite – N (ppm)	0.04 ± 0.01
Nitrate – N(ppm)	0.33 ± 0.05
Phosphate – P (ppm)	0.21 ± 0.02

All values are mean ± SD

The productivity of natural waterlogged areas in general has been found to be poor due to unfavorable conditions for crop survival and growth. In case of manmade waterlogged areas, the extent of waterlogging is predictable and it provides scope for developing and implementing the alternate crop plans with an objective of augmenting the land and water productivity. Chalanti (Jaleswar block and Baleswar district) comes under such scenario where waterlogging has been a common feature since long and farmers have been practicing rice cultivation in *kharif* season and potato and greengram, groundnut, brinjal and other vegetables in *rabi* season. Advancement of sowing time by 10 days from 3rd week of November to first week of November in greengram resulted in 16% higher pod yield from 720 kg ha^{-1} to 835 kg ha^{-1}. Similarly, practice of ridge and furrow system has bettered the fruit yield of brinjal and tuber yield of potato compared to the flat bed system. The introduction of new crops such as radish, cabbage, coriander and mustard have resulted in higher economic returns in addition to better insurance under low lying waterlogged prone environment.

Phailin cyclone and subsequent flood have resulted in crop damage to the tune of about 6.4 lakh ha covering 17 districts of Odisha affecting about 12 million people. Phailin cyclone caused severe crop damage in Ganjam, Puri, Khurda, Kendrapara, Baleswar and Cuttack districts of Odisha. The consequent flood has resulted in inundation of crop fields in Baleswar, Bhadrak, Mayurbhanj, Cuttack and Kendrapara districts. Paddy was the main affected crop during these events. The other crops affected were fruits and vegetables such as coconut, papaya, banana, cashew, brinjal and tomato. In seasonally low lying areas, the paddy faced submergence for longer period which resulted in higher crop damage. In these patches, early *rabi* crop was advocated. In considerable portion of flood affected area, paddy fields didn't experience submergence for longer period where water receded quickly resulting in good crop recovery and lesser yield loss. Moreover, the rice plants experienced the submergence during their vegetative phase (pre booting stage) which provided better scope for crop recovery. In such Phailin affected areas, an assessment was made to study the improved practices adopted by some farmers. In Jajpur district, the farmers mainly cultivated groundnut and mustard either as sole crop or as intercrop. The pod yield of groundnut was recorded as 1165 kg ha^{-1} and seed yield of mustard was 980 kg ha^{-1}. The pod number per plant and seed number per pod of mustard were found to be 286 and 11.7 respectively which contributed for higher pod yield and reflects the better resilience of this crop to survive under post flood scenario. Similarly, the average number of branches per plant, pod number per plant and 100-kernal weight of groundnut were found to be 5.1, 13.5 and 42g. Some farmers have grown cucurbits such as pumpkin and ridgegourd. In few pockets, the farmers have grown *Colocasia*. After the harvest of groundnut and mustard, about 20% of the farmers have gone for the crops such as watermelon, cucumber and pumpkin. Planting of *Acacia*, *Eucalyptus* in low lying areas were also seen.

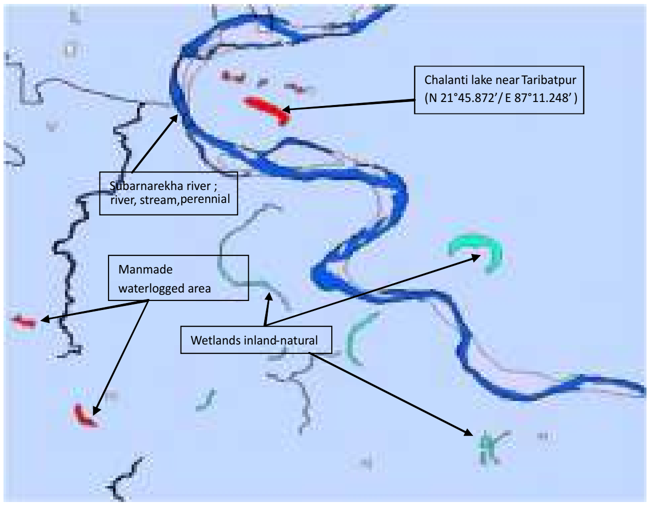


Fig. 51 Different types of waterlogged areas in Baleswar district

A, Ground truthing of Chalanti Lake in Nov, 2013; B, Damaged vegetable crops (B, Okra; C, Cucurbits) due to submergence with NH5 in background; D. Subsidence of Lake water in January, 2014; E Cabbage in peripheries of lake; F. biodrainage plantation in low lying area, Baleswar district ; G , H Mustard ground nut inter crop in Jajpur district, in 23rd November, 2013 (G) and 27th February 2014 (H); I Cabbage, tomato and chilli mixed cultivation at Taribatpur, Baleswar district.

Project Title	:	**Development of Agriculture Water Management Portal (AWMP)**
Project Code	:	DWM/12/160
Funding Agency	:	Institute
Project Personnel	:	A.K. Nayak, S. Ghosh, M.J. Kaledhonkar, P. Nanda, A. Kumar, R.G. Patil, U.M. Khodke and B.S. Yadav

A web based information system on agriculture water management is being developed for better utilization of water resources in agricultural development. The web portal contained different domains like research domain, farmer's domain, service domain, e-learning and contact information for use of different group of stake holders.

The information of all 25 centers under All India Coordinate Research Project (AICRP) on Water Management Centres regarding their general information and information related to their research activity were collected and compiled in the web pages. These developed web pages of the web portal will be kept in public domain for access by general public. Webpage format has been prepared for researches carried out by AICRP Centres across the country to access related information by the stake holders. The background information, centre information, theme of Research, Location map, soil type, alongwith the major accomplishments done by the centre has been uploaded on the website. The sample snapshots of web portal are given in Fig. 52 and 53.

The literature on research and extension on agriculture water management were collected for developing an e-learning module of the web portal for the farmers and other researchers. The published literature, bulletins and leaflets for agriculture water management in Hindi and Odia language were uploaded on the webpage as e-books. The published bulletins of DWM and e-books already available in the DWM website have also been linked with the web portal (Fig. 54).

Fig. 52 Snapshot of the Agricultural Water Management Web Portal

Fig. 53 Snapshot of the AICRP module in the web portal

Fig. 54 Snapshot for the E-learning module of the web portal

Project Title	: **Global Yield Gap and Water Productivity Atlas (GYGA)**
Funding Agency	: University of Nebraska, USA and Bill & Melinda Gates Foundation, USA
Project Personnel	: P.S. Brahmanand, Ashwani Kumar, N. Subash and B. Gangwar

The objective of this project is to collect and compile the data on yield gaps and water use efficiency in India to prepare an atlas, initially for five major crops namely maize, rice, wheat, sorghum and pearl millet. Thirty Reference weather stations sites and climatic buffer zones were identified in different agro-climatic zones of India for estimating actual and potential yields of rice, wheat, maize, sorghum and pearl millet (Table 39). The daily weather data of these sites for 30 years (1980-2010) were collected. Actual crop yields of rice, wheat, maize, sorghum and pearl millet for 10 years were estimated for all the thirty climatic buffer zones taking the respective district and surrounding district weighted mean of major crops with in 100km radius. The lowest rice yield (0.87 t ha^{-1}) was recorded with Jabalpur climate zone where as the highest rice yield (3.26 t ha^{-1}) was recorded with Paiyur zone. The lowest wheat yield (1.37 t ha^{-1}) was recorded with Palampur climate zone where as the highest wheat yield (4.59 t ha^{-1}) was noticed with Ludhiana zone. Crop distribution maps – based on triennium ending period 2011-12 for rice, wheat, maize, sorghum and millet during *kharif* and *rabi* were created. APSIM model is being used for estimation of yield potential of wheat and rice and Hybrid maize model is used for maize and WOFOST model is being used for sorghum and pearl millet.

Table 39 Geographical location of reference weather station sites along with their major crop under different agro-climatic zones of India

Sl No	Name of reference weather station	Latitude N°	Longitude E °	Major crop	Agro-climatic zone
1	Akola, Maharashtra	20.70	77.03	Sorghum	Western Plateau and Hills Region
2	Bangalore, Karnataka	12.97	77.58	Maize	Southern Plateau and Hills Region
3	Bhubaneswar, Odisha	20.25	85.83	Rice	East Coast Plains and Hills Region
4	Faizabad, Uttar Pradesh	26.78	82.13	Wheat	Middle Gangetic Plains Region
5	Hisar, Haryana	29.17	75.73	Wheat	Trans Gangetic Plains Region
6	Jabalpur, Madhya Pradesh	23.15	79.97	Rice	Central Plateau and Hills Region
7	Jorhat, Assam	26.78	94.20	Rice	Eastern Himalayan Region
8	Kanpur, Uttar Pradesh	26.43	80.37	Wheat	Upper Gangetic Plains Region
9	Ludhiana, Punjab	30.93	75.87	Wheat	Trans Gangetic Plains Region
10	Palampur, Himachal Pradesh	32.10	76.05	Wheat	Western Himalayan Region
11	Parbhani, Maharashtra	19.13	76.83	Sorghum	Western Plateau and Hills Region
12	Raipur, Chhattisgarh	21.23	81.65	Rice	Eastern Plateau and Hills Region
13	Hyderabad, Andhra Pradesh	18.98	78.92	Maize	Southern Plateau and Hills Region
14	Ranchi, Jharkhand	23.28	85.32	Rice	Eastern Plateau and Hills Region
15	Udaipur, Rajasthan	25.35	74.63	Maize	Central Plateau and Hills Region
16	Modipuram, Uttar Pradesh	29.07	77.67	Wheat	Upper Gangetic Plains Region
17	Thiruvalla, Kerala	9.15	77.11	Rice	West Coast Plains and Hills Region
18	Pune, Maharashtra	19.47	74.18	Bajra	Western Plateau and Hills Region
19	Paiyur, Tamil Nadu	12.35	78.30	Rice	Southern Plateau and Hills Region
20	Navsari, Gujarat	20.57	72.54	Rice	Gujarat Plains and Hills Region
21	Kalyani, West Bengal	23.40	88.52	Rice	Lower Gangetic Plains Region
22	Jaipur, Rajasthan	26.55	75.49	Bajra	Central Plateau and Hills Region
23	Indore, Madhya Pradesh	22.04	76.00	Wheat	Western Plateau and Hills Region
24	Coimbatore, Tamil Nadu	11.98	78.92	Rice	Southern plateau and Hills Region
25	SK Nagar, Uttar Pradesh	24.32	72.32	Wheat	Middle Gangetic Region
26	Karnal, Haryana	29.72	76.97	Wheat	Trans Gangetic Region
27	Umiam, Meghalaya	25.69	91.92	Rice	Eastern Himalayan Region
28	Pusa, Samastipur, Bihar	25.65	85.50	Wheat	Middle Gangetic Region
29	Sabour, Bihar	25.38	87.12	Wheat	Middle Gangetic Region
30	Maruteru, Andhra Pradesh	16.63	81.73	Rice	East Coast Plains and Hills Region

On-farm Research and Technology dissemination

- Tracking Change in Rural Poverty in household and Village Economies in South Asia
- Strengthening Statistical Computing for National Agricultural Research System
- Enhancing Land and Water Productivity through Integrated Farming System (Tribal Sub Plan Project)

Project Title	:	**Tracking Change in Rural Poverty in household and Village Economies in South Asia**
Funding Agency	:	Bill and Melinda Gates Foundation
Project Personnel	:	M.K. Sinha, P. Nanda and A. Kumar

Agriculture and poverty related high frequency data collected on monthly basis to enhance availability of reliable household, individual, field specific, plot level data on production, consumption, labour, expenditure and incomes throughout the year to address the dynamics of economic, social and institutional development were processed to understand the dynamic process of reducing poverty by tracking the household and village economies from Odisha villages. Data base was prepared in a user-friendly format of CSPro (Fig. 55). This software package can be accessed in user friendly format by individuals, researcher and planners.

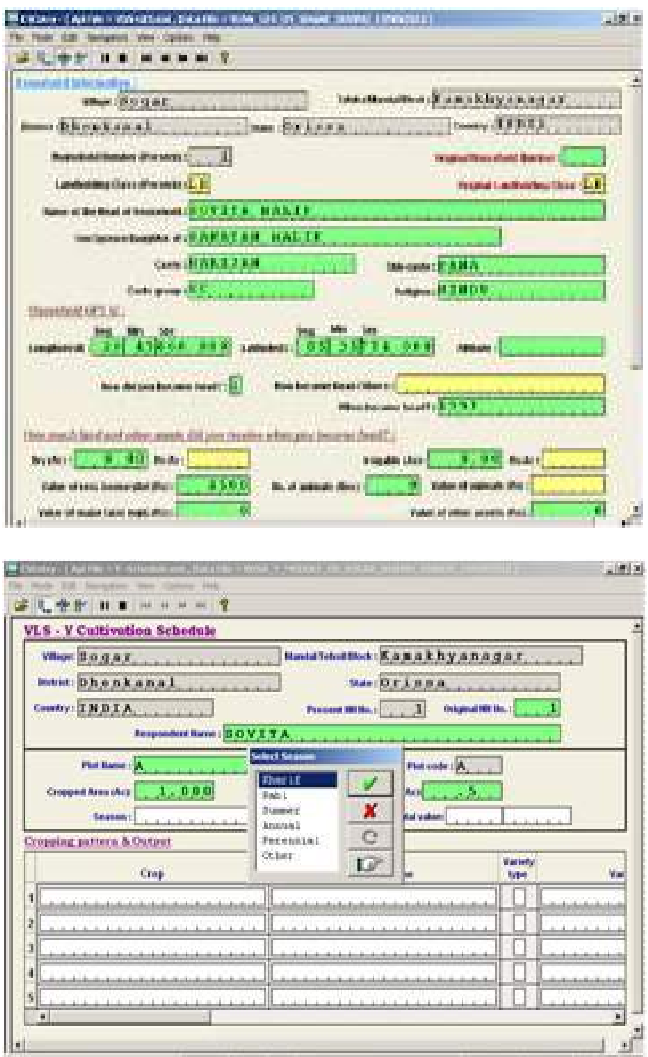


Fig. 55 User friendly Dataware CSPro Format

Data from Ainlatunga village of Balangir showed that 62 per cent populations were below poverty level (BPL) and rest 38 per cent were of APL category. Through public distribution system, the BPLs could avail 30 kg rice, 3 litre kerosene and 1.5 of sugar in each month, where the APLs could avail 7 kg of wheat and 25 kg of rice in each month. Further data suggests that almost 76 per cent of the population meet livelihood from agricultural sector, consisting of 65 per cent is cultivators and 10.89 per cent agricultural workers (Fig. 56). Second sizable population (21.07%) was of non-farm workers in the village. From the small, medium, and large farmer households, 80 per cent were cultivators as they held sufficient land area to sustain. But 75 per cent of landless households were workers, out of which 14.95 per cent were agricultural workers and 56 per cent non-farm workers. It was hard to find any households having government employment.

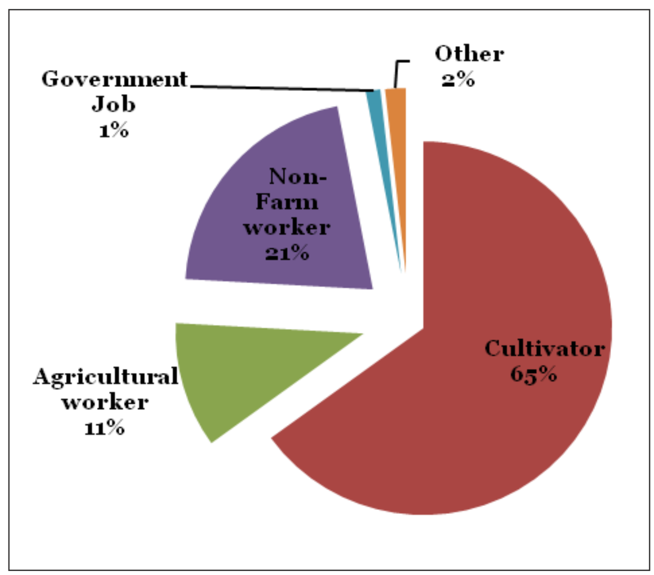


Fig. 56 Income diversification in Ainlatunga

The villages had sizable 81.82% as migrants in search of daily wage employment followed by salaried job (13.64%) and education (4.55%). Insufficient employment opportunities in agricultural sector due to regular drought situation and absence of irrigation facilities in spite the watershed development accelerated the trend. Lack of generation of employment, advance payments from the labour contractors to work in unknown land were the other major causes of migration.

Project Title	: **Strengthening Statistical Computing for National Agricultural Research System**
Funding Agency	: NAIP, ICAR, New Delhi
Project Personnel	: D. K. Panda and G. Kar

In order to improve computational efficiency of scientists and researchers of National Agricultural Research System under the NAIP project "Strengthening Statistical Computing for NARS, a 6-days training program "Data Analysis using SAS" was organized at CRIJAF, Barrackpore, during 1-6 July, 2013. A professionally diversified group of 33 personnel who participated in the programme includes 18 scientists from CRIJAF, 1 scientist from ERS-NDRI, Kalyani, 1 Assistant Professor from WBUFAS, Kolkata, and one from BAU, Katihar, Technical Assistants and research scholars of CRIJAF. They were trained on various applications of statistical tools and techniques for proper analysis agricultural datasets. Moreover, a two-day workshop on "Software installation-cum-training program" was organized at the DWM Statistical Computational Hub during September 05-06, 2013. 20 nodal officers under the DWM Hub were apprised about the recent versions of the SAS software and their applications.

Participants of the training programme on "Data Analysis using SAS" at CRIJAF, Barrackpore

Project Title	: **Enhancing Land and Water Productivity through Integrated Farming System (Tribal Sub Plan Project)**
Funding Agency	: Institute
Project Personnel	: R. K. Panda, Ranu Rani Sethi, S. K. Rautaray and Rajeeb K. Mohanty

The project has been initiated at Ghurlijore Minor Irrigation Project located in Sundargarh district of Odisha in collaboration with Department of Water Resources, Govt of Odisha. It aims to improve the land and water productivity through augmenting the irrigation infrastructure by utilizing both surface and groundwater resources and develop an integrated farming system in upland areas of Odisha. Minor Irrigation Division, Sundargarh was involved to identify the suitable site/village to carry out the project. During the initial phase, survey was carried out to select the site for engineering intervention.

Survey to identify the location

Initial survey was carried out in the Ghurlijore Minor Irrigation Project site to identify the location/village for assessment and renovation of existing water resource infrastructure. Total design Ayacut is 364 ha (*kharif*) and 210 ha (*rabi*) with the total length of canal is 7866 m out of which right main canal is 7713 m and left main canal is 153 m. Nearly 156 farmers are the members of the group. The details about the village to be benefitted by the project of MIP are given in Table 40.

Table 40 Demography of the project area

Village	Population	SC	ST	GEN
Kendmal	230	21	172	37
Birjaberna	122	0	81	41
Kinjirma	308	103	104	101
Mahuljore	201	62	62	77
Total	861	186 (21%)	419 (49%)	256 (29%)

Assessment and development of water resources

In Ghurlijore Minor Irrigation Project, total area of 200 ha (left: 170 ha and right: 30 ha) is being considered. The duty is 850 ha m^{-3} and canal discharge is 0.2353 cumec, hence, total design discharge at the inlet including 30% loss is $0.306 m^3 s^{-1}$. Similarly for downstream outlet, total area of 170 ha in left ayacut only was considered with canal discharge of $0.2 m^3 s^{-1}$. Hence, design discharge was computed as $0.3\ m^3 s^{-1}$. There are six linkage tanks within the MIP project. Birjaberna Gadhuamunda Linkage Tank was selected for the project under TSP because around 50 families are dependent on the structure and engaged in various agricultural practices and being cooperative farming community. Rainfall distribution in Sundargarh showed that monsoon rainfall is concentrated during the month of June, July, August and September only. Percentage deviation from normal rainfall during 2008-2012 is depicted in Fig. 57. It showed that during the month of April and November, percentage of deviation from normal is more than 100% deviation, where as in the month of March, there is negative deviation from the normal.

Design of inlet, outlet and surplus escape structures in Gadhuamunda Linkage Tank

Design of inlet, outlet and surplus escape has been made based on the depth-capacity curve of the structure (Fig. 58). During the month of August and September, highest water level of 3 m is available in the structure. Similarly during the month of March-May, lowest level of water is maintained in the tank. Considering this, design and constructions are made. For lowland areas, land has been modified by raised and sunken beds (5m width × 51m× 0.4m depth) for bringing diversification in crops.

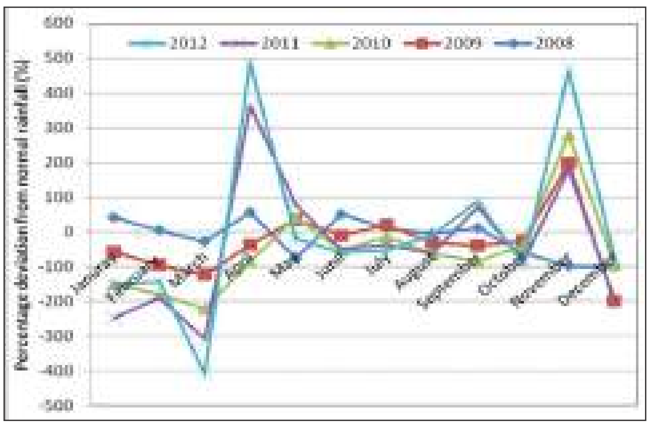


Fig. 57 Percentage of deviation from normal rainfall for Sundargarh (Source: imd.gov.in)

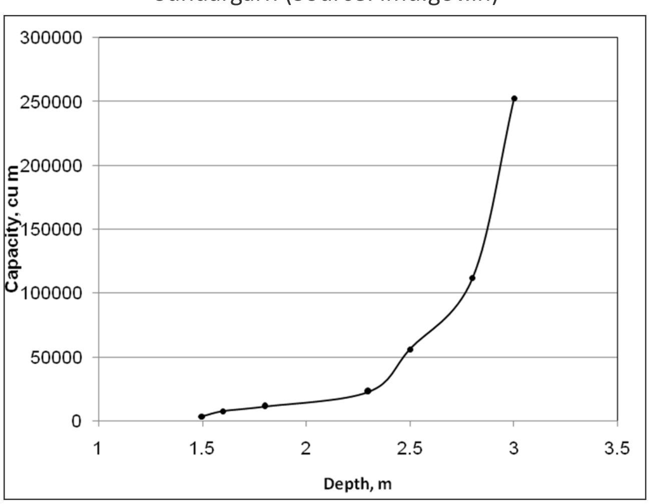


Fig. 58 Depth-capacity curve of Gadhuamund Linkage tank

Capacity building training Programmes

Three training programmes were organized during 28-29 November, 2013, 30 January and 21-22 March, 2014. Total 169 beneficiary farmers from 4 villages were imparted training on "Integrated farming system to enhance the land and water productivity" and "Improved water management techniques for sustainable agriculture".

Training programmes under TSP project

Events / Trainings Organized for Women Empowerment

- A farmers training program on "Improved water management techniques for sustainable agriculture" was conducted at Birjaberna village in Sundargarh district under TSP project during 21-22 March 2014 and was attended by 38 female participants.
- Farmers' training on "Development of climate resilient agriculture through integrated water resources development" and Hands on training on "Drip fertigation technology" and "Vegetable cultivation utilizing groundwater resources" were organized during 9-10th February, 2014 at Parbatiya, Dhenkanal and Gurpara, Cuttack. A total of 130 farmers including 50 women farmers were trained in the training programme.
- Three one-day training programs and two exposure visits were conducted under NAIP project "Sustainable Rural Livelihood and Food Security to Rainfed Farmers of Odisha" 24 women farmers participated in the training programs and 29 women farmers participated in the exposure visit programs. Dr. S. Mohanty organized these programmes.
- A Field visit of 45 B. Tech (4th year) students representing 44% of girl students from Agril. Engg. Dept. of OUAT was organized for exposing them to various farm implements and field experiments at the Institute farm on 3rd May 2013.
- Exhibited achievements of DWM at the exhibition organized under "Technology Week for Women" by DRWA, Bhubaneswar on 27th January, 2014 and showcased various technologies to farm women.
- An exposure cum interaction meet was organized during 26-27 March, 2014 for a group of 37 students, consisting of 64% girls of 4th year B. Sc. from the Dept. of Forestry, OUAT in the Institute. They were exposed to salient activities, outputs and significant achievements of the Institute under on farm water management.

All India Coordinated Research Projects

AICRP on Water Management

Twenty five centres were operating under the All India Coordinated Research Project on Water Management. Salient theme wise research achievements of the AICRP centres during 2013-14 are given below.

Evaluation of pressurized irrigation system

At Bhavanisagar, the experiment revealed that drip irrigation at 80 per cent PE with 30 cm dripper spacing recorded higher rhizome yield of 10027 kg ha^{-1}. It was comparable with drip irrigation at 80 per cent PE with 60 cm dripper spacing. Among the different spacing studied, the spacing of 30 cm x 30 cm recorded higher rhizome yield of 9867 kg ha^{-1} and this was comparable with the spacing of 30 cm x 25 cm. In the cropping system experiment on "Evaluation of micro sprinkler irrigation and nutrient dynamics under green gram-groundnut-chillies based cropping system" indicated that optimum level of irrigation at 60 per cent once in three days through micro sprinkler in groundnut with 100 per cent recommended dose of fertilizer resulted in higher pod yield of 2482 kg ha^{-1}, WUE of 3.534 kg ha-mm^{-1} with a B:C ratio of 3.10.

At Rahuri, the drip irrigation at an alternate day as per ET_c is found to be the best for yield, quality, water saving and efficiency, and storage studies followed by micro-sprinkler irrigation on alternate day as per ET_c. Amongst the INM treatments, the 100% recommended dose of fertilizer (100:50:50 kg ha^{-1} NPK) along with 5 tonnes of FYM ha^{-1} was found to be the best with respect to yield, quality and storage studies followed by 100% recommended dose of fertilizers along with application of vermin-compost on N basis of FYM. In view of the above, it can be concluded that drip irrigation on alternate day as per ETc and 100% RDF along with 5 tonnes of FYM ha^{-1} can be more suitable for growing onion to get higher yield, quality, water saving and WUE and storage.

Also at Madurai, the results of the experiment on evolving appropriate micro irrigation method, irrigation and fertigation regimes for groundnut revealed that micro sprinkler irrigation at 100% PE once in three days registered the maximum pod yield (2844 kg ha^{-1}), WUE (4.59 kg ha-mm^{-1}) and B:C ratio (2.36). Fertigation of 100% RDF (50% P and K as basal, balance NPK as WSF) once in a week from 15 to 90 DAS recorded the highest pod yield (2789 kg ha^{-1}) and WUE (4.55 kg ha-mm^{-1}) in groundnut. Also at Madurai, with regard to land configuration, sowing groundnut in ridges and furrow was best suited for subsurface drip fertigation. Fertigation of 100% N and 50% P and K as WSF with an irrigation regime at 100% PE was the best management to get higher yield (3616 kg ha^{-1}) and B:C ratio (2.25), net return (₹ 64088 ha^{-1}) and water use efficiency (6.38 kg ha-mm^{-1}) in groundnut.

At Navsari, Based on the results of yield and net income recorded during third year, it is concluded that planting of water melon in paired row with drip irrigation + mulching with either black plastic or silver black plastic is necessary for realizing higher net income. The magnitude of increase in fruit yield was 48 % with paired row, drip irrigation and mulching over control along with water saving of about 30 per cent. Also, results revealed that with the adoption of drip irrigation@ 0.6 PEF + black plastic mulching could increase seed yield of pigeon pea to the extent of 70 per cent along with saving of water by about 48 per cent over conventional method of pigeon pea cultivation during *rabi* season. Results also indicated that planting of drip irrigated castor (*rabi*) at a row spacing of 2.4 m and intra row spacing of 1.2 m along with fertigation @ 80 kg N/ha in eight equal splits at an interval of 10 days found to increase seed yield of castor by about 13 per cent along with enhancing WUE.

At Palampur, on mean basis, WUE of cauliflower-capsicum cropping sequence was 20.24 per cent higher in drip irrigation and fertigation than in recommended practices, due to 5.94 per cent higher capsicum equivalent yield (CEY) and 11.82 per cent lower TWU. The B: C ratio (34.76 %) was significantly lower in brinjal crop grown under gravity fed drip irrigation with 75 per cent of recommended NPK fertigation than crop grown with recommended practices. Further, the brinjal crop grown with 75 per cent NPK fertigation under gravity fed drip irrigation resulted in significantly higher water use efficiency (54.04 %) due to lower irrigation water use (31.14 %) than recommended practices.

At Hissar, irrigation applied at PE of 0.8 with drip produced highest seed cotton yield (2674 kg ha^{-1}) over flood and furrow methods irrigation. The water productivity of irrigation was highest when irrigations were applied through drip system at PE of 0.8 over other irrigation methods and schedules. Use of wheat straw mulch either @ 4 or 6 t ha^{-1} resulted in significantly higher seed cotton yield over control, and the yield difference between mulching @ of 4 and 6 t ha^{-1} was not marked.

Management of Rain and other Natural sources of water

At Pantnagar, In late sown wheat, under favourable weather condition wet bed method of crop establishment over moist bed and one additional irrigation at grain filling over irrigation till flowering showed significant effect on grain yield and water productivity. While, under harsh weather conditions, chemical spray at anthesis showed favorable effect to offset the adverse effect of terminal heat stress. The monetary advantages were highly linked to the grain yield. Foliar spray of 2% urea at anthesis stage was the most viable option for higher economic returns. For producing higher grain yield of transplanted rice, irrigation at 1 DADPW showed its superiority over the 3 and 5 DADPW treatments. Crop fertilized with 120 kg N ha^{-1} recorded significantly higher mean grain yield than 90 kg N ha^{-1}. Among the crop establishment methods, flat planting produced higher grain yield than raised beds but raised bed systems of rice transplanting had higher water productivity than the conventional flat method.

At Bilaspur, delaying irrigation up to 3 to 5 days after subsidence of ponded water was best water regime for paddy in clay-loam to clay soil as about 40 - 60 % of irrigation water can be saved without any loss in yield in comparison to continuous shallow submergence (± 5 cm ponded water). Soil moisture regimes significantly influenced the paddy yields. Continuous submergence produced significantly higher grain yield (5.22 t ha^{-1}) of paddy followed by irrigation at 1 DADPW and 3 DADPW. The significant difference in yield due to variable moisture regimes may be attributed mainly due to the temperature shock experienced during different physiological stages of the crop as a result of irrigation at 1 DADPW and 3 DADPW, which ultimately reflected in lower yields in these treatments.

At Madurai, under SRI there was an increase in grain yield ranging from 10.8 to 24.0% in all the technologies demonstrated as well as saving of water. The minimum water saving of 14.0 % was observed with irrigation to 5 cm depth one day after disappearance. Terminal water stress management saved 29.1 water and rotational water supply saved 27.0% water. Invariably the yield levels recorded was higher ranging from 5650 to 6850 kg ha-mm^{-1} in the above demonstrations with improved WUE of 5.70 to 7.20 kg ha-mm^{-1}.

Basic studies on soil- water- plant relationships and their interactions

At Belvatagi, land configuration with 120 cm raised bed showed significantly higher (pooled data) net income (₹ 5426 ha^{-1}) when compared with the other 60 cm raised bed treatment (₹ 3,807 ha^{-1}) and normal sowing (₹ 4,747 ha^{-1}). The interaction between Irrigation treatment 0.8 IW/CPE ratio and 120 cm raised bed configuration treatment recorded higher (pooled data) net income and on par with other treatments *i.e.*, 0.6 IW/CPE ratio and 120cm raised bed (₹ 5,076 ha^{-1}) and also with irrigation treatment 0.4 IW/CPE ratio and 120 cm raised bed (₹ 5,644 ha^{-1}). The B:C ratio on land configuration obtained a higher 2.82 in respect of 0.8 IW/CPE. This result was on par with the irrigation level 0.6 IW/CPE and 0.4 IW/CPE treatments. The interaction effect between irrigation treatment 0.8 IW/CPE ratio and normal bed configuration treatment recorded higher B:C ratio (1.5) with other treatments.

At Jammu, the laser leveling improved the smoothness of land surface which is proved through leveling index and values of application efficiency (7.8%), distribution efficiency (18.8%) and storage efficiency (14.7%) over farmer leveled field in rice-wheat sequence. Laser leveling improved the yield by 20.4% in rice (Basmati) and 20.3% in wheat as compared to farmer levelled field. The experiment has been concluded with recommendations. It was also found that SRI registered the WUE of the order of 1.60 kg ha-mm^{-1} as against the conventional practice which recorded 1.49 kg ha-mm^{-1}. The rice yield also improved by 7% with SRI as compared to traditional method of growing basmati rice.

Water management for different agricultural production system including horticultural and other high value crops.

At Bathinda, the productivity of grapes *cv. Perlette* under poor quality tubewell water irrigation can be increased considerably with the application of either sulphitation press mud or its alternate use with canal water with minimal adverse effect on soil health. Irrigation with tube well water caused detrimental effect on soil quality. Therefore in light textured soils, for optimum yield and desirable quality of grapes with sodic water, application of either sulphitation press mud @ 6 kg/vine on dry weight basis every year after pruning in January or cyclic use of sodic water with good quality canal water (1:1) was recommended to minimize any adverse effect on soil health.

At Dapoli, in arecanut the maximum plant height (5.4 m) was observed under I3 (0.6 PE) as compared to all other treatment. The percent increase in plant height during the year was maximum in treatment I3, whereas it was least in ring method of irrigation. The maximum stem girth (56.50 cm) was observed under I3 (0.6 PE) as compared to all other treatments. Overall percent increase in the stem girth of arecanut was observed to be almost same in all incorporated treatments during last six months. Study resulted in the water saving of 81, 62.5 and 44 per cent, respectively in case of I1, I2, I3 irrigation levels through drip irrigation over ring method of irrigation. The results clearly revealed that the early maturity of arecanut can be achieved with the application of water through drip irrigation as compared to the control (ring method) treatment.

At Jorhat, Among for the *rabi* vegetables, brinjal, the optimum irrigation schedule was found to be 4 cm depth of each irrigation at IW/CPE ratio 1.4 (18 days interval) requiring 4-5 irrigations against the farmers' practice of 10 days interval which required of irrigations of 3cm depth. The practice led considerable irrigation water savings (about 26 per cent) along with the yield increase of 23 per cent. Treadle pump use revealed that 89 mm twin barrel treadle pump of 100mm stroke for areas having water table within 5 m. a discharge of 0.79 to 1.24 LPS is possible and each pump can command a minimum area of 0.25 ha per crop cycle for vegetables and flowers. Benefit cost ratio adopting treadle pump is 5:1. The technology was recommended for the state. The optimum schedule of irrigation for this crop had been found to be at IW/CPE ratio 1.2. Accordingly, four irrigations of 4 cm depth each at an interval of 20 days may be optimum for the crop. The practice led to considerable irrigation water saving (41%) and yield increase (23 %).

At Rahuri, turmeric crop irrigated with 0.7 composite factor along with fertigation of water soluble fertilizer at 75% the recommended dose of fertilizer was found to have higher yield, growth attributes, water and fertilizer use efficiency with its saving further maintaining the soil health. The above treatments are at par with 0.9 CF and 100% RDF through conventional method of fertilization. Under Mula Command, Bt. cotton yield increased by 9.78 to 15.28 per cent over control plot by scheduling of irrigation at 75 mm CPE and recommended dose of fertilizer. The WUE ranged from 27.18 to 31.22 kg ha-cm^{-1} which was higher than control plot.

At Sriganganagar, On the basis of three years of experimentation, it was observed that the fruit yield of tomato increased significantly with increasing level of irrigation water only up to 0.8 ET_c with low tunnel. Further increase in irrigation water did not increase the yield of tomato significantly. In pooled data, the maximum fruit yield of tomato (56.65 t ha^{-1}) was recorded with drip irrigation at 1.0 ET_c (LT) which was at par with the yield received with 0.8 ET_c (LT) and 1.2 ET_c (LT). Also at Sriganganagar, the results revealed that the green, sun dry and oven dry forage yield and plant height of sorghum was influenced by the levels of irrigation significantly. The green forage yield of sorghum increased significantly with every increase in the level of irrigation water up to IW/CPE 0.9 (49.32 t ha^{-1}). Further increase in irrigation level increased in fodder yield but it was statistically not significant. Thus sprinkler irrigation at IW/CPE 0.9 was found optimum irrigation schedule for sorghum. The water expense efficiency (81.86 kg ha-mm^{-1}) was higher in I1 treatment (IW/CPE 0.5) followed by I4 treatment (IW/CPE 1.1) as compared to rest of irrigation treatments tested in the study.

AICRP on Groundwater Utilization

Salient theme wise research achievements of the Nine AICRP Centres on Groundwater Utilization during 2013-14 are given below.

Regional groundwater assessment and modeling

The impact of climate change on evapotranspiration, potential groundwater recharge, groundwater draft and behavior during mid century (2020-2050) and end century (2070-2098) was predicted under A1B scenario. The results indicated that the average annual irrigation water requirement for Ludhiana district in the present time scenario (PTS) (1961-1990) as 1314.5 mm, would decrease by 39.1 and 41.9 % in MC and EC respectively. The average annual groundwater draft estimated as 1113.5 mm in the PTS would decrease by 41.2 and 44.9 % in MC and EC respectively. The total potential groundwater recharge during PTS, MC and EC was 916.9 mm, 759.0 mm and 950.5 mm, respectively.

The study at 15 different locations in the Rahuri Tahsil indicated that the potential zones for the groundwater availability in hard rock region lie at the depth of 78-90 m and 97-110 m from the ground surface.

Jabalpur centre simulated groundwater system in a selected area of alluvial plain of Narmada Basin to predict the groundwater scenario of the selected area (Narsingpur district) by 2025. The water table ranged between 4.30-22.50 m deep from ground surface during pre monsoon and at 2.80-20.72 m during post monsoon season and water table was declining at a rate of 20 cm year^{-1}.

In Amaravathy basin the recharge with respect to rainfall varied from 0-252.11 mm with an average of 80.22 mm.

The pumping tests were conducted at twelve locations *viz.* Gingla, Adwas, Bhalon ka Gura, Hariyav, Jud, Vasa, Vali etc to find out the aquifer parameters in the Jaisamand basin showed transmissivity and storage coefficients ranged from 123.82 m^{2}day^{-1} to 386.94 m^{2}day^{-1} and from 0.000160 to 0.01529, respectively.

Aquifer parameters and effect of climate change on groundwater availability in the Kharun watershed of Mahanadi basin was studied. A pumping test was performed to find out the behaviour of aquifer and the aquifer performance tests were conducted to determine the performance of the well and its efficiency. The aquifer properties for Daldal Seoni (RGI EW-IV and RGI OW-I) ranges from, transmissivity (T) 2.93 to 3.16 m^2 day^{-1} and storativity (S) 3.17 x 10^{-5} to 3.46 x 10^{-5} and for FAE well, IGKV Raipur transmissivity ranges from, 9.37 to 9.51 m^2 day^{-1}.

Aquifer mapping of Uben river basin showed that six, two and six confined aquifer was found at Parab, Ranpur and Evenagar site respectively. It was found that larger the number of confined layers, lesser is the thickness.

Conjunctive use of surface and groundwater

Conjunctive Water Use Planning in Nanakmatta Canal System Command Area of district Udham Singh Nagar of Uttarakhand. in Nanakmatta Canal System Command Area of district Udham Singh Nagar of Uttarakhand for optimal cropping pattern, a linear programming model was used considering the weekly canal water availability, available ground water for irrigation for different running hours of tube wells and irrigation water requirement. Out of the three optimal crop plan, Plan-II gave maximum net return of ₹ 84.8 million utilizing 545.19 ha-m ground water (within 65% of net recharge).

Reconnaissance survey and data collection initiated to estimate spatial and temporal water availability from rainwater, surface sources and groundwater sources in the selected distributary of Lower Bhavani Project command area. Water availability in the dam is highly variable and found to be about 66.5x 10^3 m^3 on an average and varies between 35.8 x 10^3 m^3 to 149.4 x 10^3 m^3.

A study on comparative performance of Water User Association was carried out in three WUAs namely Bijori, Bauchar and Govindgarh of Jabalpur, Narsinghpur and Rewa district respectively in Narmada and Tones basin showed that the mean values of level of participation for 3 WUAs is 6.8, 6.3, 7.9, operation and management 7.2, 6.8, 8.3 for water management level, 7.5, 7.1, 8.3, for financial management 6.5, 7.0, 7.6, , and for organizational linkage 6.7, 7.0, 7.3, respectively. It was concluded that WUA 3 situated in Govindgarh tank command in Tones basin performed best among the three WUAs studied.

Study showed that water productivity of drip irrigated wheat was 1.63 kg m^{-3} whereas it was 0.98 kg m^{-3} in flood irrigated wheat in Narmada basin.

Land use and land cover map of distributaries command in the Mandhar branch canal in Raipur District of Chhattisgarh was prepared by using LISS III images and ERDAS imagine software.

Artificial groundwater recharge

The four layer filter comprising of brick flakes (30-40 mm) of 15 cm thickness, sand grade-I (0.6-2 mm) with 45 cm thickness, pea gravel grade-I (2-6 mm) with 45 cm thickness and angular gravel grade-I (9.8-15.5 mm) with 45 cm with maximum filtration efficiency (88.70%) and discharge (1.73 lps) over other combinations tested as the substitute for coal layer of MPKV recommended four layer filter for recharge of irrigation well.

The impact of artificial recharge structures in recharging groundwater in Vadachitur and Panapatti watershed under Parambikulam-Aliyar Project area in Kinathukadavu block of Coimbatore district in Tamil Nadu was studied. Ground water recharge through rainfall was 2755.83 ha-m. The potential recharge (Rep) was 35.6 mm day^{-1} for percolation pond and 17.8 mm day^{-1} for check dams. The storage structures in the watershed alone contributed 11.5% of the annual rainfall as potential recharge; whereas 6.5% of the annual rainfall actually recharged the groundwater table in the entire catchment area.

Impact of rainwater harvesting-cum-groundwater recharging structure micro-watershed in Wakal River basin in Rajasthan showed that average recharge rate was 10.34 cm day^{-1}, 7.63cm day^{-1}, 7.46 cm day^{-1} and 7.39 cm day^{-1} for the year 2010, 2011, 2012 and 2013 respectively, with net recharge volume 7873.20 m^3, 6131.06 m^3, 3933.66 m^3 and 4056.57 m^3 respectively.

At Junagadh, Gujarat, recharge techniques were evaluated and resultant vertical flow velocity of geological formation below check dam was estimated at 0.0058 m-day^{-1}. Total recharge from water spread area of 5954 sq.m was determined as 6215.9 m^3. The runoff for 20 years return period from catchment of check dam was found as 35664.1 m^3. Storage capacity of check dam is 4539 m^3 and excess runoff was estimated at 24909 m^3.

Groundwater pollution

At Budha Nala waste water drain near Ludhiana city, concentration of arsenic, manganese, lead, boron, iron and calcium in groundwater sample during the pre-monsoon and post monsoon season was found out to higher than the maximum permissible limit of 0.01, 0.1, 0.01, 0.5, 0.3 and 75 mg L^{-1} respectively. Heavy metal pollution index calculated was found to be 113 and 109 for pre-monsoon and post-monsoon season, respectively which is above the critical pollution index.

Assessment of groundwater quality in Bhatinda district of south west Punjab showed that during the pre-monsoon season, 12 % groundwater samples were fit, 28% were marginally fit and 60% were unfit for irrigation, based on sodicity and salinity. During monsoon, on the basis of sodicity and salinity, 21 % groundwater samples were found fit, 39% were marginally fit and 40% were unfit for irrigation in Bathinda district, whereas, during the post-monsoon season, 25 % groundwater samples were found fit, 54% were marginally fit and 21% were unfit for irrigation.

Three industries *i.e.* Indian Glycol limited (IGL), Cheema Paper mill and Multiwal pulp and Board paper mill in Kashipur industrial cluster of Uttarakhand State showed that effluents had higher TDS, alkalinity, BOD, Cod beyond the permissible limit contaminating the groundwater at downstream side of this industrial cluster.

Groundwater quality in Jabalpur, Mandla, Dindori and Seoni districts of Madhya Pradesh was assessed for pH, EC, NO_3^-, total hardness, Ca, Mg, Na, K, CO_3, HCO_3, Cl, P, micronutrient and heavy metals and compared with the data obtained from records (1970-75) of Water Resources Department of M.P.

Water samples collected from Amaravathy river basin from open wells, bore wells and dug cum bore wells showed that most of the samples come under high salinity class (C_3) followed by medium salinity class (C_2), very high salinity class (C_4), low salinity class (C_1) during summer, south west monsoon, north east monsoon and winter season, based on USSL classification.

The groundwater of Rajsamand district was found to be Na-Mg-Ca and Cl-HCO_3-SO_4 type. Hence the dominated salt types in groundwater might be chlorides, bicarbonates and sulphates of sodium, calcium and magnesium. On the basis of salinity it was found that the quality of groundwater in Rajsamand block was worst affected followed by Railmagra and Nathdwara blocks.

On the basis of characterization of wastewater and accumulation of heavy metals in the wastewater irrigated vegetable crops it was found out that Cu, Zn, Cd and Cr accumulation was the major problem at Kota for spinach, cabbage, cauliflower and garlic crops grown with wastewater irrigation. At Bundi Cu and Cd contamination was the main limiting factor for the safe use of wastewater for irrigation in vegetables. The wastewater of Anta and Jhalawar cities was comparatively better for vegetable production except Cd and Cr build-up in leafy vegetables (spinach and cabbage). The spinach crop at all the four most polluted site of Haroti region grown with wastewater irrigation found to accumulate cadmium more than the maximum permitted levels prescribed by WHO.

The study on wastewater irrigation at Patna bye-pass area has revealed that sewage sludge treated soils were rich in DTPA extractable micronutrients (*viz.* Zn, Cu, Fe and Mn) and heavy metal cations like Cd, Cr, Ni and Pb with maximum accumulation at the point of discharge. The study also revealed that concentration of Zn, Cu, Fe and Mn were in the range of 1.08 - 5.60, 5.31 - 37.6, 10.25 - 24.7 and 7.05 - 15.9 ppm, respectively and Cd, Cr, Ni and Pb varied in the range of 0.02 - 3.13, 0.02 - 0.38, 0.14 - 4.8 and 0.38 –1.02 ppm, respectively. Leafy vegetables *viz.*, poi and red spinach accumulated most of trace metal cations to the greater extent in comparison to other crops.

In Saurashtra Region in total 327 groundwater samples were collected from open wells and tube wells from 5 districts, Jamnagar, Rajkot, Surendranagar, Junagadh and Porbandar for suitability of groundwater for drip irrigation. The average EC and of the groundwater in Jamnagar, Rajkot, Surendranagar, Junagadh and Porbandar district were 2.68, 2.25, 3.43, 2.09 and 3.17 dS m^{-1} and total hardness 49, 46, 86, 50 and 55 mg L^{-1} respectively.

Transfer of technology

Technology developed for rainwater harvesting, groundwater recharge, water management aspects and agricultural pumps were demonstrated to the farmers and other beneficiaries. All the nine centres organized farmers' training, trainers' trainings, delivered TV or Radio talks, delivered lectures in extension programmes, participated in Krishi-Mahostav, Agriculture Science Fair, and Kisan Melas and interacted with farmers in Kisan Gosthi. Junagadh centre equipped 70 tribal farmers with sprinkler irrigation sets to use irrigation water judiciously and to reduce groundwater draft. A total of 122 tribal farmers from Nilgiri and Coimbatore districts were benefited through training on water management in hilly areas and demonstration of micro irrigation. Udaipur centre renovated existing open wells and benefitted 19 tribal families. Raipur centre equipped 5 tribal families with lift irrigation, sprinkler and drip irrigation system to improve water management aspects in *rabi* season.

The scientists working in the scheme has published nine research papers, three bulletins/manuals, eight popular articles, and three books/book chapters. They presented twenty seven papers in national and international conferences/seminars, attended eight training programmes on advanced water management topics. Two best paper presentations were awarded to scientists of Rahuri and Junagadh centres. Best teacher award was conferred to DR. H. D. Rank for the year 2011-12 instituted by JAU, Junagadh and ICAR.

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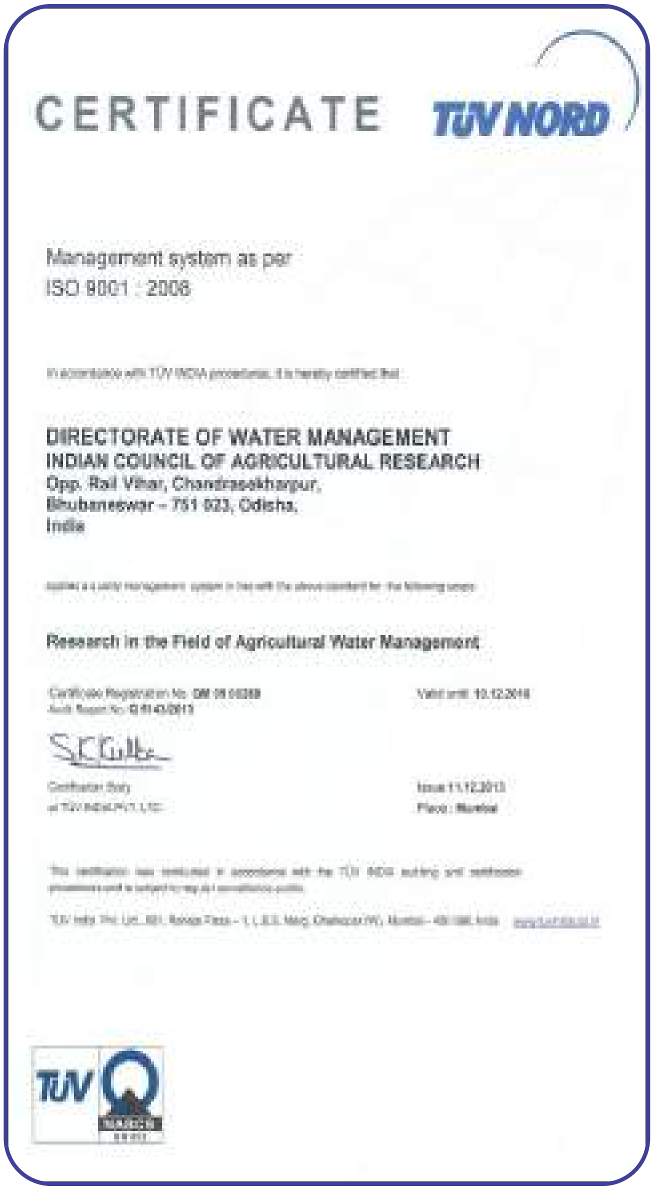
दास, एम०, वर्मा, ओ.पी., अश्वनी कुमार (२०१४) तकनीकी पुस्तिका। जल प्रबंधन निदेशालय (भा कृ अनु प), भुवनेश्वर, ओडिशा, भारत।

C. BOOKS/ TRAINING MANUAL

Roy Chowdhury, S., Brahmanand, P.S., Ghosh, S., Mohanty, R.K., Jena, S.K. and Kumar, A. 2013. Bio-drainage for reclamation of waterlogging in high rainfall deltaic areas. Directorate of Water Management, Chandrasekharpur, Bhubaneswar-751023, Odisha, India, P:142.

Awards / Honours / Recognitions

- DWM has been recognised as a ISO: 9001-2008 Certified Institute for excellence in Research in the field of Agricultural Water Management.



CERTIFICATE TÜV NORD

Management system as per
ISO 9001 : 2008

DIRECTORATE OF WATER MANAGEMENT
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Opp. Rail Vihar, Chandrasekharpur,
Bhubaneswar – 751 023, Odisha,
India

Research in the Field of Agricultural Water Management

- Dr. A.K. Thakur, Senior Scientist received USIEF's Fulbright-Nehru Senior Research Fellowship 2012-13.

- Dr. P.S.B. Anand, Senior Scientist was awarded with Guinness World Record in Longest Speech Marathon for delivering extempore talk for continuous 33 hours and 46 minutes on 'Science and Technology, Society and Human Development'.

- Dr. Madhumita Das, Principal Scientist has been awarded 2012 - 2013 Alumni Award, United States India Education Foundation (USIEF), New Delhi.

- DWM Proficiency Award for the year 2012 was given by Director, Dr. Ashwani Kumar to different categories of staff (Scientific, Administrative, Technical and Supporting) on the DWM foundation day celebration (14^{th} May) for their significant achievements. The recipients of the award in different categories were as follows:

Scientific Category	
1.	Dr. G. Kar
2.	Dr. R. K. Panda
3.	Dr. S. K. Rautaray
4.	Dr. S. Raychaudhuri
Technical Category	
1.	Mr. D.U. Patil
Supporting Category	
1.	Mr. B.N. Naik

- Dr. P.S.B. Anand, Senior Scientist has been awarded with GCBR Award for popularization of Biological Sciences - 2013 instituted by Gugly Centre for Biological Research, Bhubaneswar.

- Dr. R. R. Sethi, Scientist has been awarded Doctor of Philosophy (Ph.D) in the field of Civil Engineering, faculty of Engineering and Technology from Uttar Pradesh Technical University, Lucknow on 4^{th} September 2013 for her thesis 'Development of regional scale groundwater recharge model for irrigation use'.

- Dr. S.K. Jena, Principal Scientist has been awarded J.S.P. Yadav Best Paper Award 2010-12 by Indian Society of Coastal Agricultural Research, Canning Town, West Bengal for the paper entitled Jena, S.K., Sahoo, N., Roy Chowdhury,S., Mohanty,R.K., Kundu,D.K., Behera,M.S., Patil,D.U. and Ashwani Kumar.2011.'Reclamation of coastal waterlogged wasteland through bio-drainage' published in J Indian Soc. Coastal Agric. Res.29.57-62.

- Dr. Madhumita Das, Principal Scientist has been awarded Best Paper Presentation award for her paper entitled 'Utilization prospect of various wastewater sources in cropping', presented at International Conference on Water Quality and Management for Climate Resilient Agriculture organized by ASM foundation, New Delhi and Jain Irrigation System Pvt. Ltd., Jalgaon, India during May 28-31, 2013 in Jalgaon.

- Dr. R.C. Srivastava, Principal Scientist received Best Paper Award at International Conference on Water Quality and Management for Climate Resilient Agriculture organized by ASM foundation, New Delhi and Jain Irrigation System Pvt. Ltd., Jalgaon, India during May 28-31, 2013 in Jalgaon.

- Dr. A.K. Nayak, Senior Scientist has been awarded Best Paper Presentation Award for the paper entitled '*Jal-jeev palan ke liye sthanik nirnay samarthan pranali*' at National seminar on '*Parvatiya Kshetron nein jal-jeev palan vividhikaran*' organized by Directorate of Coldwater Fisheries Research, Bhimtal, Uttarakhand during 23-24 September 2013.

- Dr. Madhumita Das, Principal Scientist has been awarded Best Paper Presentation award for her paper entitled 'Das, Madhumita, Verma, O. P., Patri, D., Nayak, A. K. and R R Sethi (2013) Water quality appraisal and perspective of use in agriculture', presented at National Seminar organized by Odisha Bigyan Academy, ISCA Bhubaneswar chapter on 23 – 24 November 2013.

- Dr. S. Mohanty, Senior Scientist received Best Presentation Award at 'National Workshop on Achieving Food Security in the Face of Climate Variability' held at Bhubaneswar during 26th November 2013.

- Dr. M. Raychaudhuri participated in ICAR Sports Meet for Eastern Zone 2013 at CRRI Cuttack held during 18th to 22nd October 2013 and won Women Chess Championship and also became Women Table tennis Runners up.

- Dr. M. Das, Principal Scientist was appointment as an external examiner for evaluation of Environmental Science (theory paper) by OUAT, Bhubaneswar.

- Dr. S. Raychaudhuri, Principal Scientists has been appointed as Paper setter for External Theory Examination, 2012 – 13 for course Fundamentals of Geology and Soil Science (NRM 112).

- Dr. S. Raychaudhuri, Principal Scientists guided Mr Arnoud van Spronsen, a Bachelor degree student of International Land and Water Management program, Wageningen University, The Netherlands for his internship at DWM, Bhubaneswar during January – March, 2014.

- Dr. S. Raychaudhuri and Dr. M. Raychaudhuri, Principal Scientists has been appointed as Technical Editor of Vision 2035 document on 'Food and Agriculture' of TIFAC, DST, GOI.

- Dr. K.G. Mandal, Senior Scientist has been elected as Recorder for the Section of Agriculture and Forestry Sciences of The Indian Science Congress Association (ISCA) for the year 2014-15 & 2015-16 i.e. 102nd and 103rd Sessions of the Indian Science Congress.

- Dr. S.K. Jena, Principal Scientist has been nominated by ICAR as Member, Institute Management Committee (IMC) of ICAR Research Complex for NEH Region, Barapani, Meghalaya.

- Dr. S.K. Jena, Principal Scientist has been nominated by ICAR as Chairman, Assessment Committee of CRIJAF, Kolkata.

- Dr. S.K. Jena, Principal Scientist has been Invited as speaker during NAAS brain storming session 'Bio-drainage: An Eco-friendly tool for combating waterlogging' at NAAS Hqr., New Delhi.

- Dr. S. Roy Chowdhury, Principal Scientist has delivered a policy paper at NAAS brain-storming session 'Bio-drainage: An Eco-friendly tool for combating waterlogging'.

- Dr. S. Roy Chowdhury, Principal Scientist has delivered an invited lead paper entitled 'Physiological strategies for improved livelihood in flooded and waterlogged areas' at National Conference of Plant Physiology held at Junagad during 13th-16th December, 2013.

- Dr. K.G. Mandal, Senior Scientist has been reappointed as one of the Editorial Board Members up to two additional years from March 5, 2014 for the Journal of Sustainable Bioenergy Systems (JSBS) of the Scientific Research Publishing Inc., USA.
- Dr. S. Roy Chowdhury, Principal Scientist has been selected as editor for Indian Journal of Plant Physiology (Springer), ISPP, New Delhi.

Visit Abroad on Deputation

- Dr. Amod K. Thakur, Senior Scientist visited Cornell University, Ithaca, NY, USA during 15th March to 14th November, 2013 under Fulbright-Nehru Senior Research Fellowship 2012-13 and worked on project entitled 'Understanding the physiological mechanisms of assimilate partitioning and nitrogen uptake during grain-filling in wheat under different plant densities'.

- Dr. Ashwani Kumar, Director, DWM; Dr. S. Raychaudhuri, Dr. M. Raychaudhuri and Dr S.K. Rautaray, Principal Scientists visited Germany and The Netherlands during 13th to 27th September 2013 under the New Indigo project, 'Reuse options for marginal quality water in urban and peri-urban agriculture and allied services in the gambit of WHO guideline'(REOPTIMA)' sponsored by DST, Government of India.

- Dr. P.S. Brahmanand, Senior Scientist visited The Netherlands during10-12 September 2013; USA (Florida and Nebraska) during 4-10 November, 2013; and Ethiopia during 25-27 March 2014 to attend Workshop of International Collaborative Project of ICAR and University of Nebraska, USA entitled 'Global Yield Gap and Water Productivity Atlas (GYGA)'.
- Dr. D. K. Panda, Senior Scientist visited University of Colorado, USA for 3-months training during 1 October to 31 December, 2013 as a part of the ICAR Challenge Research Project 'Impact of Climate Variability and Anthropogenic Factor on Groundwater Resources of India', associated with the Lal Bahadur Shastri Outstanding Young Scientist Award, 2011.

- Dr. P. Panigrahi, Scientist (SS) visited Cornell University, New York, USA during December 7, 2013 - March 6, 2014 for 3-months training on 'Sensor Based Application Including Bio-indicators' under NAIP, ICAR, New Delhi.

- Dr. G. Kar, Principal Scientist; Dr. K.G. Mandal and Dr. P.S.B. Anand, Senior Scientists visited Colombo, Sri Lanka for participation and presented their research papers in the International Conference on Agriculture and Animal Sciences (AGRIANIMAL 2013) organized by International Centre for Research and Development (ICRD) at Colombo, Sri Lanka during 8-9 July 2013.

RAC/ IRC/ AICRPs Meetings

QUINQUINNIAL REVIEW TEAM (QRT) MEETING

The concluding meeting of 4th QRT of the institute was held from 24th to 26th July, 2013 at DWM, Bhubaneswar under the chairmanship of Dr. G.B.Singh, former Deputy Director General (NRM), ICAR. Other QRT members who attended the meeting were Prof. Jaswant Singh, Prof. S. Raman, Dr. Debaraj Panda. In the meeting the activities of different programme of the DWM and its co-operating centres were deliberated. The draft report was prepared and discussed for its finalization. The team also visited on-farm research sites of DWM under NICRA project on 25th July, 2013 at Gurpara, Cuttack and Parbatiya, Dhenkanal and appreciated the drip-fertigation technology which was implemented to develop climate resilient agriculture. Dr. Gouranga Kar, Principal Scientist, DWM and member secretary, QRT organized the meeting and visit.

QRT team visiting a on farm research site of DWM at Dhenkanal district, Odisha

RESEARCH ADVISORY COMMITTEE (RAC) MEETING

The second meeting of sixth Research Advisory Committee of Directorate of Water Management was organized on 12 and 13 December 2013 at DWM Bhubaneswar. The meeting was chaired by Dr. S.R. Singh, former Vice Chancellor, RAU, PUSA and Project Director, DWMR, Patna, and held at Directorate of Water Management, Bhubaneswar. The meeting was attended by Chairman, RAC Dr. S.R. Singh, Former VC, RAU PUSA and PD, DWMR, Patna, and other members, Dr.S.D. Sharma, Ex-Dean (Agric. Engg.) OUAT, Bhubaneswar, Dr. S.K. Tripathi, Professor, IIT, Roorkee and Dr. Ashwani Kumar, Director, DWM, Bhubaneswar along with the scientists of Directorate of Water Management, Bhubaneswar. At the beginning of the meeting, Dr. Ashwani Kumar, Director, DWM, welcomed the Chairman and all other members. Dr. S.R. Singh, Chairman in his opening remark elaborated the need for storage of part of 1179 BCM water at appropriate sites for use in agriculture without adversely affecting the environmental flows in different rivers. Director presented the progress and achievements of the institute and AICRPs during 2012-13 followed by presentation of work under different programmes and AICRPs by programme leaders and Principal Scientists of AICRPs. The Chairman and other members appreciated the work of the scientists and the achievements made by DWM, AICRP on WM as well as AICRP on GWU projects during the said period.

2nd meeting of 6th RAC

INSTITUTE RESEARCH COUNCIL (IRC) MEETINGS

During the year 2013-14, Institute's Research Council (IRC) meeting was organized 14-15th February, 2014. The results of the on-going research projects were presented and deliberated in the meeting and new research project proposals were presented and discussed. The meeting was organized by Dr. R.C. Srivastava, Principal Scientist and Member Secretary, IRC and was chaired by Dr. Ashwani Kumar, Director, DWM, Bhubaneswar. All the scientists participated in the meeting. During the meeting RPF III of seven projects, RPF II of 15 projects were presented which was approved after through discussion. One new project was presented and was approved.

BIENNIAL SCIENTISTS' MEET OF AICRP-WM and AICRP-GWU

The Biennial Scientists Meet of All India Coordinated Research Project on Water Management was organized at Navasari Agricultural University, Navsari from 29th July 2013 to 1st August 2013. The inaugural session of the Biennial Workshop was held in the Central Examination

Hall of the University. The Hon'ble Minister of Agriculture, Food and Civil supplies, Consumer affairs, Forest and Environment, Govt. of Gujarat, Mr. Govinbhai Patel was the Chief Guest of the meeting. Dr. A.K. Sikka, DDG, NRM (ICAR), and Shri. Mathurbhai Savani, President, Saurashtra Jaldhara Trust graced the occasion as Guests of Honour. Dr. A.R. Pathak, Hon'ble Vice Chancellor, Navsari Agricultural University presided over the function. The session commenced with lighting of the lamp by the Chief Guest and Guests of Honour followed by Saraswati Banadana and Krishi Geet. Dr. R.G. Patil, Head, SWMRU, NAU and Chief Scientist, AICRP on Water Management welcomed the delegates and also briefed the house about the various activities of the University.

The 4-day workshop reviewed the progress of the work carried out on different themes of AICRP on Water Management and AICRP on Groundwater Utilization like regional assessment of water availability under selected command area, Water management of different cropping systems, Evaluation of pressurized irrigation system for horticultural and high value crops, Conjunctive use of canal and underground saline water, Rainwater management in high rainfall areas, Enhancing

AICRP Workshop

productivity by multiple-use of water, groundwater recharge techniques, groundwater pollution, groundwater assessment for 2013-14. The technical programme was finalized for next year for 25 AICRP on Water Management centres and 9 Groundwater Utilization centres for efficient use of irrigated water in well defined themes of the project.

List of Completed / Ongoing / New In-House Projects

A. LIST OF IN-HOUSE RESEARCH PROJECTS COMPLETED DURING 2013-14

Sl. No.	Project Code	Project Title	PI Name
1.	DWM/09/138	Micro-catchment water harvesting in the rainfed ecosystem of humid region	Dr. A. Mishra
2.	DWM/09/140	Assessment and development of water resources for diversified agriculture in waterlogged high rainfall area	Dr. R. K. Panda
3.	DWM/09/143	Development of water and energy efficient integrated farming system model for the rainfed fa rmers	Dr. S. K. Rautaray
4.	DWM/10/145	Sustainability of water Users associations (WAUs) and effect of participatory irrigation management (PIM) on agriculture and system performance	Dr. S. Ghosh
5.	DWM/10/146	Ground water modeling to determine the safe yield of coastal aquifer	Dr. R. R. Sethi
6.	DWM/10/148	Assessment of water logging and land use system in different coastal district of Orissa using remote sensing and GIS	Dr. A. K. Nayak
7.	DWM/11/150	Ground water recharge guidelines for agro-ecological Region No. 8 with hard rock Geology	Dr. M. J. Kaledhonkar

B. LIST OF IN-HOUSE ONGOING RESEARCH PROJECTS DURING 2013-14

Sl. No.	Project Code	Project Title	PI Name
1.	DWM/10/147	Conservation agriculture practices in maize based cropping system with special emphasis on nutrient and water availability for the rainfed sub -humid agro-ecosystem	Dr. P. K. Panda
2.	DWM/11/151	Performance evaluation of drip irrigated mango (*Mangifera indica* L) under deficit irrigation	Dr. S. Mohanty
3.	DWM/11/152	Impact of wastewater effluents on soil productivity constituents and its prospect of utilization in farming	Dr. M. Das
4.	DWM/11/153	Effect of dry spell occurrence on reduction in paddy yield and optimum design of rain water harvesting structure for its mitigation	Dr. S. Mohanty
5.	DWM/12/154	Extreme climate effects on major cropping systems of Odisha	Dr. D. K. Panda
6.	DWM/12/155	Water budgeting in high value shrimp monoculture and carp poly culture under varying intensification levels	Dr. R. K. Mohanty
7.	DWM/12/156	System of Rice Intensification: Studies on water management, micronutrient uptake and crop rotation	Dr. A. K. Thakur
8.	DWM/12/157	Development of runoff recycling model for production and profit enhancement through alternate land and crop management practices	Dr. P. K. Panda
9.	DWM/12/158	Evaluating deficit irrigation under drip system for rice based cropping sequence in canal command area	Dr. P. Panigrahi
10.	DWM/12/159	Identification of suitable crops for wastewater irrigation	Dr. Sachidulal Raychaudhuri

Sl. No.	Project Code	Project Title	PI Name
11.	DWM/12/160	Development of Agricultural Water Management Portal (AWMP)	Dr. A. K. Nayak
12.	DWM/12/161	Design and development of small filters for reducing undesirable substances in poor quality water at farmers level for safe irrigation in peri urban areas	Dr. M. Raychaudhuri
13.	DWM/12/162	Delineation of waterlogged areas in eastern India and formulating strategies for fitting in suitable crops and aquaculture through harnessing agro-biodiversity for enhancing water productivity	Dr. Somnath Roy Chowdhury
14.	DWM/12/163	Eco-efficient agricultural practices for enhancing nutrient use efficiency of rice (*Oriza Sativa*) under waterlogged ecosystem	Dr. P. S. Brahmanand
15.	DWM/12/164	Development of technological options for comprehensive water resource management in non exploration zone (CRZ III) of coastal Odisha	Dr. R. R. Sethi

C. LIST OF IN-HOUSE NEW RESEARCH PROJECTS UNDERTAKEN DURING 2013-14

1.	Development of decision support system for conjunctive use of surface and ground water	Dr. O. P. Verma

Human Resource Development

Participants	Name of the Seminar / workshop / training / conference	Organized by	Date of events
All Scientists of DWM	Seminar on ISO 9001-2008 Certification by Chief Consultant, AQL Systems & Consultants, Kolkata	DWM, Bhubaneswar	April 6, 2013
Dr. Ashwani Kumar	International 'Workshop on the Eastern Gangetic plains'	IWMI, New Delhi	April 7-8, 2013
Dr. R.C. Srivastava Dr S. Raychaudhuri Dr. M. Raychaudhuri Dr. S. Mohanty	India Water Week 2013	MOWR, Govt. of India at New Delhi	April 8-12, 2013
All Scientists of DWM	Workshop on 'Rubber Dam Technology for Agricultural Water Management'	DWM, Bhubaneswar	May 14, 2013
Dr. R.C. Srivastava Dr. M. Das	International Conference on 'Water Quality and Management for Climate Resilient Agriculture'	ASM foundation, New Delhi and Jain Irrigation System Pvt. Ltd., Jalgaon, India	May 28-31, 2013
Dr. S. Raychaudhuri	National Workshop on 'Water Resource Management for Sustainable Development'	Institute of Advance Technology and Environmental Studies (IATES)	May 29-31, 2013
Dr. Ashwani Kumar Dr. P.S. Brahmanand	NAIP Pre-Commercialization workshop on 'Flexi rubber check dam for watershed application'	DWM, Bhubaneswar and CIRCOT, Mumbai and NAIP, New Delhi	May 30, 2013
All Scientist of DWM	Training Programme on Internal Auditing for Quality Management - ISO 9001-2008 Certification	AQL Systems & Consultants, Kolkata and DWM, Bhubaneswar	June 13-15, 2013
Dr. R. K. Panda	Agri-Business Camp	NRC on Orchid, Gangtok, Sikkim	June 24, 2013
All Scientists of DWM	Inception Workshop on Evaluation of IWMP Watershed	DWM, Bhubaneswar	June 25, 2013
Dr. R. K. Panda	Agri-Business Camp	NIRJAFT, Kolkata	June 26, 2013
Dr. M.K. Sinha	Field Investigators training on Field Survey, Electronic Compilati on & Analysis of Data	ICAR-RCER, Patna	July 1-7, 2013
Dr. M.K. Sinha	Project Advisory Meeting of Village Dynamics Studies Project	ICAR-RCER, Patna	July 9, 2013
Dr. A.K. Nayak	International Training programme on 'Flood Risk Mapping, Modeling and Assessment using Space Technology'	CSSTEAP, UNOOSA/UN-SPIDER, UNESCAP and IWMI at IIRS, Dehradun	July 22-26, 2013

All Scientists of DWM	National Workshop on 'Water quality issues, opportunities and socio-cultural concerns of wastewater use in agriculture' under USIEF Alumni Award 2013	DWM, Bhubaneswar	August 7-8, 2013
Dr. Ashwani Kumar Dr. G. Kar Dr. P.S. Brahmanand Dr. A.K. Nayak	Sensitization Workshop on 'Enhancing Water Use Efficiency in Yamuna Basin'	NRM Division, ICAR and DWM, Bhubaneswar	August 30, 2013
Dr. D.K. Panda	Workshop on 'Water Use Efficiency of Irrigation Projects'	CWC, New Delhi	September 10, 2013
Dr. P. Nanda Dr. M.K. Sinha	Workshop on 'Emerging issues in South Asian Agriculture'	ICRISAT, Hyderabad	September 17, 2013
Dr. D.K. Panda	Workshop on 'NAIP Project Evaluation'	IASRI, New Delhi	September 17-18, 2013
Dr. R.R. Sethi	Advisory committee meeting of projects under Decision support system and water productivity thematic area of NFBSFARA	WTC, New Delhi and PAU, Ludhiana	September 17 and 20, 2013
Dr. P. Nanda Dr. M.K. Sinha	4th Annual Review meeting on Transformation of rural economies in south Asia: Insights from Village Dynamics Studies	ICRISAT, Hyderabad	September 18-19, 2013
Dr. A.K. Nayak	National Seminar on '*Parvatiya kshetron mein jaljeev palan vividhikaran*'	Directorate of Coldwater Fisheries Research, Bhimtal, Uttarakhand	September 23-24, 2013
Dr. R. K. Panda	Annual workshop for ZITMC (EZ) and Agri- Investor Meet	NIRJAFT, Kolkata	September 26-27, 2013
Dr. P.S. Brahmanand	*Dwiteeya Akhila Bharatiya Rajbhasha Sammelan*	KIIT, Bhubaneswar	October 18-20, 2013
Dr. S. Raychaudhuri Dr. M. Raychaudhuri	National Seminar on 'Developments in Soil Science: 2013' Indian Society of Soil Science, 78th Annual Convention, at CAZRI, Jodhpur, Rajasthan	ISSS, New Delhi	October 23 -26, 2013
Dr. G. Kar Mr. S.K. Das	Workshop on 'Implementation of Management Information System (MIS) including Financial Management System (FMS)'	ICAR at Ranchi, Jharkhand	October 31, 2013
Dr. R. K. Panda	Launching workshop of Business Planning & Development Unit	CIFA, Bhubaneswar	November 02, 2013
Dr. G. Kar	International Conference on climate change and implications for water resources and nutritional security	International Life Science Institute, India and Centre for Integrated Modeling of Sustainable Agriculture and Nutritional Security,Washington DC at Bengaluru, India	November 15-16, 2013

Dr. M. Das	National Seminar on Innovations in Science and Technology for Inclusive Development	Odisha Bigyan Academy, ISCA Bhubaneswar chapter at Bhubaneswar	November 23 – 24, 2013
Dr. S. Mohanty	National Workshop 'A chieving Food Security in the Face of Climate Variability'	GCBR, Bhubaneswar	November 26, 2013
Dr. M.K. Sinha	ICAR-ICRISAT Trainin g program on Adoption and Impact Assessment for Research and Development Project	ICRISAT, Hyderabad	November 27-30, 2013
Dr. M.K. Sinha	ICAR-ICRISAT Training program on 'Small farm value chain and market linkages'	ICRISAT, Hyderabad	December 1-4, 2013
Dr. K.G. Mandal	Showcasing of Agricultural Technologies under NAIP Project on Mobilizing of Mass Media Support for Sharing Agro-information	ICAR-RC for ER, Patna & Directorate of Knowledge Management in Agriculture (ICAR), New Delhi	December 6-7, 2013
Dr. S.K. Jena	10th National Symposium on 'Managing Natural resources for enhancing agricultural and allied productivity in coastal region under changing climate'	ISCAR at CSSRI RRS, Bharuch	December 11-14, 2013
Dr. S. Roy Chowdhury	National Conference of Plant Physiology on 'Current Trends in Plant Biology Research'	ISPP, New Delhi, GAU and DGR, Junagad	December 14-16, 2013
Dr. R. K. Panda	Agri-business Development Meet	NRC on Yak, Dirang, Arunachal Pradesh	December 17, 2013
Dr. S. Roy Chowdhury	Brain storming session on 'Biodrainage: an Eco-friendly Tool for Combating Waterlogging'	NAAS, New Delhi	December 19, 2013
Dr. P. Nanda	Odisha Environment Congress	Centre for Environmental Development & Human Development Foundation, Odisha	December 23-24, 2013
Dr. Ashwani Kumar Dr. R.R. Sethi	Workshop of Aus-Aid project 'Improving the capacity of Indian State level water authorities on systemic and adaptive governance to climate change'	Irrigation management Institute (IMTI), Kota and University of Melbourne, Australia at Jaipur, Rajasthan.	February 6-7, 2014
Dr. M. Das Dr. P.S. Brahmanand	National Agricultural Fair cum Exhibition 'Krishivasant-2014'	CICR, Nagpur	February 9-13, 2014
All scientists of DWM	National workshop on 'Rubber dam technology'	DWM, Bhubaneswar	February 10-11, 2014
Dr. S. Roy Chowdhury	'World Congress on Agroforestry 2014'	ICAR, New Delhi and World Agroforestry Center (ICRAF), Nairobi, Kenya	February 10-14, 2014

Dr. M. Das Dr. P. Nanda Dr. S. Mohanty Dr. A.K. Nayak	International Symposium on 'Integrated Water Resources Management'	CWRDM, Kozhikode, Kerala	February 19-21, 2014
Dr. G. Kar	Indo-US bilateral workshop on 'Adaptation of rural communities to climate change: Bridging the gap between academia and community workers and identifying research needs'	Columbia University, USA at ATREE, Bengaluru	February 20-21, 2014
Dr. Ashwani Kumar Dr. M. Raychaudhuri Dr. R.R. Sethi	48th Annual Convention of ISAE and Symposium on Engineering Intervention in Conservation Agriculture	Indian Society of Agricultural Engineers and College of Technology and Engineering, MPUAT, Udaipur, Rajasthan	February 21-23, 2014
Dr. R.C. Srivastava	Seminar on 'Development of fisheries in water deficient regions'	Fisheries Technocrats Forum, Chennai	February 25-26, 2014
Dr. P. K. Panda	National Seminar on 'Enhancing Water Productivity through Weed Management'	BHU, Varanasi	March 10-11, 2014
Dr. M. Raychaudhuri	Seminar on 'Integrated Nutrient Management for sustainable Crop Production' during 35th Annual Convention of Bhubaneswar Chapter of ISSS	Bhubaneswar Chapter of Indian Society Soil Science & OUAT, Bhubaneswar	March 14, 2014
Dr. R.K. Mohanty Dr. K.G. Mandal Dr. S. Mohanty	State Level Workshop on Livelihood Improvement Through Agriculture, Fisheries and Livestock Intervention in Odisha, NAIP Livelihood Project (Component 3)	CIFA (ICAR) & OUAT, Bhubaneswar	March 21, 2014
Dr. M. Raychaudhuri Dr. D.K. Panda	Workshop on 'Augmentation and Conservation of Groundwater Resources of Odisha'	CGWA & CGWB, Bhubaneswar, Odisha	March 21, 2014
Dr. P. K. Panda	International Congress on 'Agriculture, Food Engineering and Environmental Sciences- Sustainable Approaches'	*Krishi Sanskriti*, JNU, New Delhi	March 29-30, 2014

List of Sponsored / Collaborative / Consultancy Projects

Title	Budget (₹ in lakh)	Duration	P.I. / CCPI	Sponsored by
Design and development of rubber dams for watersheds	900.84	2008-2014	Dr. S.K. Jena	NAIP, ICAR, New Delhi
Sustainable Rural Livelihood and Food Security to Rainfed Farmers of Orissa	30.74	April 2008 to March 2014	Dr. S. Mohanty	NAIP, ICAR, New Delhi
Strengthening statistical computing for NARS	57.30	April 2009-March 2014	Dr. D.K. Panda	NAIP, ICAR, New Delhi
Georeferenced soil information system for land use planning and monitoring soil and land quality for agriculture	35.16	2010- 2014	Dr. M. Raychaudhuri	NAIP (C-4), ICAR, New Delhi
Enhancing land and water productivity through integrated farming system (Tribal Sub Plan Project)	10.00	1 year	Dr. R.K. Panda	Institute (Plan)
Improving water productivity under canal irrigation command through conservation and recycling of runoff, seepage, rainwater and groundwater using tanks and wells	45.49	2010-2014	Dr. K.G. Mandal	INCSW (formerly INCID), Ministry of Water Resources, GOI, New Delhi
Decision Support System for Assessing Impact of Low Quality Water Used in Irrigated Agriculture on Food Production	27.10	2009-2014	Dr. Ashwani Kumar	DST, GOI under Indo–Bulgarian Inter-Governmental Programme of Cooperation in Science and Technology
Tracking Change in Rural Poverty in Household and Village Economies in South Asia	70.35	May 2010 to April 2015	Dr. M.K. Sinha	Bill and Melinda Gates Foundations, USA
National Initiative for Climate Resilient Agriculture	600	2011-2017	Dr. G. Kar	ICAR, New Delhi
Development of Decision Support System (DSS) for irrigation water management in Hirakud Canal Command area	11.70	January 2012 to December 2015	Dr. R.K. Panda	ISRO, NRSA, Hyderabad
Reuse options for marginal quality water in urban and peri-urban agriculture and allied services in the gambit of WHO guidelines	19.78	2012-2014	Dr. Ashwani Kumar	DST, GOI under New Indigo
Improving the capacity of Indian State level water authorities on systemic and adaptive governance to climate change	Aus $ 499490	2012-2014	Dr. Ashwani Kumar	Australia Centre of International Agricultural Research (Aus-Aid Project)
Decision Support System for Enhancing Water Productivity of Irrigated Rice - Wheat Cropping System	54.90	June 2012-May 2016	Dr. R.R. Sethi	National Fund for Basic, Strategic & Frontier Application Research in Agriculture, ICAR, New Delhi
Impact of climate variability and anthropogenic factor on groundwater resources of India	35.00	Nov. 2012-Oct. 2015	Dr. D.K. Panda	ICAR-Challenge project
Appropriating the use of Sakthi Sugars Limited - distillery effluent in different cropping practices	2.00	Aug. 2012-Aug. 2014	Dr. M. Das	Sakthi Sugars Limited
Global Yield Gap and Water Productivity Atlas (Collaborative project of ICAR with University of Nebraska, Lincoln, USA)	$56,000	2 years	Dr. P.S. Brahmanand	University of Nebraska, USA and Bill & Melinda Gates Foundation, USA
Evaluation of IWMP (2010-11) watersheds (Consultancy)	56.00	2013-14	Dr. Ashwani Kumar	Odisha Watershed Mission, Bhubaneswar

Events Organized

Workshops Organized

- One day stake holders' workshop on “Rubber dam technology for agricultural water management” was organized on 14th May 2013 where utility of this technology for improving production was discussed on the occasion of foundation day of the Institute.
- A sensitization workshop was organized on “Enhancing water use efficiency in Yamuna basin” on 30th August 2013, jointly by Directorate of Water Management, Bhubaneswar, NRM, Division ICAR and Ministry of Water Resources, Government of India. About 150 scientists and officials from ICAR and Ministry of Water Resources, Government of India attended the workshop and deliberated different issues regarding enhancing water use efficiency of Yamuna basin.
- An inception Workshop on Evaluation of IWMP Watershed Projects (2010-11) as per the Common Guidelines 2008, Government of India was organized on 25th June, 2013. In the workshop the evaluation criteria of preparatory phase of IWMP watershed programme (2010-11 batch) was discussed. About 150 watershed officials, evaluating team, Project Directors, Project Implementing Agencies (PIA) attended this programme. Dr. Gouranga Kar, Principal Scientist and Coordinator, IWMP organizing secretary of the workshop gave a detailed presentation on “Evaluation criteria of preparatory phase of IWMP watershed”.
- A two-day workshop on “Software installation-cum-training program” was organized during September 05-06, 2013 at the DWM Statistical Computational Hub for the nodal officers of eastern India. Dr. D.K. Panda organized this workshop.
- NAIP's Pre-Commercialization Workshop on 'Flexi rubber check-dam for watershed application' was organized by DWM on 30th May 2013 at CIRCOT, Mumbai
- A National Workshop on “Water quality issues, opportunities and socio-cultural concerns of wastewater use in agriculture” supported by USIEF Alumni Award 2013, was organized at the Institute on 7-8th August, 2013. Seventy five persons including invitees, dignitaries and participants were attended and actively participated in five Technical Sessions in the workshop. An Awareness campaign for wastewater - reuse among the farmers groups was organized under plenary session of the workshop, six farmers covering three villages of two districts of Odisha, shared their field level experience on waste water use in various crops and soil types.

Summer School

- DWM organized ICAR sponsored 21-day Summer School on 'Bio-drainage for Reclamation of Waterlogging in High Rainfall Deltaic Areas' during 07-27 May 2013. Twenty three participants from

five different states of India participated in this training. They were trained about various aspects of reclamation of waterlogged areas with the help of biological drainage as a tool. The course director Dr. S. Roy Chowdhury and course coordinators Dr. P.S. Brahmanand, Dr. S.K. Jena, Dr. S. Ghosh and Dr. R.K. Mohanty conducted the summer school.

Field day cum farmers' awareness programme Organized

- Four field day cum farmers' awareness programme were organized by DWM, Bhubaneswar on 'Development of climate resilient agriculture' at Jagatpur village, Kanas block, Puri district on 12.06.2013, at Tanar village, Kendrapara block, Kendrapara district on 22.06.2013, at Village-Benakera Satyabadi block, Puri district on 26.06.2013, and at Village Parbatia, Dhenkanal Sadar block, Dhenkanal district on 30.06.2013. On this occasion farmers-expert interaction meeting was also held and more than 100 farmers participated in each program. Dr. Gouranga Kar organized these programmes.

- One one-day farmers training program on 'Rainwater management for sustainable agriculture and rural livelihoods' and two trainings on 'Field demonstration on drip irrigation systems' were conducted at Talagotha, Dhenkanal on 10.11.2014, at Khallibandha, Dhenkanal on 11.11.2014, and at Kotapala, Dhenkanal on 22.3.2014. Thirty farmers in each programme were trained. Dr. S. Mohanty organized these training programs.

- A farmers field day was organized on 'Development and Effective utilization of groundwater for Enhanced productivity under Climatic Variability' at Gudpada village, Athgarh Block, Cuttack district on 25th May 2013. Fifty nine farmers attended the meeting. Dr. M. Raychaudhuri organized this program.

- Three training programmes were organized during 28-29 November, 2013; 30 January and 21-22 March, 2014 in Birjaberna village of Sundargarh district, Odisha under TSP project. Total 169 beneficiary farmers from 4 villages were imparted training on "Integrated farming system to enhance the land and water productivity" and "Improved water management techniques for sustainable agriculture". Dr. R.K. Panda and his team of scientists organized these programs.

- DWM Scientists interacted with the farmers in the Eastern Zone Regional Agricultural Fair on the aspect of "Production Technology For Food Security" on 27th February, 2014 held at CRRI, Cuttack.

- Two one-day farmers' training programme on "Agricultural management Strategies for Waterlogged Area" was organized at Patsanipur village, Pipli Block, Puri district, Odisha on 28.12.2013. Dr. S. Roy Chowdhury, Dr. S. Raychaudhuri, Dr. P. S. B. Anand and Dr. A. K. Nayak organized the training programme and at Madana village, Garadpur block, Kendrapada district, Odisha on 21.3.2014. Dr. S. Roy Chowdhury, Dr. S. Raychaudhuri, Dr. P. S. B. Anand, Dr. A. K. Thakur and Dr. A. K. Nayak organized the training programme. A total of 110 farmers participated in these training programmes.

- A farmer – scientist interaction was organized at Sunity village at Mahakalapada block of Kendrapara district on 29th April, 2013. Thirty farmers including members of ATMA Krishak Parisad participated and interacted on subsurface water harvesting structures, groundwater pumping options and other aspects of water managements in waterlogged and coastal areas.

◆ Two One-Day 'Farmers Interaction Program' under Village Dynamics in South Asia (VDSA) Project were organized at villages Sogar and Chandrasekharpur, Dhenkanal district on 28th and 29th March, 2014, respectively. A total of 241 farmers participated in the program. Dr. M. K. Sinha organized these programs.

Exposure visits for Farmers

◆ An exposure visit was organized by Dr. S. Mohanty to Soil Conservation Demonstration Centre, Bishwanahakani, Tangi on 30.1.2014 and 1.2.2014. Total 40 farmers each from Odapada block and Dhenkanal Sadar block of Dhenkanal district visited these two programs.

Training of Students

◆ One year "Diploma course on Watershed Management" was initiated at DWM from session 2013-14 under IGNOU. An induction meeting held at DWM on October 06, 2013 and Regional Director, IGNOU Regional Center, Bhubaneswar graced this occasion. Dr. R. K. Panda, Principal Scientist is acting as the Programme-In-Charge for the course. A total of six students enrolled for this course for 2013-14 session.

◆ Three students of Department of Environmental Sciences, Utkal University, Vani Vihar completed their M.Sc. dissertation work of four - months duration in July 2013 under supervision of Dr. M. Das, Dr. G.Kar and Dr. M Raychaudhuri.

◆ One month summer training programme for six B. Tech final year students of CAEPHT, Central Agricultural University Gangtok was organized at DWM during 3-31 March, 2014. Dr. M. Das was training co-ordinator for this program.

◆ Mr Arnoud van Spronsen, a Bachelor degree student of International Land and Water Management program, Wageningen University, The Netherlands visited DWM for his internship/training for nine weeks from January to March 2014. Dr. S. Raychaudhuri was his training coordinator.

Scientists-School Children Interactive Meet Organized

◆ On the occasion of National Science Day on 28th February, 2014, a Scientists-School Children Interactive Meet was organized at Joypurpatna Primary School, Khurda district. School children of class III, IV and V participated in this program. Dr. S.

Raychaudhuri, Dr Somnath Roy Chowdhury and Dr. S. K. Rautaray of DWM interacted with the children to inculcate interest in science. Mr Arnoud van Spronsen of Wageningen University also interacted with the students for their encouragement.

World Water Day 2014 celebrated

- DWM celebrated World Water Day on 22nd March 2014 with theme 'Water-Energy Nexus'. A seminar was delivered by Dr. G. Kar on "Climate change: Reality versus Uncertainty and its role as a driver to hamper food, water and environmental security" on this occasion.

Seminar cum Monthly meet

- Fifteen seminars cum monthly meetings were organized during April 2013 to March 2014. During the seminars scientists delivered seminars on important water related issues under institute mandate. Seminar presentations were based on contemporary topics which appeared in reputed journals, alongwith deputation seminars given by scientist for abroad visit and dissertation work etc. given by the students.

Exhibition Organized

- Exhibition of DWM's significant accomplishments was made in National Agricultural Fair cum Exhibition "Krishi Vasant-2014" held at CICR, Nagpur, Maharashtra during 9-13 February 2014. Also our scientists participated in Scientist-farmer question answer session on 'Soil and water conservation measures' held on 13.2.2014.

- DWM achievements were exhibited on the occasion of foundation day celebration of CRRI, Cuttack on 23rd April 2013.

- Institute's achievements were exhibited on the occasion of an interface meet for the year 2013 – 2014 organized at CRRI, Cuttack on 26-27th November, 2013.

- Technologies developed by DWM were displayed in the "Showcasing of Agricultural Technologies 2013" organized by ICAR Research Complex for Eastern Region, Patna on 6-7th December, 2013.

Weather Summary

Meteorological data 2013-14

The daily rainfall and open pan evaporation data was recorded at DWM Central Research Farm, Deras, Mendhasal, Khurda and were analyzed. The monthly rainfall and mean monthly evaporation data are presented in Figure 59. The total annual rainfall was 2058.5 mm during 2013-14 and October month was wettest with the highest rainfall of 886.7 mm. The monthly average pan evaporation data varied from 2.79 mm during December to 6.25 mm during the month of May.

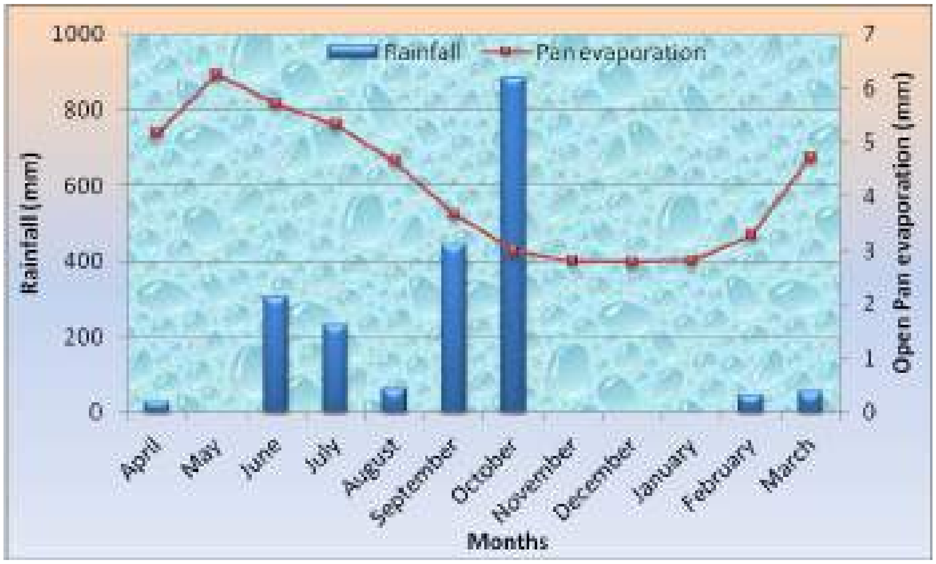


Fig. 59 Monthly rainfall and mean monthly evaporation data during 2013-14

Promotion / Transfer / Retirement

- Dr. S. Raychaudhuri and Dr. M. Raychaudhuri were promoted to the post of Principal Scientist under CAS with effect from 1.1.2011.
- Dr. S. Ghosh, Dr. D. K. Panda and Dr. R. R. Sethi were promoted from RGP ₹ 8000 to ₹ 9000 under CAS with effect from 10.07.2012, 24.10.2012 and 07.10.2012 respectively.
- Mr. S. Lenka was promoted to Senior Technical Assistant (Field investigator) w.e.f. 18.4.2012.
- Mr. A. Parida was promoted to Senior Technician (Lab) w.e.f. 28.5.2012.
- Mr. R. K. Dalai was promoted to Assistant w.e.f. 15.4.2013.
- Mr. N. K. Mallick was promoted to UDC w.e.f. 17.6.2013.
- Mr. S. K. Mathur, AO was transferred to CRRI, Cuttack on 25th June, 2013.
- Dr. M. S. Behera, Farm manager (T-9) got selected as Senior Scientist at CRIJAF, Barrackpore, W.B. , left this institute on 10th June, 2013.
- Dr. M. J. Kaledhonkar, Principal Scientist was transferred to NIASM, Baramati on 24th August 2013.
- Mr. R. C. Behera, AAO was retired from his duty on 31.3.2014.

Personnel

Director
Dr. Ashwani Kumar

Principal Scientist

Dr. R.C. Srivastava
Dr. Atmaram Mishra [b]
Dr. M. Das
Dr. S. Roy Chowdhury
Dr. P. Nanda
Dr. R.K. Panda
Dr. S.K. Rautaray
Dr. M.J. Kaledhonkar [a]
Dr. G. Kar
Dr. S.K. Jena
Dr. R.K. Mohanty
Dr. (Mrs.) M. Raychaudhuri
Dr. S. Raychaudhuri

Senior Scientist

Dr. S. Mohanty
Dr. M. K. Sinha
Dr. K.G. Mandal
Dr. P.K. Panda
Dr. A.K. Thakur
Dr. P.S. Brahmanand
Dr. S. Ghosh [b]
Dr. D.K. Panda
Dr. A.K. Nayak

Scientist (SS)

Dr. Ranu Rani Sethi
Dr. P. Panigrahi

Scientist

Dr. O.P. Verma

Chief Technical Officer

Dr. M.S. Behera [a]
Er. D.U. Patil

Asst. Chief Technical Officer

Mrs. Sunanda Naik

Technical Officer

Dr. V.K. Tripathi [b]
Mr. Chhote Lal

Senior Technical Assistant

Mr. R.C. Jena
Mr. P.C. Singh Tiyu
Mr. S.K. Dash
Mr. B.K. Acharya
Mr. S. Lenka

Technical Assistant

Mr. A.K. Binakar
Mr. P. Barda
Mr. L. Singh Tiyu

Senior Technician

Mr. A. Parida

Administrative Officer

Mr. S.C. Sheet
Mr. S.K. Mathur [a]

Finance & Accounts Officer

Mr. S.K. Das

Assistant Administrative Officer

Mr. R.C. Behera [c]

Private Secretary

Mrs. M. Padhi

Personal Assistant

Mr. Trilochan Raut

Assistant

Mr. A. Mallik
Mr. J. Nayak
Mr. B.P. Sahoo
Mr. R.K. Dalai

Upper Division Clerk

Mr. A.K. Pradhan
Mr. N.K. Mallick

Lower Division Clerk

Mr. C.R. Khuntia
Mr. B.S. Upadhyaya
Mr. S.C. Das

Skilled Support Staff

Mr. Sanatan Das
Mr. H.K. Bal
Mr. B.N. Naik
Mr. B. Bhoi
Mr. S.K. Panda
Mr. B. Dutta

a- Transferred; b- Lien; c-Retired

Finance

(₹. in lakhs)

Sl. No.	Head of A/C	Non-Plan		Plan	
		Budget 2013-14	Expenditure 2013-14	Budget 2013-14	Expenditure 2013-14
1.	Establishment Charges	462.00	462.00	-	-
2.	O.T.A.	0.05	0.05	-	-
3.	T.A.	3.00	3.00	9.00	9.00
4.	Other charges including equipment	30.95	30.95	69.46	69.46
5.	Other charges-IT	-	-	-	-
6.	Repair & maintenance of building	11.00	11.00	10.00	10.00
7.	Works	-	-	3.38	3.38
8.	Library Books & Journals	-	-	20.16	20.16
9.	H.R.D.	-	-	3.00	3.00
10.	Others	41.00	40.68	10.00	10.00
	Total	**548.00**	**547.68**	**125.00**	**125.00**
11.	**AICRP on Water Management**	-	-	**1565.00**	**1565.00**
12.	**AICRP on GWU (P)**	-	-	**340.00**	**340.00**

AICRP WM-PC Unit

(₹. in lakhs)

Sl. No.	Head of A/C	Sanctioned (Non plan) (2013-14)	Actual Expenditure (Non plan) (2013-14)
1.	Establishment	36.00	36.00
2.	T. A.	0.50	0.50
3.	Other charges including equipment	-	-
	Total	**36.50**	**36.50**

भाकृअनुप
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भारतीय कृषि अनुसंधान परिषद

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Directorate of Water Management

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