वार्षिक प्रतिवेदन
Annual Report
2016-17

ICAR-IIWM

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भाकृअनुप – भारतीय जल प्रबंधन संस्थान
ICAR-Indian Institute of Water Management
Bhubaneswar, Odisha, India

जय किसान
जय विज्ञान

Annual Report
2016-17

ICAR-IIWM

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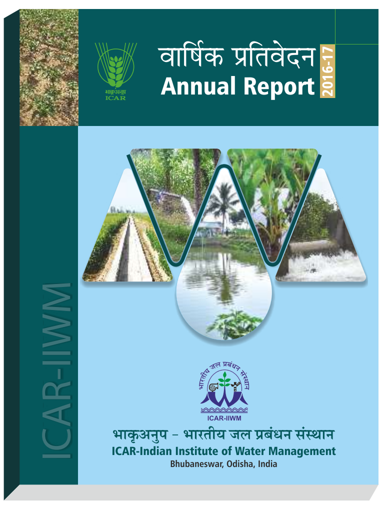

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PREFACE

Agricultural water management is a prime challenge for enhancing agricultural production in the country. The most important task is to improve water productivity at basin, farm and individual field level under both rainfed and irrigated conditions. As availability of irrigation water is being seriously affected and net cropped area remains the same over decades, major challenges would be to increase the marketable produce from each unit of water used, to reduce all outflows viz., runoff, seepage and percolation, including evaporative outflows, and to increase the effective use of rainfall, stored water, and water of marginal quality. With these background and challenges, our Institute is striving for agricultural water management research in the country, capacity building of associated personnel and farmers, and transfer of technologies. I feel extremely happy to bring out the detailed presentation of Institute's progress in the Annual Report of the Institute for the year 2016-17.

Significant research achievements for the year 2016-17 have been included in this annual report under five approved programs of the Institute i.e., rainwater management, canal water management, groundwater management, waterlogged area management and on-farm research and technology dissemination. Our scientists have assessed groundwater storage potential using NASA's GRACE satellites, development of water resource management plans for coastal areas in Odisha and delineation of waterlogged areas in Bihar using land use land cover (LULC) data of ISRO. Projects have been continued for development of drainage plan for Mahanadi delta and computing virtual water and water trade potential for agro-based products. There has been a considerable research work conducted towards development of runoff water recycling, and land modification technique for enhancing productivity, water and nutrient self-reliant farming system for rainfed areas; climate resilient agriculture, groundwater management for enhancing adaptive capacity to climate change, options for enhancing irrigation efficiency and development of integrated farming systems in canal commands, and water saving irrigation technologies in rice production. With the aim of water budgeting and enhancing water productivity in aquaculture systems, stocking density of pacific white shrimp culture has been optimized. Significant research work has been carried out on drip irrigation systems for rice-based cropping, drum-based drip irrigation for vegetable crops etc. As an attempt to explore wastewater use in agriculture, a filter has been designed and developed for wastewater treatment. Studies are being carried out for bio-remediation of polluted water, impact assessment of industrial wastewater, intensive horticultural system for improving farm income from degraded land, social and sustainability implications of water management interventions. A considerable work has been done for livelihood improvement of tribal farmers through water management intervention. Our institute has also initiated development of web-based expert system on agricultural water management.

Under the *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) of the Government of India, Institute has played a major role in capacity building for project implementing agencies of GoO, prepared district irrigation plan (DIP) for five districts of Odisha. In addition to research and development efforts at the Institute level, different agricultural water management related issues at the regional level are being addressed by different centres under the AICRP on Irrigation Water Management. Through ICAR-Agri-Consortia Research Platform on Water project, institute has successfully installed rubber dams in different agro-ecological regions of India, initiated improvement strategies for enhancing water productivity in canal commands, drip-irrigation in horticultural crops, eco-friendly wastewater treatment, multiple use of water in aquaculture production systems, addressing issues related to water governance and policy. With the aim of transfer of technology and working with farmers, Scientists are involved with thirty adopted villages across seven blocks in Odisha under *Mera Gaon Mera Gaurav* (MGMG) programme; conducted training programs for Government officials, farmers and students on various aspects of water management, participated in exhibitions to showcase Institute developed technologies.

Scientists of the Institute have published 39 research papers in reputed and peer-reviewed journals, 5 books/ bulletins/ training manuals and 7 popular articles/leaflets/ folders/ brochures during the year 2016-17. As recognition for significant achievements, our Scientists have received ICAR- Dr. Rajendra Prasad *Puruskar* for technical books in Hindi, ICAR-Team Research Award, Ekamara Shree Award, Hooker Award, Fellow Award by prestigious Societies and Academies in the country, Guinness world record, along with many others viz., Best Scientist Award, Outstanding Researcher Award and presentation awards, honours and recognitions.

I acknowledge sincerely the valuable guidance, suggestion and support of Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR; Dr. A.K. Sikka, former Deputy Director General, Natural Resource Management (NRM), ICAR; Dr. K. Alagusundaram, Acting Deputy Director General, NRM, ICAR; Dr. S.K. Chaudhari, Assistant Director General (S&WM), NRM, ICAR, New Delhi and other concerned officials of the Council. I express my sincere thanks to the esteemed Chairman and members of RAC and IMC for their valuable guidance, inputs and involved support. I thank all members of IRC, Chairman and members of different institute committee, administration and finance section of the Institute for help, cooperation and smooth functioning of the Institute. The publication committee deserves applaud and appreciation for the efforts rendered for compilation and editing the Annual Report. I thank all staffs of the institute for their support in carrying out institute's activities. I hope that our Annual Report will be immensely useful for stake holders i.e. policy makers, researchers, development functionaries and farmers.

30 June 2017
Bhubaneswar

S.K. Ambast
Director, ICAR-IIWM

कार्यकारी सारांश

वर्षा आधारित क्षेत्रों के लिए पानी एवं पोषक तत्व आत्मनिर्भर खेती: सामान्यतः जैविक खाद के प्रयोग से रासायनिक खाद की तुलना में फसलों की उपज में कमी होती है। लेकिन, रासायनिक खाद के प्रयोग के बजाय जैविक पोषण के तहत मूँगफली और उड़द की फसलों से धान तुल्य उपज (REY) में बहुत कम क्रमश: 14.4% एवं 18.1% की ही कमी प्राप्त हुई जो कि इन फसलों की आत्मनिर्भर खेती पद्धति के लिए उपयुक्तता को बताती है। इस अनुसंधान में उगाई गई छ: टेस्ट फसलों में से पत्ता गोभी से अधिकतम धान तुल्य उपज (8.56 टन/हे), शुद्ध आय (₹ 69,204/हे) एवं शुद्ध आर्थिक जल उत्पादकता (₹ 32.67/घन मीटर) प्राप्त हुई। इसके बाद लोबिया और मूँगफली की फसलों में पायी गई। जबकि शुद्ध ऊर्जा उत्पादन (40.3 गीगा जूल/हे) मक्का की फसल से अधिक था और उसके बाद मूँगफली की फसल से प्राप्त हुआ।

उत्पादकता बढ़ाने के लिए वर्षा अपवाह रीसाइक्लिंग मॉडल का विकास: इस विकसित वर्षा अपवाह रिसाइक्लिंग मॉडल के तहत केवल धान की खेती की तुलना में कई फसलें (धान, पपीता, मूँग, उड़द, सरसों, ब्रोकोली पत्ता गोभी) / तालाब में मछलीपालन के संयोजनों से जल उत्पादकता में ₹ 5.96/घन मीटर से ₹ 19.33/घन मीटर तक वृद्धि हुई। इस पद्धति से धान-उड़द पैरा फसल पद्धति की तुलना में शुद्ध आय में 4.5 गुना वृद्धि प्राप्त हुई।

झींगा (लिटोपिनियस वानैमी) पालन के लिए स्टॉकिंग घनत्व का अनुकूलन: वाणिज्यिक स्तर पर झींगा पालन में स्टॉकिंग घनत्व इसके विकास, उपज प्रदर्शन और पानी के उपयोग पर महत्वपूर्ण प्रभाव डालता है। एल.वानैमी के विभिन्न स्टॉकिंग घनत्वों में से, 5,00,000 पोस्ट लार्वा/हे घनत्व के साथ काफी अधिक उपज (10.58 टन/हे) प्राप्त हुई और कम उपभोगित पानी उपयोग सूचकांक (1.72 घन मीटर/किलो बायोमास उत्पादन) प्राप्त हुआ। साथ ही साथ अधिक आर्थिक लाभ (खेती की लागत के लिए उत्पादन मूल्य,1.97) मिला तथा शुद्ध उपभोगित जल उत्पादकता (₹ 88.3/घन मीटर) पायी गयी।

नहरी कमांड की सिंचाई दक्षता में सुधार: ओडिशा राज्य के सुंदरगढ़ जिले में घुरलीजोर लघु सिंचाई कमांड के तहत कुऐं के हाइड्रोलिक मूल्यांकन से पता चला कि 3 सेमी/घंटे की पुन:भरण की दर के साथ कुऐं का ड्राडाउन स्तर 36 सेमी/घंटा था। अलग-अलग सिंचाई पद्धतियों में से यह पाया गया कि मूँगफली फसल में कूंड (320 मिमी) और बाढ़ (400 मिमी) सिंचाई पद्धति की तुलना में फव्वारा सिंचाई से 12-30% तक पानी की बचत होती है।इसी प्रकार, कुएं से 160 मिमी सिंचाई के पानी का उपयोग करने पर मूँग फसल की उपज एवं सिंचाई जल उत्पादकता क्रमश: 0.65 टन प्रति/हे और 0.4 किलो/प्रति घन मीटर थी।

सब्जियों में ड्रिप-फर्टिगेसन द्वारा जल एवं उर्वरक उपयोग दक्षता में सुधार: धान की फसल में ऊर्जा संतुलन के मौसमीय और दैनिक परिवर्तन को एडी-कोवेरियंस तकनीक का उपयोग करके निर्धारित किया गया। करेला, भिंडी और आलू की फसलों में परंपरागत सतह सिंचाई एवं उर्वरक प्रयोग पद्धति की तुलना में ड्रिप-फर्टिगेसन द्वारा पानी और उर्वरक उपयोग दक्षता में क्रमश: 35-42% और 30-40% तक वृद्धि हुई। ब्राह्मणी नदी बेसिन में बदलते जलवायु परिदृश्यों के तहत संयोजी जल उपयोग की रणनीति भी विकसित की गई।

धान आधारित फसल अनुक्रम के लिए ड्रिप सिंचाई पद्धति का मूल्यांकन: पूर्ण सिंचाई (100% ETc) के तहत बेबी कॉर्न की पैदावार (2.16 टन/हे) अधिकतम थी, जो सांख्यिकीय रूप से 75% (ETc) सिंचाई के तहत प्राप्त उपज (1.98 टन/हे) के बराबर थी। धान में 100% ETc पर ड्रिप सिंचाई से उपज उत्पादन में 12% कमी हुई लेकिन साथ ही 42% सिंचाई पानी की बचत हुई जिसके परिणामस्वरूप सतह सिंचाई के मुकाबले 55% अधिक जल उत्पादकता प्राप्त हुई। दोनों फसलों के लिए लैटरल से लैटरल की दूरी 1.0 मीटर ने 1.4 मीटर की दूरी की तुलना में अधिक पैदावार का उत्पादन किया।

धान की खेती के तरीकों का प्रदर्शन मूल्यांकन: धान की खेती पर प्रयोग दर्शाता है कि वर्षा आधारित खेती की तुलना में पूरक सिंचाई (49.6 मिमी) के साथ दाना उपज (3.62 टन/हे) और पानी की उत्पादकता (0.51 किग्रा/घन मीटर) काफी अधिक प्राप्त हुई। इसके अलावा, सीधे बीज बुआई की तुलना से प्रत्यारोपित धान में उपज और जल उत्पादकता 19% (3.76 टन/हे, 0.55 किग्रा/घन मीटर) तक बढ़ गयी। सिंचित प्रत्यारोपित धान में उच्च उपज मूलतः बेहतर फसल विकास और पादप कर्यिकी में सुधार की वजह से प्राप्त हुई।

वाटर फूटप्रिंट्स (आभासी जल) का आकलन: भारतीय संदर्भ में वर्तमान और भविष्य के जलवायु परिदृश्यों के तहत पशु और पशु आधारित उत्पादों के लिए वाटर फूटप्रिंट्स की गणना हेतु कार्य

प्रणाली को मानकीकृत किया गया। भारत के विभिन्न क्षेत्रों की प्रमुख फसलों के लिए वाटर फूटप्रिंट्स की गणना भी तैयार की गई। यह परिणाम बताते हैं कि पंजाब में धान की अधिक उत्पादकता के कारण वॉटर फूटप्रिंट कम (1,485 घन मीटर/टन) है, जबकि मध्य प्रदेश (3,592 घन मीटर/टन) में वाटर फूटप्रिंट अपेक्षाकृत अधिक है जिसका कारण फसल की कम उत्पादकता एवं उच्च वाष्पीकरण हो सकता है। इसके अलावा, प्रसंस्कृत उत्पादों के वाटर फूटप्रिंट्स के आकलन की पद्धति को भी मानकीकृत किया गया।

मूँगफली फसल की वृद्धि पर सुपर अवशोषक पॉलिमर (SAP) का प्रभाव: मूँगफली फसल के विकास और इसकी पैदावार पर SAP's के विभिन्न खुराकों का मूल्यांकन करने के लिए खेत में एक प्रयोग आयोजित किया गया। प्रारंभिक परिणाम मिट्टी के गुणों, फसल विकास तथा पादप कार्यिकी प्रदर्शन पर SAP की विभिन्न खुराकों ने कोई महत्वपूर्ण प्रभाव नहीं दर्शाया।

नहरी सिंचाई पद्धति के प्रदर्शन का आकलन करने के लिए बेंचमार्किंग: किसी भी नहरी सिंचाई पद्धति के प्रदर्शन का आकलन करने के लिए बेंचमार्किंग एक उपयोगी तकनीक है। महाराष्ट्र राज्य की 50 प्रमुख, 33 मध्यम और 36 लघु सिंचाई परियोजनाओं के वर्ष 1999 -2000 से लेकर वर्ष 2011-12 की अवधि के बेंचमार्किंग आँकड़ों का विश्लेषण सिस्टम प्रदर्शन एवं कृषि उत्पादकता संकेतकों का उपयोग करके किया गया।

भूजल संसाधनों पर जलवायु परिवर्तनशीलता का प्रभाव: एक अध्ययन से भारत में सूखे, कैसे सतही एवं भूजल संसाधनों को प्रभावित करते हैं तथा कैसे गर्मी लहर और गर्मी की अवधि में योगदान देते हैं? का पता करने के लिए एक अध्ययन आयोजित किया गया। इसमें प्रभावित क्षेत्रों की एक विस्तृत श्रृंखला को समायोजित करने के लिए गर्मी लहर सूचकांक के एक बहु-तथ्य ढाँचे का उपयोग किया गया। दुनिया के कई हिस्सों में सूखा एवं गर्मी की चरम सीमाओं में लगातार वृद्धि देखी गई है। भारतीय उपमहाद्वीप ने वर्ष 2002 से सूखे के रूप में गंभीर गर्म जलवायु के साथ सबसे अधिक अकालों का अनुभव किया है।

कठोर चट्टानी क्षेत्रों के लिए भूजल पुन:भरण संरचनाओं की डिजाइन: ओडिशा के नयागढ़ जिले के दसपाला ब्लॉक की नचिपुर ग्राम पंचायत में स्थित बारघरीया नाला सूक्ष्म वाटरशेड को कठोर चट्टानों में हाइड्रोलोजिक विश्लेषण, डिजाइन तैयार करने एवं खेत पर भूजल पुन:भरण संरचनाओं का अध्ययन करने के लिए चुना गया। डिजिटल एलीवेशन मॉडल (DEM) का प्रयोग करके जल प्रवाह संचय एवं दिशा का निर्धारण किया गया। विश्लेषण के आधार पर श्रीरामपुर गांव में पुन:भरण संरचना की डिजाइन और इसके खेत में मूल्यांकन हेतु एक स्थल की पहचान की गई।

अपशिष्ट जल उपयोग के लिए फिल्टर का विकास: शहरी अपशिष्ट जल से भारी धातु, तलछट एवं जीवाणु (माइक्रोबियल) भार को कम करने के लिए छोटे पैमाने पर चार संभाग वाले ऑनलाइन हाइब्रिड फिल्टर का डिजाइन तैयार किया गया और विकसित किया गया। भुवनेश्वर के नजदीक शहरी क्षेत्रों में इस फिल्टर का एक किसान के खेत में मूल्यांकन भी किया गया। बारिश के बाद के मौसम के दौरान इस फिल्टर सिस्टम को प्रभावी पाया गया तथा इस सिस्टम को वापस धोने (backwash) के माध्यम से पुन:भरित (recharge) किया जा सकता है।

प्रदूषित जल स्रोतों से क्रोमियम का जैविक उपचार: ओडिशा राज्य के सुखिन्दा में क्रोमाइट खदान क्षेत्रों में अलग-अलग जल निकासी प्रवाहों से मानसून के दौरान एकत्र किए गए 82% पानी के नमूने क्रोमियम विषाक्तता से ग्रसित थे जो उपयोग के लिए असुरक्षित थे। वहाँ की वनस्पति पर इसके प्रभाव की जांच से पता चला कि जल निकासी चैनलों जिनमें खदानों का अपशिष्ट जल बहता है के पास उगाई गई धान की फसल के पत्ती क्षेत्र सूचकांक में काफी कमी आई है। जल कल्चर अध्ययन से पता चला कि जलीय पौधे जैसे पिस्टिया स्ट्रेटियोट्स, साल्विनिया मिनीमा और आइपोमिया एकवेटिका आदि प्रदूषित पानी से 10-97% क्रोमियम सांद्रता को कम कर सकने में सक्षम पाये गये।

सतही एवं भूजल के संयोजी उपयोग के लिए अनुकूलन मॉडल का विकास: केन्द्रपाड़ा जिले के विभिन्न ब्लॉकों हेतु उचित फसल योजना के माध्यम से शुद्ध वार्षिक लाभ को अधिकतम करने के लिए एक अनुकूलन मॉडल को विकसित किया गया। इस मॉडल का विकास भूमि क्षेत्र, सतही एवं भूजल संसाधनों से पानी की उपलब्धता और विभिन्न फसलों की सिंचाई जल आवश्यकता आदि समस्याओं को ध्यान में रख कर किया गया। इस मॉडल ने बताया कि खरीफ मौसम में धान सिंचित क्षेत्रों में अधिकतम लाभ प्राप्त करने के लिए इष्टतम क्षेत्र आवंटन 23.9 से 51.2% की सीमा में होना चाहिए। इसी प्रकार, रबी मौसम में विभिन्न ब्लॉकों में वर्षा की स्थिति के तहत रबी तिलहन के लिए 28.5-81.7% का अधिकतम क्षेत्र आवंटित किया जाना चाहिए।

पोर्टेबल ड्रम आधारित ड्रिप सिंचाई पद्धति का विकास: एक ड्रम आधारित ड्रिप सिंचाई पद्धति को सब्जियों की खेती के लिए विकसित किया गया तथा खेत पर इसका मूल्यांकन भी किया गया। इस पद्धति के माध्यम से 24.8 टन/हे बैंगन की पैदावार तथा 9.4 टन/हे भिंडी की उपज प्राप्त हुई, एवं इस पद्धति के तहत तकरीबन 100 वर्ग मीटर क्षेत्रफल में लगी सब्जियों की सिंचाई की जा सकती है।

जलवायु परिवर्तन के तहत गन्ने की खेती पद्धति में दक्ष भूजल प्रबंधन: उत्तर प्रदेश के मुजफ्फरनगर जिले में जलवायु अनुरूप सिंचाई पद्धति जैसे भूमिगत निर्वहन पाइप लाइन पद्धति को 45 किसानों के खेत में लागू किया गया तथा ड्रिप सिंचाई पद्धति को तीन किसानों के खेत में स्थापित किया गया। वहाँ इससे संबन्धित गाँव के लिए पानी का पूरा बजट तैयार किया गया। रसूलपुर जट्टन गाँव के पास भूजल पुन:भरण केविटी और चेक बाँध का निर्माण कार्य प्रगति में है। इस अध्ययन से संबंधित गाँव में जल प्रबंधन के विभिन्न पहलुओं के संदर्भ में कई प्रशिक्षण कार्यक्रम भी आयोजित किए गए।

तटीय जलभृतों (acquifers) में भविष्य के जलवायु परिदृश्यों

का आकलन: वैश्विक सिमुलेशन मॉडल के डाउन स्केलिंग उत्पाद का उपयोग करके पूर्वी भारत के तटीय जलभृतों का आकलन किया गया जो कि प्रमुख नदियों द्वारा संचालित होती हैं। यह देखा गया कि भविष्य में अनेक सूखी-गर्म घटनाओं के द्वारा हमारे जल संसाधनों पर और भी अधिक दवाब बढ़ेगा।

तिलहनी फसलों पर औद्योगिक अपशिष्ट जल का प्रभाव: ओडिशा राज्य के अंगुल औद्योगिक क्षेत्र के सतही पानी की गुणवत्ता के मूल्यांकन से पता चला कि मॉनसून के दौरान उद्योगों के अधिकांश अपशिष्ट इस समय नालों में डाले जाते है जो कि खरीफ फसलों की सिंचाई के लिए अनुपयोगी है। अतः रबी मौसम के दौरान ताजा पानी के साथ औद्योगिक अपशिष्ट जल का संयोजी उपयोग करके सूरजमुखी की फसल में इसका मूल्यांकन किया गया। 75% अपशिष्ट और 25% ताजा जल के संयोजी संयोजन से सूरजमुखी का उत्पादन केवल 100% अपशिष्ट जल सिंचाई के बराबर ही पाया गया।

जल उत्पादकता एवं खेती की आय में सुधार के लिए अवक्रमित भूमि में गहन बागवानी पद्धति: जल उत्पादकता में सुधार और अवक्रमित भूमि से अधिक लाभ करने के लिए पपीता एवं अनानास के अंतरसस्य को ड्रिप सिंचाई तथा धान भूसा पलवार के साथ फलन पूर्व आम के पौधों में एक प्रयोग आयोजित किया गया। नए आम के पौधों की ऊँचाई, पत्तों की चौड़ाई, तना व्यास जैसे गुण ड्रिप सिंचाई एवं धान भूसा पलवार के तहत अंतरसस्य फसलों पपीता/अनानास से प्रभावित नहीं हुये। हालांकि, पपीता में केनोपी व्यास काफी प्रभावित हुआ। परंतु, आम और पपीता के अंतरसस्य तथा पलवार से अनानास के वनस्पति विकास पर कोई प्रभाव नहीं पड़ा।

पूर्वी भारत के जलाक्रांत क्षेत्रों का आंकलन एवं उपयुक्त फसलों की सलाह: पी 6-LISS-तृतीय इमेजरी और टॉपो शीट नक्शे के विश्लेषण से पता चला कि नवंबर 2014 के दौरान जलमग्न क्षेत्रों में मॉनसून अवधि के बाद बिहार, पश्चिम बंगाल तथा झारखंड के बारह जिलों में वृद्धि हुई। पश्चिम बंगाल के पूर्व मेदिनापुर एवं हावड़ा जिले में रूप नारायण नदी के किनारे तकरीबन 2,86,100 हेक्टेयर के अध्ययन क्षेत्र में से 928 हेक्टेयर क्षेत्र टाईफा खेती के लिए उपयुक्त पाया गया। इसके अलावा, ओडिशा में बालेश्वर जिले के 92,452.61 हेक्टेयर क्षेत्र में से 607.87 हेक्टेयर क्षेत्र एकीकृत सिंघाड़ा-मछलीपालन खेती के लिए उपयुक्त पाया गया।

सूक्ष्म सिंचाई के उपयोग द्वारा दलहन फसलों की उत्पादकता में वृद्धि: मूँग की फसल में दो महत्वपूर्ण विकास अवस्थाओं अर्थात फूल आने तथा फली निर्माण के समय फव्वारा सिंचाई पद्धति से सिंचाई देने से फूल आने पर एकल सिंचाई और कोई सिंचाई न देने की तुलना में बेहतर फसल वृद्धि पायी गयी। इसी प्रकार, सिर्फ नाइट्रोजन प्रयोग की तुलना में राइजोबियम ईनोकूलेसन+यूरिया के माध्यम से 20 किलो/हे नाइट्रोजन का प्रयोग फसल वृद्धि के लिए बेहतर पायी गया।

पूर्वी तटीय डेल्टा की जलनिकास योजना: पूर्वी तट डेल्टा (भार्गवी-दया दोआब) की जलनिकास योजना भू-सूचना विज्ञान साधन का उपयोग करके तैयार की गई। लैंड-सैट (LANDSAT) की छवियों से जलाक्रांत क्षेत्रों का मानचित्रण करने से पता चला कि सितंबर, 2015 को जल क्षेत्र का फैलाव 355.1 वर्ग किमी था जो कि अक्टूबर, 2015 तक घट कर 259.3 वर्ग किमी हो गया। यदि फसल 6 दिनों के जलमग्न के प्रति सहिष्णु है तो वहाँ जलनिकास गुणांक 10 वर्षों की वापसी अवधि के आधार पर 48.3 मिमी/दिन पाया गया।

अपशिष्ट जल सिंचाई के तहत उपयुक्त फसलें: मृदा से फसल तक भारी-धातु के हस्तांतरण, सब्जियों के खाद्य भागों में उनके संचय को समझने के लिए एक अध्ययन किया गया, ताकि किसी भी प्रकार के मानव स्वास्थ्य संबंधी खतरों के बिना अपशिष्ट जल से सिंचाई की स्थिति में उपयुक्त फसलों का सुझाव दिया जा सके। इस अध्ययन से पता चला कि भारी धातु संचय (Cr एवं Cd) सबसे कम उन सब्जियों (टमाटर, भिंडी, तुरई, ग्वार फली) में होता है जिनका खाद्य हिस्सा फल के रूप में होता है वहीं सबसे ज्यादा भारी धातु संचय चौलाई की पत्तियों तथा गाजर की जड़ों में पाया गया। इसलिए, पत्तेदार और जड़ वाली सब्जियाँ जिनको धातु प्रदूषित जल से सिंचित किया जाता है का उपभोग उचित नहीं है। जबकि वो सब्जियाँ जिनके हम फल खाते हैं जैसे की टमाटर, भिंडी, तुरई, ग्वार फली आदि उपभोग के लिए सुरक्षित हैं।

धान एवं गेहूँ की वैश्विक उपज अंतर पर अध्ययन: सिमुलेशन मॉडलिंग (APSIM) का उपयोग करके ये पता चला कि पंजाब के अमृतसर तथा पश्चिम बंगाल के कल्याणी जलवायु बफर क्षेत्रों के लिए धान का अनुमानित उपज अंतर संभावित उपज से 65.9% (5.59 टन/हे) और 67.8% (4.83 टन/हे) क्रमशः था। गेहूँ की फसल में हिमाचल प्रदेश के पालमपुर एवं पंजाब के पटियाला जलवायु बफर क्षेत्रों के लिए संभावित उपज से अनुमानित उपज का अंतर क्रमश: 68.2% (2.95 टन/हे) और 22.5% (1.33 टन/हे) पाया गया।

कृषि जल प्रबंधन पर वेब आधारित विशेषज्ञ पद्धति का विकास: कृषि, बागवानी, मत्स्य पालन और पशुपालन सहित कृषि जल प्रबंधन के लिए एक वेब आधारित विशेषज्ञ पद्धति का विकास शुरू किया गया। अनाज वाली फसलों पर विभिन्न आंकड़े वेब पृष्ठों के रूप में संकलित किए गए। अनाज वाली फसलों के लिए वेब पेज प्रारूप ओपन एक्सेस (PHP) भाषा में विकसित किया गया जो की उपयोगकर्ता द्वारा उसकी मैत्रीपूर्ण उपयोगिता को बढ़ा देगा।

जल प्रबंधन तकनीकियों के अपनाने और स्थिरता का मूल्यांकन: ओडिशा राज्य के विभिन्न कृषि-पारिस्थितिक क्षेत्रों में भाकृअनुप-भारतीय जल प्रबंधन संस्थान द्वारा पहले से विकसित विभिन्न जल प्रबंधन तकनीकों के किसानों द्वारा अपनाने एवं उनकी स्थिरता का मूल्यांकन किया गया। इन तकनीकों के संबंध में सिंचाई संरचनाओं की भौतिक स्थिति, उनका वर्तमान उपयोग, मौजूदा खेती की पद्धतियाँ और किसानों की राय की मिश्रित प्रतिक्रिया प्राप्त हुई। वहाँ जल प्रबंधन तकनीकों के कारण

उत्पादन क्षेत्र फैलाव में काफी सुधार देखा गया जिससे किसानों के समग्र जीवन स्तर में भी बढ़ोतरी हुई।

बेहतर जल प्रबंधन विधियों के माध्यम से आदिवासी किसानों की आजीविका में सुधार: सुंदरगढ़ जिले के महुलजोर गाँव में आदिवासी किसानों की आजीविका में सुधार लाने के लिए सिंचाई की बुनियादी सरंचनाओं को विकसित किया गया जहाँ मॉनसून और गर्मी के मौसम के दौरान किसान प्राय: सिंचाई पानी की अनुपलब्धता से ग्रसित रहते हैं। बिर्जबरना और महुलजोर गाँवों में जल प्रबंधन पर क्षमता निर्माण संबंधी कार्यक्रम भी आयोजित किए गए। पाइप द्वारा सिंचाई के साथ दबाव सिंचाई पद्धति से कुल 2.1 हेक्टेयर क्षेत्र को सिंचित किया गया। इससे वहाँ सिंचाई तीव्रता में 164% तक वृद्धि हुई तथा किसानों की आर्थिक आय में ₹ 17,000/हे (तकनीक को लागू करने से पहले) से ₹ 1,10,272/हे तक यानि 6 गुना बढ़ोतरी हुई।

सिंचाई जल प्रबंधन पर अखिल भारतीय समन्वित अनुसंधान परियोजना: देश में भाकृअनुप-भारतीय जल प्रबंधन संस्थान कुल 26 एआईसीआरपी केन्द्रों के लिए एक समन्वय केंद्र के रूप में कार्य करता है। इस संस्थान के निर्देशन में इन समन्वित केन्द्रों द्वारा मृदा-पानी-पौधा संबंध एवं इनकी परस्पर प्रतिक्रिया पर बुनियादी अध्ययन तथा पानी की उपलब्धता का आकलन, अधिक वर्षा वाले क्षेत्रों में वर्षा जल प्रबंधन, भूजल आकलन एवं पुनःभरण, दवाब सिंचाई प्रणाली का मूल्यांकन, बागवानी एवं अधिक मूल्य वाली फसलों में जल प्रबंधन, नहरी जल एवं भूजल का संयोजी उपयोग तथा जल उत्पादकता बढ़ाने के लिए जल निकासी अध्ययन आदि विषयों पर प्रचार-प्रसार का अनुसंधान किया जाता है।

जल पर कृषि भागीदारी अनुसंधान मंच: भाकृअनुप-भारतीय जल प्रबंधन संस्थान जल पर कृषि भागीदारी मंच के लिए एक समन्वयक केंद्र के रूप में काम कर रहा है। इस अनुसंधान मंच के तहत कुल 6 परियोजनाएँ चल रही है, जो कि इस प्रकार है: भारत के विभिन्न कृषि पारिस्थितिकी क्षेत्रों में एकीकृत जल संसाधन विकास एवं प्रबंधन; स्वतः सिंचाई एवं ड्रिप-सिंचित केला की फसल में फर्टीगेशन; कृषि क्षेत्रों में अपशिष्ट जल के पुन: उपयोग के लिए उपाय; विभिन्न मछलीपालन उत्पादित पद्धतियों में जल के बहुआयामी उपयोग द्वारा जल बजट तथा जल उत्पादकता बढ़ाना; नहरी कमाण्ड क्षेत्र में सिंचाई पद्धति का मूल्यांकन तथा अधिक जल उत्पादकता में सुधार के लिए उपाय; तथा कृषि में जल के उपयोग को नियंत्रित करने के लिए संस्थागत एवं विपणात्मक नवाचार।

प्रकाशन, पुरस्कार एवं सम्मान: भाकृअनुप-भारतीय जल प्रबंधन संस्थान के वैज्ञानिकों ने वर्ष 2016-17 के दौरान कुल 39 शोध पेपर, 5 पुस्तकें/बुलेटिनों/प्रशिक्षण मैन्युअल एवं 7 लोकप्रिय तकनीकी लेख प्रकाशित किए। संस्थान के निदेशक डॉ. एस.के. अम्बष्ट एवं उनके सहयोगीयों को हिंदी में कृषि और संबन्धित विज्ञान में तकनीकी पुस्तक लेखन के लिए वर्ष 2015 के 'डॉ. राजेन्द्र प्रसाद पुरस्कार' से सम्मानित किया गया। प्रधान वैज्ञानिक, डॉ. एस.के. जेना एवं उनके सहयोगीयों को वर्ष 2013-14 के लिए भाकृअनुप का कृषि और संबंधित विज्ञान में उत्कृष्ट अनुसंधान अंतर-अनुशासनिक टीम के रूप में पुरस्कार प्राप्त हुआ। प्रधान वैज्ञानिक, डॉ. जी. कर को 'एकामरा श्री' पुरस्कार और 'हूकर पुरस्कार' से सम्मानित किया गया। डॉ. के.जी. मंडल, प्रधान वैज्ञानिक को भारतीय विज्ञान संस्थान और पश्चिम बंगाल की एकेडमी ऑफ साइंस एंड टेक्नोलॉजी के 'फैलो' के रूप में सम्मान प्राप्त हुआ। भाकृअनुप-भारतीय जल प्रबंधन संस्थान के अन्य वैज्ञानिकों ने भी सम्मान और कई पुरस्कार प्राप्त किए।

अनुसंधान परियोजनायें: भाकृअनुप - भारतीय जल प्रबंधन संस्थान के वैज्ञानिक 2 परामर्श परियोजनाओं के अलावा 23 संस्थान तथा 13 बाहरी वित्त-पोषित अनुसंधान परियोजनाओं पर कार्य कर रहे हैं।

प्रशिक्षण एवं क्षमता निर्माण: प्रधानमंत्री कृषि सिंचाई योजना (PMKSY) के तहत भाकृअनुप - भारतीय जल प्रबंधन संस्थान ने छह उन्नत क्षमता निर्माण कार्यक्रमों का सफल आयोजन किया। सात किसान-विशेषज्ञ बातचीत संबंधी सह-व्यावहारिक प्रशिक्षण कार्यक्रमों का आयोजन किया गया जिससे कुल 270 किसानों को लाभ मिला। इसके अलावा कृषि जल प्रबंधन के विभिन्न विषयों पर सरकारी अधिकारियों तथा छात्रों के लिए कई प्रशिक्षण कार्यक्रम भी आयोजित किए गए। साथ ही साथ 8 कृषि प्रदर्शिनीयों के माध्यम से कृषि जल प्रबंधन की तकनीकियों को विभिन्न स्थानों पर प्रदर्शित किया गया।

मेरा गाँव - मेरा गौरव कार्यक्रम: मेरा गाँव - मेरा गौरव कार्यक्रम के तहत भाकृअनुप - भारतीय जल प्रबंधन संस्थान के वैज्ञानिकों के छ: समूहों में ओडिशा राज्य के पाँच जिलों (पूरी, खुर्धा, ढेंकानाल, केंद्रापाड़ा एवं जगतसिंहपुर) से 30 गाँवों को अपनाया। इस कार्यक्रम के तहत जल प्रबंधन सहित कृषि के विभिन्न विषयों पर जागरूकता के बारे में जानकारी दी गयी तथा साथ ही किसानों के लिए कई प्रशिक्षण/संगोष्ठी/ बैठकों का आयोजन करके उनको लाभान्वित किया गया।

स्वच्छ भारत अभियान: भाकृअनुप - भारतीय जल प्रबंधन संस्थान ने स्वच्छ भारत अभियान में सक्रिय रूप से भाग लिया। संस्थान परिसर, आवासीय कॉलोनी, ओडिशा के केंद्रपाड़ा और जगतसिंहपुर जिलों में खेतों के अनुसंधान स्थलों पर सक्रिय रूप से कुल 30 साफ-सफाई अभियानों को वर्ष 2016-17 के दौरान आयोजित किया गया। इसके अलावा स्कूल को सफाई की महत्ता के बारे में भी बताया गया एवं कई वाद विवाद/सेमिनार/प्रशिक्षण कार्यक्रम भी आयोजित किए गए।

EXECUTIVE SUMMARY

Water and nutrient self-reliant farming system for rainfed areas: Generally, organic nutrition decreases grain yield compared to inorganic nutrition. However, groundnut and blackgram showed least decrease in rice equivalent yield (REY) due to organic nutrition, i.e., 14.4% and 18.1% than inorganic nutrition respectively, implying suitability of these crops for self-reliant farming system. Among the six test crops, highest REY (8.56 t ha^{-1}), net return (₹ 69,024 ha^{-1}) and net economic water productivity (₹ 32.67 m^{-3}) was found for cabbage followed by cowpea and groundnut. Net energy output was the highest for maize crop (40.3 GJ ha^{-1}) followed by groundnut.

Development of a runoff recycling model for productivity enhancement: In a developed runoff recycling model, water productivity increased from 5.96 ₹ m^{-3} in a system of rice cultivation only to 19.33 ₹ m^{-3} in the system comprising of multiple crop/ fish combinations viz. rice, papaya, greengram, blackgram, mustard, broccoli, cabbage and fish in the pond. Net return of the system increased by 4.5 times (₹ 1,80,000) compared to the rice- blackgram paira cropping.

Optimization of stocking density for shrimp (*Litopenaeus vannamei*): Higher stocking density significantly influences density-dependent growth, yield performance and water use in commercial shrimp aquaculture. From a range of different stocking densities of *L. vannamei*, 5,00,000 post-larvae ha^{-1} resulted significantly higher yield (10.58 t ha^{-1}), lower consumptive water use index (1.72 m^3 kg^{-1} biomass production), higher economic benefit (Output value to the cost of cultivation, 1.97) and net consumptive water productivity (₹ 83.3 m^{-3}).

Improving irrigation efficiency in canal command: The hydraulic evaluation of dug well at Ghurlijore minor irrigation command, Sundargarh, indicates that drawdown of the well was 36 cm hr^{-1} with recuperation rate of 3.0 cm hr^{-1}. Amongst different irrigation methods, sprinkler irrigation saved 12-30% irrigation water than furrow (320 mm) and flooding (400 mm) methods in groundnut. Similarly, with using 160 mm irrigation water from dugwell, the yield and irrigation water productivity of the greengram were 0.65 t ha^{-1} and 0.4 kg m^{-3}, respectively.

Improvement in water and fertilizer use efficiency through drip-fertigation in vegetables: Seasonal and diurnal variation of energy balance of rice crop was determined using eddy covariance technique. Water and fertilizer use efficiency of bittergourd, okra and potato was found to be increased by 35-42 and 30-40%, respectively through drip-fertigation as compared to surface irrigation with conventional fertilizer application method. Conjunctive use strategy under changing climate scenarios in Brahmani river basin was also developed.

Evaluation of drip systems for rice based cropping sequence: Yield of baby corn was the highest (2.16 t ha^{-1}) under full irrigation (FI, 100% ET_c), which was statistically at par with the yield (1.98 t ha^{-1}) under irrigation at 75% ET_c. In rice, the yield under drip irrigation at 100% ET_c produced 12% reduction in yield with 42% irrigation water saving, resulted in 55% higher water productivity compared to surface irrigation. For both the crops, 1.0 m lateral distance produced higher yields than 1.4 m.

Performance evaluation of rice cultivation methods: Field experiment on rice show that grain yield (3.62 t ha^{-1}) and water productivity (0.51 kg m^{-3}) of rice was significantly higher with supplemental irrigation (49.6 mm) than rainfed condition. Also, yield and water productivity enhanced by 19% in transplanted rice (3.76 t ha^{-1}, 0.55 kg m^{-3}) than direct-seeding. Higher yield was attributed to better crop growth and physiological performances in irrigated transplanted rice.

Computed virtual water footprint: Methodology for computing virtual water of animal and animal- based products has been standardized in Indian context under current and future climate scenarios. Virtual water of major crops of India was computed for different regions. Results revealed that due to higher productivity of rice in Punjab, virtual water footprint is low (1,485 m^3 t^{-1}), whereas in Madhya Pradesh (3,529 m^3 t^{-1}) virtual water footprint is comparatively higher owing to lower crop productivity and higher evapotranspiration. Also, methodology of computing water footprints of processed products was standardized.

Impact of super absorbent polymers (SAP) on crop growth of groundnut: A field experiment was conducted to evaluate different rate of SAP on crop growth and yield of groundnut. Initial results show insignificant impact of different rate of SAP on soil properties, crop growth and physiological performances.

Benchmarking for assessing the performance of canal irrigation system: Benchmarking is a useful tool for assessing the performance of any canal irrigation system. The benchmarking of data of Maharashtra state for 50 major, 33 medium and 36 minor irrigation projects were analyzed for the period of 1999-2000 to 2011-12 using system performance and agricultural productivity indicators.

Impact of climate variability on groundwater resources: A study to investigate how droughts affecting the surface and groundwater resources, contributing to the amplification of heat waves and warm spells in India was conducted. A multi-aspect framework of heat wave indices has been utilized to accommodate a wide range of impact sectors. Consistent with the simultaneous increase in dry and hot extremes over several regions of the world, the Indian subcontinent appears to have experienced the most severe hot episodes when preceded with a drier climate since 2002.

Design of groundwater recharge structures for hard rock areas: Bargharianala micro watershed of Nachipur Gram Panchayat, Daspalla block, Nayagarh, Odisha has been selected to study hydrological analysis, design and field evaluation of recharge structure in hard rocks. Water flow accumulation and direction was carried out using Digital Elevation Model (DEM). Based on the analysis, a site has been identified in Srirampur village for design and field evaluation of recharge structure.

Development of filters for wastewater use: A four chambered online hybrid small scale filter was designed and developed to reduce heavy metal content, sediments and microbial load from the urban wastewater. It has been evaluated in a farmer's field in peri-urban areas of Bhubaneswar. Filtration system was found effective during the post-rainy season and the system can be recharged through back washing.

Bioremediation of chromium from polluted water sources: Majority (82%) of water samples collected during monsoon season from different drainage streams at chromite mine areas in Sukinda, Odisha had chromium [Cr (VI)] toxicity, and unsafe for use. Investigation on its impact on vegetation shows significant reduction in leaf area index of rice crop grown near the drainage channels carrying mine effluents. Water culture study shows that aquatic plants viz., *Pistia stratiotes, Salvinia minima* and *Ipomoea aquatica* are promising in reducing 10-97% Cr-concentration from polluted water.

Development of optimization model for conjunctive use of surface and groundwater: An optimization model for crop planning was developed for maximizing net annual return for different blocks of Kendrapada district, considering constraints of land area, water availability from surface and groundwater resources and irrigation water requirement of different crops. Model suggests for *kharif* irrigated rice, the optimal area allocation should be in the range of 23.9- 51.2% to get maximum net return. Similarly, during *rabi* season the optimal area of 28.5- 81.7% should be allocated for *rabi* oilseeds under rainfed situation in different blocks.

Developed portable drum based drip irrigation system: A drum based drip irrigation system was developed and evaluated for vegetable cultivation. Yield of 24.8 t ha^{-1} of brinjal and 9.4 t ha^{-1} of ladies finger was obtained using this system. Nearly 100 m^2 area under vegetables can be irrigated using the system.

Efficient groundwater management under climate change in sugarcane farming system: Climate resilience irrigation system such as underground conveyance pipeline system was installed in 45 farmer's field and drip system in three farmers field nearing completion in Muzaffarnagar district, UP. The water budgeting was carried out for the study village. Construction of recharge cavities and check dam was undertaken near Rasulpur Jattan village. Several training programs related to various aspects of water management were also conducted at the study area.

Assessment of future climate scenario in coastal aquifers: Using downscaled products of global simulation models, future climate scenario in coastal aquifers of eastern India, drained by major rivers were assessed. It shows that future will be characterized by frequent dry-hot events to stress the water resources.

Impact of industrial wastewater on oilseeds crop: Assessment of surface water quality of Angul industrial area in Odisha revealed that most of the effluents from the industries were discharged during the monsoon season makes it unsuitable for use as irrigation to crops. A pot experiment was conducted to evaluate impact of using industrial wastewater in conjunction with freshwater on yield of sunflower crop during *rabi* season. The conjunctive use of 75% wastewater and 25% freshwater showed yield attributes and yield of sunflower at par with 100% wastewater irrigation.

Intensive horticultural system in degraded land: To improve water productivity and generate profits from degraded land, an experiment was conducted in pre-bearing mango orchard intercropped with papaya and pineapple under drip irrigation and paddy straw mulch. The plant height, canopy diameter and trunk girth of young mango plants were not affected significantly either by papaya and/ pineapple intercropping under drip irrigation and paddy straw mulching. However, in papaya, the canopy diameter was affected significantly. The mulching and intercropping with mango and papaya did not affect the vegetative growth of pineapple.

Delineation of waterlogged areas in eastern India for fitting in suitable crops and aquaculture: Analyses of P6- LISS-III imagery and topo sheet maps reveal that waterlogged area during November, 2014 increased in post-monsoon period in twelve districts of Bihar, West Bengal and Jharkhand. In East Medinipur and Howrah district in West Bengal along Rup Narayan river bank from study area of 2,86,100 ha, 928 ha area found suitable for *Typha* cultivation. Also, out of 92,452.61 ha study area of Baleswar district in Odisha, 607.87 ha was found suitable for integrated water chestnut-aquaculture farming.

Enhancing pulse productivity using micro-irrigation: Sprinkler irrigation at two critical crop growth stages of greengram *i.e.,* flowering and pod formation resulted in better crop growth compared to single irrigation at flowering and no irrigation. *Rhizobium* inoculation and nitrogen application @ 20 kg ha^{-1} through urea showed better crop growth than nitrogen application only @ 20 kg ha^{-1} and also no nitrogen.

Drainage planning of eastern coast delta: Drainage planning of eastern coast delta (Bhargabi-Daya doab) was done using geo-informatics tool. The mapping of water logging from LANDSAT images revealed that spread of waterlogged area on September, 2015 was 355.1 km^2 and reduced to 259.3 km^2 by October, 2015. The drainage coefficient found to be 48.3 mm d^{-1} for a return period of 10 years, if the crop is tolerant for 6 days submergence.

Suitable crops under wastewater irrigation: Studies conducted to understand metal-transfer from soil to crops, their accumulation in different parts of vegetables, so that suitable crops could be suggested under wastewater irrigated condition with least hazards on human health. Cadmium and Chromium are accumulated least in fruits and higher in leaves and roots among plant parts. Leafy and root vegetables (amaranth and radish) irrigated with heavy metals polluted water are risky for consumption, where fruiting vegetables (okra, ridge gourd, bitter gourd, tomato) are relatively safer for consumption.

Study on global yield gap of rice and wheat: Simulation modeling using APSIM shows that the yield gap of rice was estimated as 65.9% (5.59 t ha^{-1}) and 67.8% (4.83 t ha^{-1}) of the potential yield for Amritsar climatic buffer zone of Punjab and Kalyani climatic buffer zone of West Bengal, respectively. For wheat, yield gap was found to be 68.2% (2.95 t ha^{-1}) and 22.5% (1.33 t ha^{-1}) of the potential yield for Palampur, Himachal Pradesh and Patiala climatic buffer zone of Punjab, respectively.

Development of web-based expert system on agricultural water management: A web-based expert system development was initiated for agricultural water management including agriculture, horticulture, fisheries and animal husbandry. The data on cereal crops were compiled in the form of web pages. The web page formats for cereal crop was developed in open access PHP language for enhanced user friendliness on Wamp Server platform.

Evaluation of adoption and sustainability of water management technologies: Assessment of adoption and sustainability of water management interventions in different agro-ecological zones of Odisha was made. Mixed response was observed on the physical status of irrigation structures, their present day utilization, existing field practices and farmers' response. Acreage, production, development of farmer assets significantly improved due to water management interventions.

Livelihood improvement of tribal farmers through improved water management practices: For an improvement of farmer's livelihood, irrigation infrastructures were developed in the newly adopted village (Mahuljore village, Sadar block, Sundergarh district), as farmers suffer with unavailability of irrigation water during post-monsoon and summer season. Total 2.1 ha area brought under piped irrigation with pressurized irrigation system. The irrigation intensity increased by 164% and profitability increased by around 6-folds from ₹ 17,000 ha^{-1} (pre-intervention period) to ₹ 1,10,272 ha^{-1}. Three programs on capacity building were carried out in Birjaberna and Mohuljore village.

AICRP on Irrigation Water Management: ICAR-IIWM acts as a coordinating center of twenty six centers of AICRP-IWM to carry out basic studies on soil, water, plant relationship & their interaction and extension work in the field of assessment of water availability, rainwater management in high rainfall areas, enhancing productivity by multiple use of water, groundwater use at regional level, groundwater assessment and recharge, evaluation of pressurized irrigation system, water management in horticultural and high value crops, conjunctive use of canal and groundwater, and drainage studies for enhancing water productivity.

Agri-CRP on Water: ICAR-IIWM acts as a coordinating center of Agri-CRP on Water and six research projects are continued at this institute namely, Development and management of integrated water resources in different agro-ecological regions of India; Evaluation of irrigation system and improvement strategy for higher water productivity in canal commands; Automatic irrigation and fertigation in drip-irrigated banana; Eco-friendly wastewater treatment for re-use in agri-sectors: Lab to land initiative; Water budgeting and enhancing water productivity by multiple use of water in different aquaculture production systems; and Institutional and marketing innovations governing use of agriculture water.

Publication, awards and recognitions: During 2016-17, scientists of ICAR-IIWM published 39 peer reviewed research papers, 5 books / bulletins / training manuals and 7 popular articles. Dr. S.K. Ambast with associates received 'Dr. Rajendra Prasad Puruskar for Technical Books in Hindi in Agricultural and Allied Sciences, 2015'; Dr. S.K. Jena and team received 'ICAR Award for Outstanding Inter-disciplinary Team Research in Agricultural and Allied Sciences 2013-14'; Dr. G. Kar received Ekamara Shree Award and Hooker Award; Dr. K.G. Mandal admitted as Fellows of Indian Society of Agronomy and West Bengal Academy of Science and Technology (WAST). Scientists of ICAR-IIWM received many awards, honors and recognitions.

Research projects: Scientists of ICAR-IIWM working on 23 in-house and 13 externally-funded research projects along with two consultancy projects.

Training & capacity building: ICAR-IIWM conducted six advanced capacity building program under PMKSY; seven farmers-expert interaction cum-practical training programs benefiting 270 farmers; and several training programs for government officials and students on various topic of agricultural water management; eight exhibitions to showcase ICAR-IIWM technologies.

Mera Gaon Mera Gaurav: Six groups of scientists of ICAR-IIWM adopted 30 villages across 7 blocks spreading over 5 districts of Odisha under the '*Mera Gaon Mera Gaurav'* program. Scientists of ICAR-IIWM provided information on awareness on various areas in agriculture to the farmers of adopted villages and conducted several trainings/ interaction meetings.

Swachh Bharat Abhiyan: ICAR-IIWM actively participated in *Swachh Bharat Abhiyan* and organized thirty programs/ campaigns / cleanliness drives during 2016-17 covering institute campus, residential colony, on-farm research sites in Kendrapara and Jagatsinghpur districts of Odisha; motivated students for cleanliness; organized debate, seminars and trainings.

CONTENT

INTRODUCTION

The ICAR-Indian Institute of Water Management (erstwhile Directorate of Water Management or 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 institute 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 International Airport, Bhubaneswar. Thelocation of the Institute is at 20°15' N and 85° 52' E at 23 m 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

- Strategies for efficient management of on-farm water resources for sustainable agricultural productivity.
- Coordinate research for generating location-specific technologies for efficient use of water resources.
- Centre for training in agricultural water management.

Research achievements

Core research activities of the institute are carried out under five programs, viz., rainwater management, canal water management, groundwater management, waterlogged area management and on-farm research & technology dissemination to solve the agricultural water management related problems. The institute has experienced multi-disciplinary team of scientists.

Significant research achievements for the year 2016-17 include assessment of groundwater storage potential using NASA's GRACE satellites, development of water resource management plans for coastal areas in Odisha and delineation of waterlogged areas in Bihar using land use land cover (LULC) data of ISRO. Projects have been continued for development of drainage plan for Mahanadi delta and computing virtual water and water trade potential for agro-based products. There has been a considerable research work conducted towards development of runoff water recycling, and land modification technique for enhancing productivity, water and nutrient self-reliant farming system for rainfed areas; climate resilient agriculture, groundwater management for enhancing adaptive capacity to climate change, options for enhancing irrigation efficiency and development of integrated farming systems in canal commands, and water saving techniques in rice. With the aim of water budgeting and enhancing water productivity in aquaculture systems, stocking density of pacific white shrimp culture has been optimized. Significant research work has been carried out on drip irrigation systems for rice-based cropping, drum-based drip irrigation for vegetable crops etc. For management of waterlogged areas, drainage planning of eastern coast delta has been initiated. As an attempt to explore wastewater use in agriculture, a filter has been designed and developed for wastewater treatment. Studies are being carried out for bioremediation of polluted water, impact assessment of industrial wastewater, intensive horticultural system for improving farm income from degraded land, social and sustainability implications of water management interventions. A considerable work has been done for livelihood improvement of tribal farmers through water management intervention. Our institute has also initiated development of web-based expert system on agricultural water management.

Under the *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) of the Government of India, Institute has played a major role in capacity building for project implementing agencies of GoO, prepared district irrigation plan (DIP) for five districts of Odisha. In addition to research and development efforts at the Institute level, different agricultural water management related issues at the regional level are being addressed by different centres under the AICRP on Irrigation Water Management. Through ICAR-Agri-Consortia Research Platform on Water project, institute has successfully installed rubber dams in different agro-ecological regions of India, initiated improvement strategies for higher water productivity in canal commands, drip-irrigation in horticultural crops, eco-friendly wastewater treatment, multiple use of water in aquaculture production systems, addressing issues related to water governance and policy. With the aim of dissemination of technology and working with farmers, scientists are involved with thirty adopted villages across seven blocks in Odisha under *Mera Gaon Mera Gaurav* (MGMG) programme;conducted training programs for Government officials, farmers and students on various aspects of water management, participated in exhibitions to showcase Institute developed technologies.

Infrastructure facilities and organization

The institute 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 equipment for research activities. An engineering workshop 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 and LAN. The institute has its own web server and regularly updated website (www.iiwm.res.in). The entire network administration of the computers, internet and website management is looked after by the ARIS cell. The ARIS cell also accommodates a fully developed GIS laboratory. The air-conditioned library of the Institute has more than 2000 reference books and subscribes to 14 international and 6 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 ICAR-IIWM 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 Ground Water Board, Command Area Development Agency, Government of Odisha, WALMI, ORSAC to implement farmer friendly water management technologies in the region. In addition to ongoing in-house research projects, the institute is awarded with many sponsored/ collaborative projects by various organizations like Ministry of Agriculture, GOI; University of Nebraska, Lincoln, USA; and consultancy project by Odisha Watershed Mission for preparing District Irrigation Plan (DIP) under PMKSY. The institute is coordinating center for AICRP on irrigation water management and ICAR-Agri-Consortia Research Platform on Water, ICAR, New Delhi. Also, ICAR-IIWM has conducted ICAR entrance examinations for UG, PG, JRFand SRF at national level.

Finances

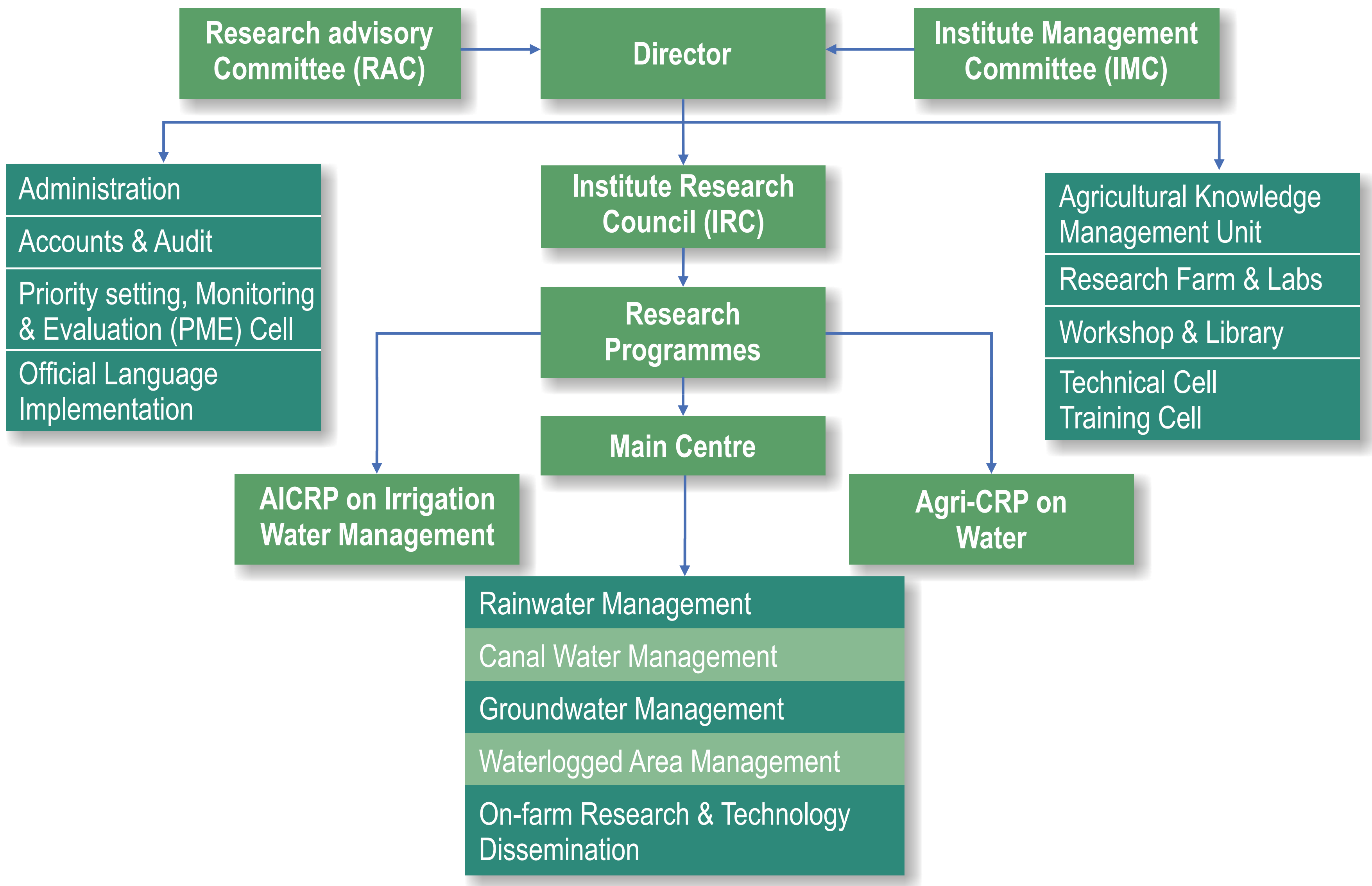
Summary of fund allocation, and expenditure during the year 2016-17 under plan and non-plan budget of the institute is presented at the end of this report.

Staff

At the end of March 2017, ICAR-IIWM had 80 sanctioned posts (including AICRP-IWM) out of which 56 are in position. The breakup of the posts under different categories is given below:

Cadre	Sanctioned	In Position	Vacant
RMP	01	01	nil
Scientific	35	28	07
Administrative	16	11	05
Technical	17	11	06
Supporting	11	05	06
Total	80	56	24

ORGANOGRAM


Research advisory Committee (RAC)
Director
Institute Management Committee (IMC)
Administration
Accounts & Audit
Priority setting, Monitoring & Evaluation (PME) Cell
Official Language Implementation
Institute Research Council (IRC)
Research Programmes
Main Centre
Agricultural Knowledge Management Unit
Research Farm & Labs
Workshop & Library
Technical Cell
Training Cell
AICRP on Irrigation Water Management
Agri-CRP on Water
Rainwater Management
Canal Water Management
Groundwater Management
Waterlogged Area Management
On-farm Research & Technology Dissemination

RAINWATER MANAGEMENT

Water and Nutrient Self-reliant Farming System for the Rainfed Farmers in High Rainfall Zone

Project Code: IIWM/15/168

Investigators: S.K. Rautaray, S. Mohanty, S. Raychaudhuri, R.K. Mohanty, R. Dubey and S. Pradhan

Identification of suitable dry season crops for self-reliant farming system

Blackgram, cowpea, groundnut, maize, cabbage, and *utera* blackgram were grown in sub-plots to identify suitable crop(s) for the dry season, 2016 after rice harvest. Two main plot treatments viz., inorganic and organic nutrition were continued which were initiated in *kharif* season. For organic nutrition, vermicompost was applied at 3175, 3968, 4127, 5460 and 9127 kg ha^{-1} for blackgram, cowpea, maize, groundnut and cabbage, respectively which were grown in sub-plots. The yield and the rice equivalent yield were highest for cabbage followed by cowpea, both under inorganic and organic nutrition. Highest rice equivalent yield was noted for groundnut crop and was 5.22 t ha^{-1} under inorganic nutrition and 4.47 t ha^{-1} under organic nutrition. In general, equivalent yield of test crops decreased in organic nutrition as compared to inorganic nutrition, except for *utera* blackgram. Such decrease in yield was highest in maize (25.2%) followed by cabbage (24.2%) and was the least in groundnut (14.4%) followed by blackgram (18.1%). This implies that these crops can be recommended for self-reliant farming system with organic mode of nutrition using farm generated compost. Moreover groundnut is an energy rich crop and haulm of groundnut and blackgram are protein rich fodder for livestock which is an integral part of self-reliant farming system. Net return as well as net economic water productivity were the highest for cabbage followed by cowpea (Table 1). Among the crops grown for seed purpose, groundnut crop gave highest net return i.e., ₹ 29,228 ha^{-1} under inorganic nutrition and ₹ 18,032 ha^{-1} under organic nutrition. Similar net return was obtained for blackgram crop. Net water productivity of groundnut and blackgram were similar under organic nutrition. Net energy was highest for maize followed by groundnut. Considering the net energy, net water productivity, net return, rice equivalent yield and percent yield decrease under organic nutrition, groundnut is identified as the best crop among the test crops under self-reliant farming system.

Table 1. Yield, net return, net energy and net economic water productivity of selected crops during *rabi*, 2016

Treatments	Yield (t ha^{-1})		Rice equivalent yield (t ha^{-1})			Net return (₹ ha^{-1})			Net energy (GJ ha^{-1})			Net economic water productivity (₹ m^{-3})		
Nutrition mode (NM)	Inorg	Org	Inorg	Org	Mean	Inorg	Org	Mean	Inorg	Org	Mean	Inorg	Org	Mean
Blackgram	1.12	0.92	3.87	3.17	3.52	27701	16375	22038	8.99	6.16	7.58	15.97	9.47	15.97
Cabbage	28.2	21.4	9.74	7.38	8.56	86845	51203	69024	4.72	4.84	4.78	32.67	19.23	32.67
Cowpea	10.9	8.4	7.54	5.82	6.68	61286	35445	48366	8.05	3.19	5.62	19.83	11.47	19.83
Groundnut	1.79	1.54	5.22	4.47	4.85	29228	18032	23630	20.14	17.77	18.96	8.60	5.33	8.60
Maize	4.14	2.10	3.90	2.92	3.41	12773	1011	6892	46.32	34.27	40.30	4.13	0.33	4.13
Utera*	0.18	0.21	0.61	0.71	0.66	1193	2693	1943	0.88	1.32	1.10	9.2	20.73	9.2
Mean	7.73	5.94	5.15	4.08	-	36504	20793	-	14.85	11.26	-	15.07	11.09	-
LSD (p=0.05)		-												
Nutrient		-		0.52			7542			0.97			NS	
Crop		-		0.38			5561			1.82			4.58	
Nut x Crop		-		0.54			7865			2.58			6.47	

*Utera blackgram was grown under the residual of inorganic and organic nutrition. Inorg-Inorganic nutrition, Org-Organic nutrition

Field view of different crops under self-reliant farming system

Water balance analysis of the farm pond under self-reliant farming system

Water level of the farm pond from July 2016 to March 2017 showed highest water level of 2.75 m in the monsoon season of 2016 and lowest level of 0.95 m on March 31, 2017. Total amount of water harvested at the end of monsoon was 9,932 m^3. About 36.5% of harvested water was lost through seepage and percolation followed by evaporation (26.3%) during the post-monsoon period. The remaining amount was utilized for crop production.

Economics of drip irrigation in banana and papaya grown on the dyke

On the dyke top, two rows of banana (cv. *Bantal*) were planted at 5 m x 2.5 m spacings. Between two rows of banana, one row of papaya hybrid 'Red Lady' was planted in diagonal pattern. At the centre of each square with 4 banana plants, a papaya was planted. Spacing between two papaya plants in a row was 2.5 m. A drip irrigation system was designed andinstalled for irrigating 3 rows of banana and papaya on each side. Two numbers of emitters with 4 litres hour^{-1} (lph) discharge capacity were provided for each plant.

The first year fruiting of papaya crop was 15.5 kg plant^{-1} while yield from second fruiting was 32.8 kg plant^{-1} with average yield of 24.15 kg plant^{-1}. Banana crop yielded 68.5 and 67.0 fingers plant^{-1} for the first and second year, respectively. Papaya was sold at ₹ 12 kg^{-1} and banana at ₹ 4 finger^{-1}. Gross income per annum from these two crops under drip (180 banana and 80 papaya plants) was ₹ 72,780. The gross income from surface irrigated system was ₹ 58,422. Thus, drip irrigated system gave additional ₹ 14,556 annual return. The cost of the drip irrigation system was ₹ 60,000. Assuming average life of the drip system as 8 years and 10% as annual depreciation value, the variable cost of the system for the first year was ₹ 6,750. Considering interest on borrowed capital as ₹ 3,000 and maintenance cost of ₹ 1,200, total cost for drip use for the first year was ₹ 10,950. Therefore, net benefit due to drip system was ₹ 3,606 with B: C ratio of 1.33.

Development of a Runoff Recycling Model for Production and Profit Enhancement through Alternate Land and Crop Management Practices

Project Code: DWM/12/157

Investigators: P.K.Panda, R.K.Mohanty and P.Panigrahi

The experiment was conducted in the Institute Research Farm at Mendhasal, Bhubaneswar under Deras minor command during 2016-17. Out of the total 9,700 m^2 system area, one water harvesting structure was constructed in 1200 m^2 area and portion of excavated soil was used for pond dyke and left over soil was used for construction of paraboloid heap at a distance of 7 m with 1 m height and 2 m base diameter. During *kharif* season, paddy (var. Lalat) was transplanted in the inter-row space of heaps, and recommended package of practices was adopted for rice cultivation. On the slope of heaps, cowpea (var. EC-4216) was grown for production of vegetable, fodder and to control soil erosion and promoting nitrogen fixation. On the pond dyke, papaya (var. Red Lady) was planted at distance of 2 m in a single row. In the harvested water, 1200 fish fingerlings of Indian major carps were released and recommended feeding schedule was followed. In *rabi* season, harvested water was used for growing mustard (var. NRCBH-101), cabbage (Indam-1299, F_1 hybrid), broccoli (CHB-1, F_1 hybrid), black gram (var. OBG-17) and green gram (var. OBGG-57) following their recommended package of practices in the inter-row spaces of the heaps after *kharif* rice. In *kharif* season, total of 4,860 m^3 of excess runoff was collected in water harvesting structure and was utilized for growing *rabi* crops (Table 2). From the on-dyke papaya plantation average raw fruit yield of 38. 6 kg $plant^{-1}$ was recorded. Mean fish growth was 427 g $fish^{-1}$ and the fish productivity was 2.97 t ha^{-1}. Water productivity was calculated to be 5.96, 9.45, 16.0 and 19.33 ₹ m^{-3} for rice only, rice- papaya, rice-papaya-fish and rice + papaya + fish+ greengram + black gram+ mustard+ broccoli +cabbage, respectively. With application of this technology, net income from the entire system increased to ₹ 1,80,000 ha^{-1}, which is 4.5 times higher than the existing standard practice of rice-blackgrampaira cropping.

Rice (*kharif*) and cabbage (*rabi*) in inter row space of heap

Table 2. Yield of various crops grown in the experiment

Name of crops	Variety	Yield (t ha^{-1})
Rice	Lalat	4.9
Cowpea	EC-4216 (green fodder)	20.6
Broccoli	CHB-1	8.00
Cabbage	Indam-1299	40.7
Mustard	NRCBH-101	1.30
Blackgram	OBG-17	0.98
Greengram	OBGG-57	1.00

Density-Dependent Water Use in Coastal Aquaculture of *Litopenaeus vannamei*

Project Code: IIWM/15/175

Investigators: Rajeeb K. Mohanty, D. K. Panda and P. Panigrahi

An attempt is being made to quantify the consumptive water use (CWU), total water use (TWU), total crop water requirement (TWR) and consumptive water use index (CWUI) of commercially important *Litopenaeus vannamei* (Pacific white shrimp) at varying intensity levels to ensure higher water productivity and profitability. The main objectives of this study are: to study the effect of different stocking densities on the consumptive and total water requirement of Pacific white shrimp *(Litopenaeus vannamei)* in monoculture system, and to study the impact of varying intensification levels on water quality, sediment load, water productivity, growth and production performance of *Litopenaeus vannamei.* Results of an experiment conducted during 2016 show that density-dependent TWR was 3.02, 3.25, 3.75 ha-m in T_1 (400000 post-larvae ha^{-1}), T_2(500000 post- larvae ha^{-1}) and T_3 (600000 post- larvae ha^{-1}) respectively, while the CWU was 1.63, 1.82 and 2.34 ha-m in T_1, T_2 and T_3 respectively (Fig. 1). As density increases, TWU and CWU increases due to increased necessity of water replenishment. Evaporation & seepage losses contribute significantly to CWU. On an average, evaporation loss was 0.56-0.68 m^3 water kg^{-1} bimass of *L. vannamei* while, the seepage loss was 0.47-0.57 m^3 water kg^{-1} biomass of *L. vannamei*. The estimated CWUI was 1.78, 1.72 and 2.10 in T_1, T_2 and T_3 respectively. Size of shrimps at harvest was 28.2g, 26.1g and 24.4g in T_1, T_2 and T_3 respectively and the recorded productivity (t ha^{-1}) was 9.15, 10.58 and 11.13 in T_1, T_2 and T_3 respectively.

The shrimp pond water quality suitability index or hydrological index (HI) that expresses the overall water quality in a given place and time infers that regulated / less water exchange (T_2) improves the overall suitability of water quality for shrimp culture. Water quality suitability index (WQSI) up to 90 days of culture (DOC) range between 7.5-9.0 in T_1 and T_2, was very good, needs little management while in the last month of rearing it was good (5.5-7.5) with moderate management requirements (Fig. 2). The estimated net total water productivity (NTWP, Rs. m^{-3}) was 45.0, 46.6 and 37.8 in T_1, T_2 and T_3 respectively, while the net consumptive water productivity (NCWP, Rs. m^{-3}) was 83.4, 83.3 and 60.5 in T_1, T_2 and T_3 respectively (Fig. 3). Output value to the cost of cultivation (OV: CC) was 2.05, 1.97 and 1.78 in T_1, T_2 and T_3 respectively.

Density-dependent growth and yield performance takes place at higher intensity levels, probably due to mutual competition for food and space that cause physiological stress, resulting in slow growth, size-heterogeneity and weight distribution of shrimp, which ultimately affects the water productivity. Lower the density, higher was the feeding efficiency (FE) and lower was the apparent feed conversion ratio (AFCR). Higher the density, higher was the sedimentation rate/load that ranged between 40.4-56.6 m^3 t^{-1} biomass in monoculture of *L. vannamei* under varying intensity levels. 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 stocking density (post-larvae (PL) m^{-2}) that gives significantly higher yield, economic benefit (OV: CC) and NCWP is 5, 00,000 post-larvae ha^{-1}.

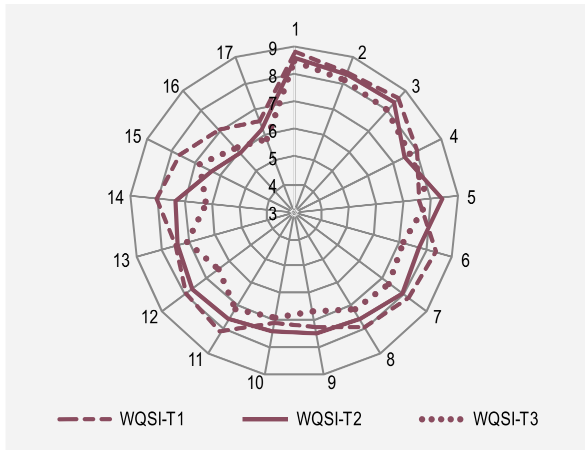


Fig. 2. Treatment-wise weekly water quality suitability index (WQSI)

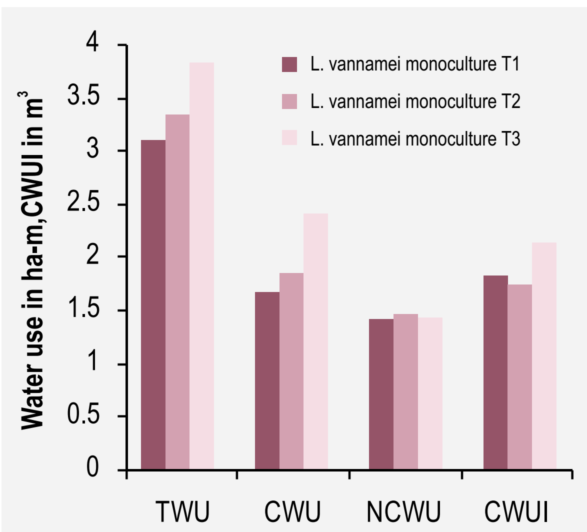


Fig. 1. Density-dependent water use for *Litopenaeus vannamei*. TWU-total water use, CWU-consumptive water use, NCWU-net consumptive water use, CWUI-consumptive water use index.

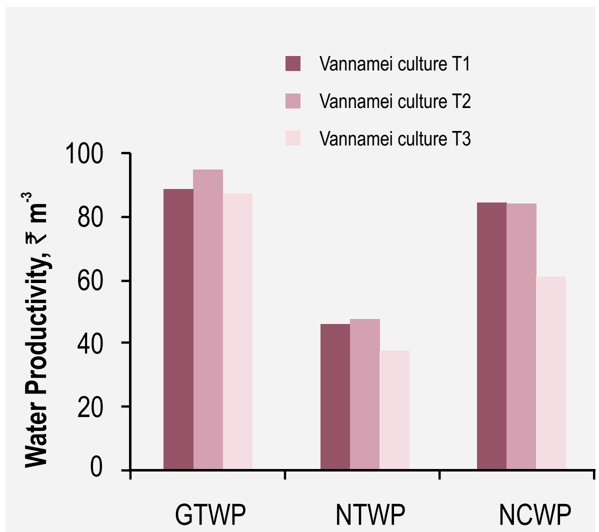


Fig. 3. Treatment-wise water productivity in monoculture of *L. vannamei*. GTWP- gross total water productivity, NTWP-net total water productivity, NCWP-net consumptive water productivity

CANAL WATER MANAGEMENT

Feasibility Study of Enhancing Irrigation Efficiency through Improved Surface and Pressurized Irrigation Methods with Adjunct Service Reservoir and Open Dugwell

Project Code: IIWM/15/172

Investigators: R.K. Panda, R.R. Sethi, S.K. Rautaray, R.K. Mohanty and P. Panigrahi

During 2016-17, assessment of available water resources in the canal linked service reservoir and dug well along with the crop plan was taken up in the study area (Ghurlijore minor irrigation command of Sundargarh district, Odisha) under the project. The total rainfall at the study site was 700 mm during July-September. The study on hydraulics of dug well at the study site during post-monsoon season revealed that the average drawdown and recuperation rate of the well were 36 cm hr^{-1} and 3 cm hr^{-1}, respectively. The surface spreading areas of the canal linked service reservoir was 2.31 ha with average depth of ponding of 1.65 m, and 1.05 ha with average depth of ponding of 0.58 m during monsoon and post monsoon season, respectively (Fig. 4).

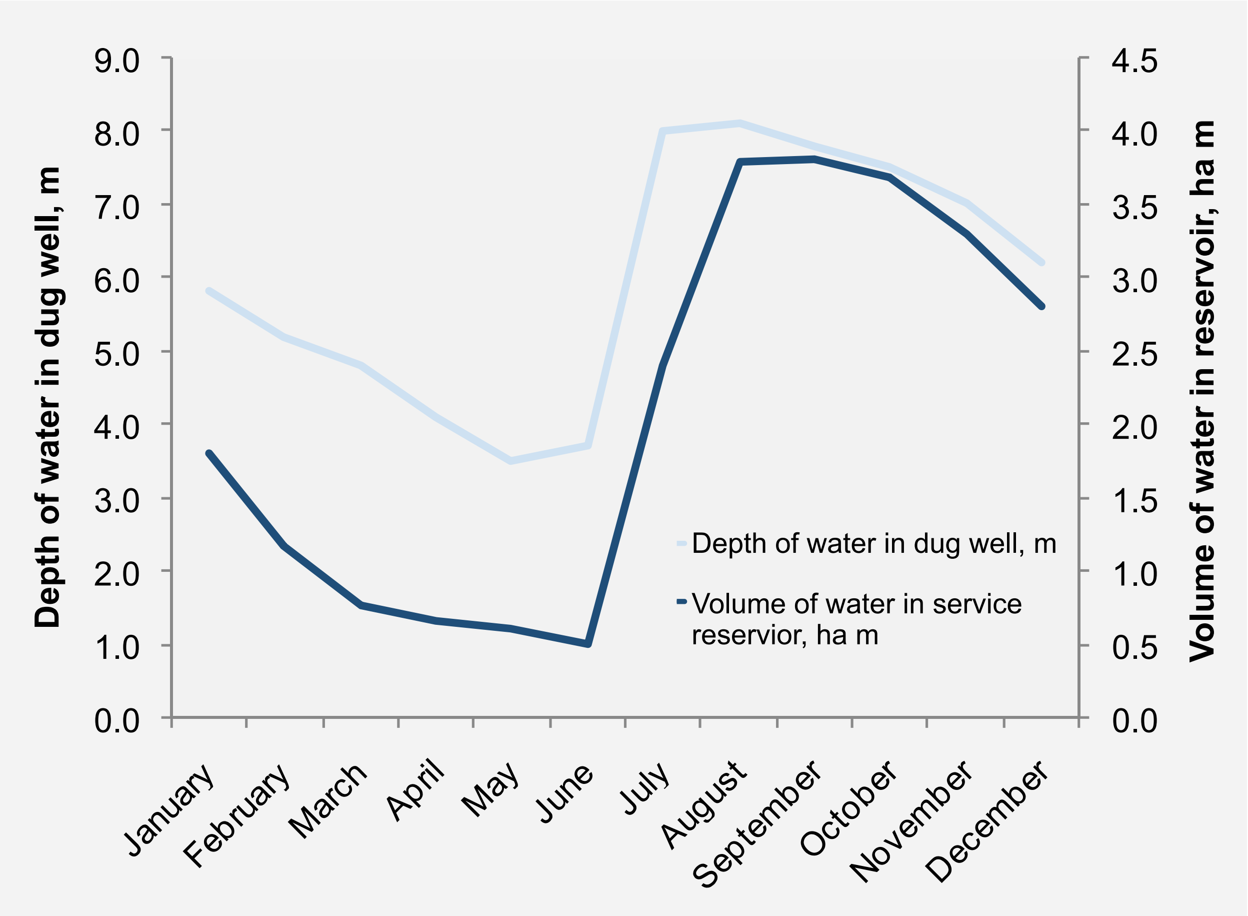


Fig. 4. Depth of water in dug well and volume of water in service reservoir during different months at the study site

Impact of service reservoir along with the dugwell on water productivity

Impact of the service reservoir along with the dugwell in total command area is 2.1 ha was studied in both *kharif* and summer seasons. Due to late transplanting of *kharif* paddy (cv. Swarna), monsoon rain could not be available during the later stage of the crop. However, with two supplemental irrigations (10 cm each) from dug well and canal linked surplus reservoir, the yield and irrigation water productivity of the paddy were 3.5 t ha^{-1} and 1.75 kg m^{-3}, respectively (Table 3). After paddy, groundnut (cv. Smruti) and greengram (cv. K-851) were grown during dry season. The water from dugwell was used in groundnut through sprinkler irrigation, whereas water from service reservoir was used with flooding and furrow irrigation in the crop. Sprinkler system with 7 numbers of irrigation saved 12.5% and 30% irrigation water compared with furrow irrigation (320 mm) and flooding (400 mm), respectively. The groundnut crop is yet to be harvested. However, in green gram, 0.65 t ha^{-1} yield was harvested with using 160 mm irrigation water from dug well, resulting in 0.4 kg m^{-3} irrigation water productivity.

Table 3. Yield and water productivity during *kharif* and summer crops

Season	Crops	Crop area (ha)	Total water used (Irrigation + Effective rainfall) (mm)	Water supplied from source (mm)		Yield (t ha^{-1})	Water productivity (kg m^{-3})
				Dug well	Service reservoir		
Kharif	Paddy cv. Swarna	2.10	851.8	100	100	3.50	0.41
Summer	Green gram cv. K-85	10.25	160.0	160	-	0.65	0.40

Impact of service reservoir in pisciculture activities

Low input-based fish culture was undertaken in the service reservoir to enhance the economic output and water productivity under the system. During the year, fish fingerlings of IMCs (*Catla catla, Labeo rohita* and *C. mrigala*) were stocked in the first week of August @ 7,500 ha^{-1} with a stocking composition of 30:30:40 and mean body weight (MBW) of 20, 13 and 12 g, for *Catla*, *Rohu* and *Mrigal*, respectively. After 210 days of rearing, the average MBW was observed as 950.0 g, 620.0 g and 650.5 g for *Catla, Rohu,* and *Mrigal,* respectively. Total harvested biomass was 2.42 t ha^{-1}, with highest contribution by *C. catla* (48%) followed by *C. mrigala* (32%). The performance index and apparent feed conversion ratio for different species was 232.2-288.8 and 1.38, respectively.

National Innovations for Climate Resilient Agriculture (NICRA)

Externally funded project: NICRA, ICAR, New Delhi

Investigators: G. Kar, S. Mohanty, P.S.B. Anand, D.K. Panda, A. Raviraj, R.D. Rank and P.K. Singh

Seasonal and diurnal variation of energy balance of rice using eddy covariance technique

Using eddy covariance technique, seasonal variation of net radiation (Rn), latent heat flux (LE), sensible flux (H) and soil heat flux (G0) were determined (Fig. 5). The ratio of latent heat flux to net radiation, LE/Rn, reached a maximum value (0.75) during peak growth stage of rice. The ratio of sensible heat flux to net radiation, H/Rn was maximum (0.63) at initial vegetative stage and reached a minimum value of 0.34 during panicle to boot leaf stage; on seasonal average, H/Rn was 22%, LE/Rn was 63%, and G0/Rn was 12%. The course of G was affected by the development of crop canopy or LAI, declined trend during peak growing stage. From panicle initiation stage to boot leaf stage, the Bowen ratio (H/LE) was almost constant and did not vary much, which suggests partitioning surface available energy (Rn−G0) into sensible and latent heat flux at constant rate at these stage. At senescence stage, again the β ratio is higher due to more sensible heat flow than latent heat flux. Taking a seasonal average, the Bowen ratio was 0.32 (Fig. 6). The evaporative fraction was also found to be higher at booting stage of crop growth.

Diurnal energy partitioning i.e. diurnal cycles of surface energy fluxes like net radiation, sensible heat flux, latent heat flux, soil heat flux was determined at four different growth stages, (i) tillering stage (ii) panicle initiation stage (iii) booting stage, and (iv) milking stage. The solar radiation penetrates considerably after 08:00 h for the surface warming so that positive value of Go is obtained only from 09:00 hrs. The diurnal variation is characterized by a crossover from negative to positive values in the early morning (7.00 AM) occurrence of maximum around noon (12.00-12.30 PM) and return to negative values in the late evening (6.30 PM).

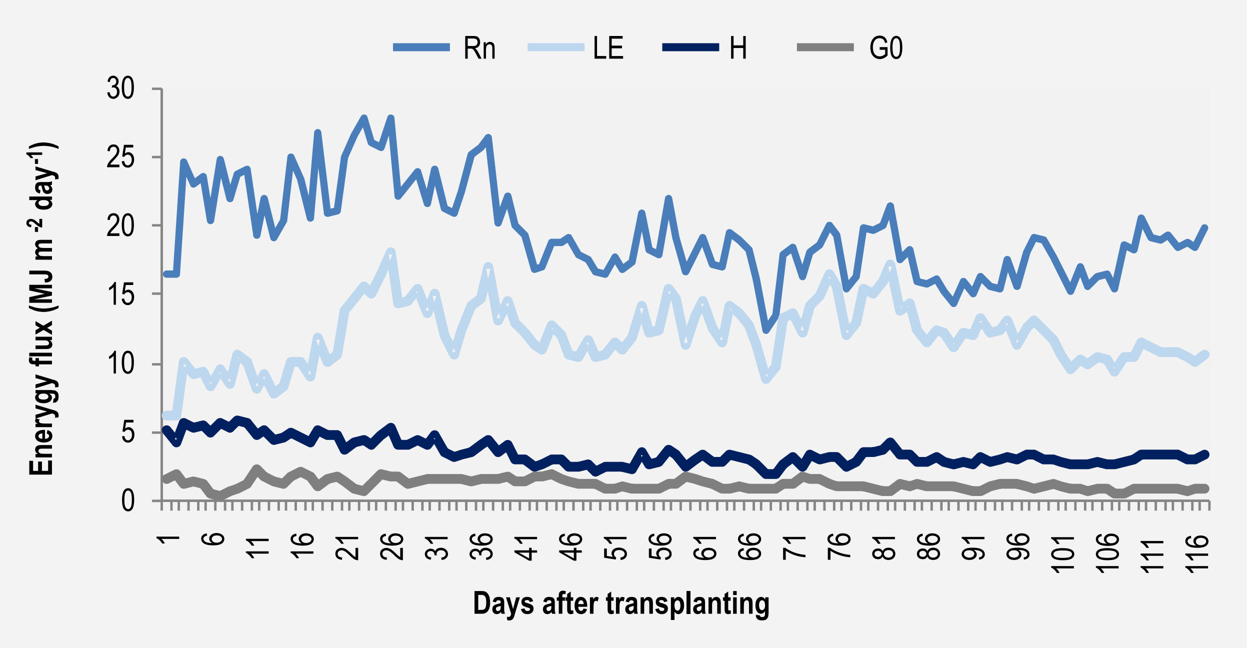


Fig. 5. Seasonal variation of surface energy balance components

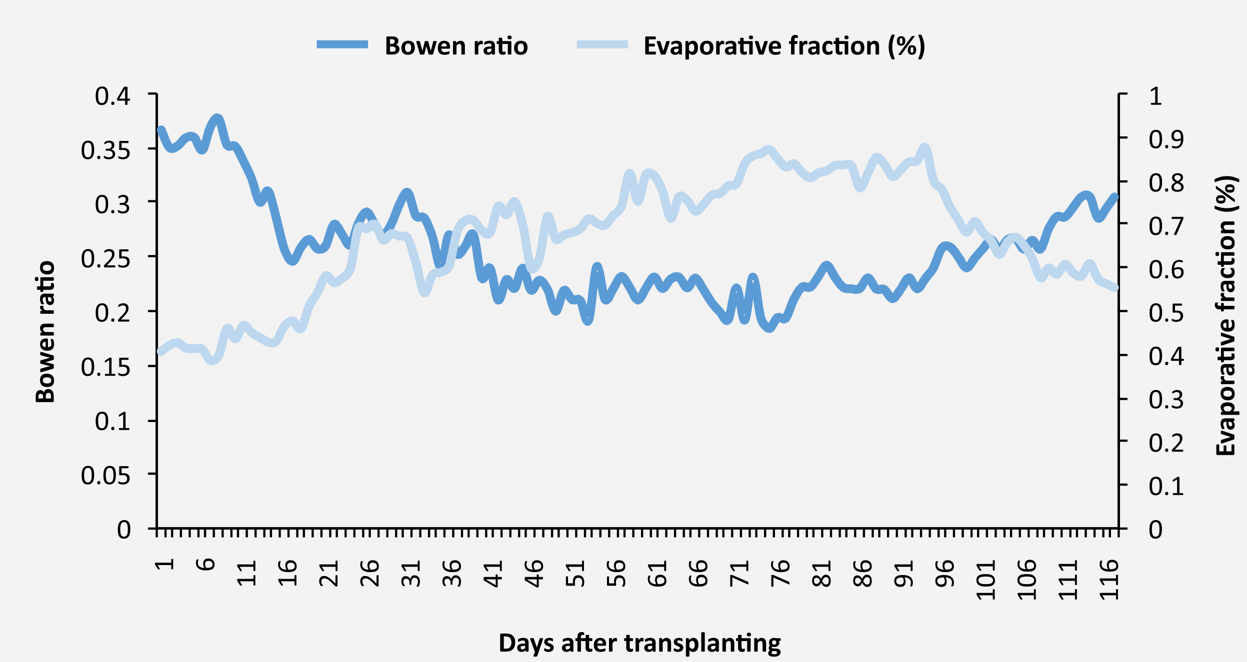


Fig. 6. Seasonal variation of Bowen ratio and evaporative fraction (%) of rice

Fertigation in vegetable based farming system to develop climate resilient agriculture

To improve the water and nutrient use efficiency under drip and surface irrigation, on-farm experiments on drip-fertigation were conducted on bittergourd, okra and potato in separate fields with various treatments (Table 4). The irrigation was applied through drip under 80% ETc along with soluble fertilizer (19:19:19 N, P_2O_5, K_2O) at different doses. Study revealed that drip + 100% RFD through fertigation was the best to improve the yield but statistically at par with the treatment of drip + 80% RFD fertigation.

Table 4. Comparison of crop productivity of vegetable crops under drip-fertigation and soil application of fertilizers

Treatments	Bitter gourd Fruit yield (t ha^{-1})	Okra Fruit yield (t ha^{-1})	Potato Tuber yield (t ha^{-1})
T1: Surface irrigation + 100% RDF (soil application)	7.10	7.60	9.40
T2: Drip + 100% RDF (soil application)	7.90	10.90	14.30
T3: Drip + 100% RDF (fertigation)	11.40	12.80	20.90
T4: Drip + 80% RDF (fertigation)	10.10	13.20	17.90
T5: Drip + 60% RDF (fertigation)	8.20	11.10	13.90
LSD (P= 0.05)	1.75	1.35	2.97

Development of conjunctive use strategy under changing climate scenarios in Brahmani river basin

The Badajor watershed, Hindola block, Dhenkanal, Odisha present within Brahmani river basin was selected for the study. The total area of the watershed is 188 km^2. The unconfined aquifer in the study area with a thickness of 12.5 to 18.5 m is underlain by hard rock with granite and gneiss as the dominant rock formation. The canal system in the watershed is fed by Sapua dam and Nuabaga barrage. A feeder canal from the Sapua dam supplies about 1 cumec of water to the Nuabaga Barrage. Sapua right main canal and Sapua left main canal originates from Nuabaga barrage. Command area of Sapua link canal is 1450 ha in *kharif* and 350 ha in *rabi*. The design command area of the Sapua right main canal is 1192 ha in kharif and no area under *rabi*. The design command area of the Sapua left main canal is 561 ha in *kharif* only. Delineation of drainage lines in the watershed is presented in Fig. 7. The drainage density of the watershed was found as 1.48 km km^{-2} and stream frequency was 1.72 km^{-2}. Elongation ratio, form factor and circulatory ratio of the watershed were 0.53, 0.22 and 0.41, respectively. The analysis of 21 years (1995-2015) data of CGWB on groundwater levels during pre-monsoon and post-monsoon seasons indicates that the correlations between the monsoon rainfall and rise in water level in the monsoon season were 0.56 and 0.43 at Hindola and Rasol, respectively. Monthly groundwater monitoring was carried out in 16 open dug wells in the watershed. The groundwater level during May, August and November, 2016 were 2.7-14.0 m, 0.6-7.82 m and 1.01-9.52 m below ground level, respectively. Daily gauging of runoff in monsoon season at Giridhariprasad village Indicated that the highest average daily discharge (5.13 m^3 sec^{-1}) was occurred in August and the flow continued upto mid-January. Based on the conceptual model developed, the groundwater model setup for the unconfined aquifer underlain by hard rocks in the study area was done using Visual MODFLOW software.

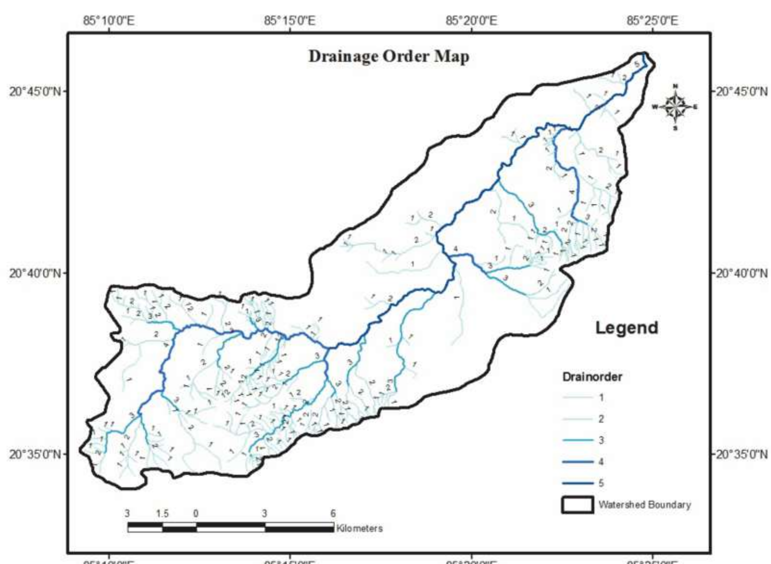


Fig. 7. Drainage order map of the study area

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

Project Code: DWM/12/158

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

Field experiments were conducted at ICAR-IIWM Research farm, Mendhasal, Bhubaneswar during 2016-17 to evaluate the performance of baby corn and summer rice (*aerobic*) under drip irrigation laid out at 1.4 m and 1.0 m lateral spacing with differential irrigation scheduling. Irrigation was scheduled at 100% ET_c (Full irrigation, FI), 75% ET_c, 50% ET throughout the crop growing season and 50% ET_c except knee height stage (KHS) to pre tussling (PT) stage for baby corn; whereas for summer rice, irrigation was scheduled at 125% ETc, 100% ETc and 75% ETc and compared with surface irrigation at 40 kPa (2-3 DAD).

The system hydraulics of drip irrigation was found satisfactory with mean emitter flow rate variation (Q_v) of 4%, co-efficient of variation (CV) of 5% and distribution uniformity (DU) of 95%. Irrigation was applied to baby corn once in two days during March to May. The water applied under different treatments varied from 195 mm to 390 mm. The higher soil water content (15-28%, v/v) and available nutrients (N, P and K) at 0-45 cm depth was observed with FI. However, soil water content and available nutrients below 45 cm depth did not affected significantly under different irrigation treatments. The higher level of irrigation with 1.0 m lateral spacing resulted higher rate of photosynthesis, stomatal conductance and transpiration of leaves, and higher nutrients (N, P and K) uptake in baby corn. The growth and yield performance of the crop as well as water productivity (WP) under different irrigation regimes and lateral layouts are presented in Table 5. Drip irrigation at 100% ET_c with 1.0 m lateral spacing produced the highest yield of baby corn which was statistically at par with the yield under irrigation at 75% ET_c. Irrigation at 50% ET_c produced 24-30% reduction in yield with 40-52% improvement in water productivity compared with FI.

Table 5. Vegetative growth, yield and IWP of baby corn under drip irrigation

Treatments		Vegetative growth			Yield parameters				Irrigation (mm)	WP (kg m^{-3})
		Plant height (m)	LAI at harvest	Plant girth (cm)	Yield of cob (t ha^{-1})	Yield of baby corn (t ha^{-1})	Yield of fodder (t ha^{-1})	TSS of baby corn (^{o}Brix)		
DI_{100}	L_1	1.12	5.5	6.50	6.69	1.71	30.11	8.79	390	0.44
	L_2	1.20	6.8	6.57	8.17	2.16	32.43	8.66	390	0.55
DI_{75}	L_1	1.01	5.3	6.26	6.44	1.66	28.51	9.74	293	0.56
	L_2	1.13	6.6	6.38	7.83	1.98	29.13	9.13	293	0.67
DI_{50}	L_1	0.88	4.4	5.87	5.77	1.31	24.36	7.17	195	0.67
	L_2	0.99	5.2	5.79	6.17	1.48	25.24	7.36	195	0.76
DI_{50}	L_1	0.93	4.9	5.99	6.27	1.54	24.97	7.88	255	0.60
EKHS to PT	L_2	1.08	5.4	5.85	6.73	1.64	25.63	7.91	255	0.64
$CD_{0.05}$	I	0.03	0.18	0.11	0.14	0.22	1.17	0.5		
	L	0.008	0.10	ns	0.33	0.38	0.72	ns	----	----
	IxL	0.07	0.38	1.03	0.57	0.77	1.08	0.8		

DI_{100}: Drip irrigation at 100% ET_c, DI_{75}: Drip irrigation at 75% ET_c, DI_{50}: Drip irrigation at 50% ET_c, L_1: 1.4 m lateral distance; L_2: 1.0 m lateral distance; EKHS: Except knee high stage and PT: Pre-tasseling stage; WP: Water productivity

The response of summer rice (*aerobic* rice, 'Apo') to different level of irrigation and lateral lay out indicated that the higher vegetative growth of the plants were observed under surface irrigation. The grain yield under drip irrigation at 100% ET_c (5.28 t ha^{-1}) was marginally lower (10-13%) with 42% water saving compared to surface irrigation (Table 5). However, irrigation water productivity under drip irrigation was 55% higher than that under surface irrigation. Lower lateral-to-lateral distance (1.0 m) under drip irrigation produced better plant growth and grain yield in rice. The drip-irrigated plot had higher (60–85%) weed infestation compared with surface irrigated plots. The available nutrients (N, P and K) content below 60 cm soil was significantly higher under surface irrigation. Drip-irrigated plants developed finer roots with shallow rooting depth (20-25 cm) compared with plant under surface irrigation (40 cm). Overall, drip irrigation with 1.0 m lateral spacing in rice-capsicum-baby corn cropping sequence produced the net profit of ₹ 3,35,000 ha^{-1} with benefit-cost ratio of 3.35 compared with net profit of ₹ 76,000 ha^{-1} with benefit-cost ratio of 1.62 under surface irrigation in rice-rice cropping sequence in the region.

Drip-irrigated baby corn (left) and rice fields (right) under the experiment

Enhancing Water Productivity through Water Management in Transplanted and Aerobic Rice in Canal Command Area

Project Code: IIWM/15/174

Investigators: K.G. Mandal, A.K. Thakur, R.R. Sethi, M. Raychaudhuri and R.K. Panda

A field experiment was conducted on rice during *kharif* season 2016 at the Institute research farm, under Deras minor command, to study the effects of rainfed cultivation and supplemental irrigation to two types of cultivation systems viz. direct seeding (DS) and transplanting (TP) with var 'Khandagiri'. In every treatment, rice crop was grown with recommended rate of N, P_2O_5 & K_2O @ 80, 40 & 40 kg ha^{-1}, manual weeding and plant protection measures against inset-pests and diseases. Water balance parameters were monitored through drum culture techniques. It was estimated that the average percolation (P), evaporation (E) and transpiration (E) rate was as 1.2, 3.2 and 4.3 mm d^{-1}, respectively excluding the rainfall received (249 mm) during the period (28 August – 2 October, 2016) of active crop growing. Crop physiological and yield parameters were determined for the crop receiving different treatment combinations. Results show that grain yield (3.62 t ha^{-1}) and water productivity (0.51 kg m^{-3}) of rice was significantly higher with supplemental irrigation of 49.6 mm in addition to rainfall than rainfed condition (Table 6). Water requirement was estimated for irrigated and rainfed conditions; it was slightly higher in irrigated due to receiving of one supplemental irrigation in the irrigated crop. Both yield and water productivity enhanced by 19% in transplanted rice (3.76 t ha^{-1}, 0.55 kg m^{-3}) than direct-seeding. Higher yield was attributed to better crop growth and physiological processes of the crop i.e. better leaf area index (LAI 2.84) during panicle initiation, SPAD chlorophyll meter reading (42.2 at tillering and 43.3 at panicle initiation) and interception of photosynthetically active radiation (PAR 66.4-76.2%) in irrigated-transplanted rice. Consequently, yield components viz. number of spikelet per panicle (118) increased with better grain-filling (80%) than rainfed-direct seeded rice.

Table 6. Yield and water productivity of rice as influenced by cultivation methods and supplemental irrigation

Treatments	Grain yield (t ha^{-1})	Straw biomass (t ha^{-1})	Water productivity (kg m^{-3})
DS (rainfed)	3.06c	5.81a	0.46b
TP (rainfed)	3.54b	5.38b	0.54a
DS (suppl. irrig.)	3.26bc	5.92a	0.45b
TP (suppl. irrig.)	3.98a	5.64b	0.56a

DS: direct-seeding; TP: transplanting; Values with different letter in a column differ significantly as per DMRT at 5%

A view of the experimental plots having rice at the seedling stage

A view of transplanted and direct-seeded rice divided with irrigation channels

Inter-Regional Virtual Water Trade in India through Agro-based Products

Project Code: IIWM/15/173

Investigators: G. Kar and P.K. Panda

Impact of elevated temperature on virtual water of some winter season crops

As per the multi-model analysis (IPCC7) and the ranges derived from the concentration-driven CMIP5 model simulations, the increase of global mean surface temperatures for 2081–2100 relative to 1986–2005 is projected to be 0.3°C to 1.7°C (RCP2.6), 1.1°C to 2.6°C (RCP4.5), 1.4°C to 3.1°C (RCP6.0), 2.6°C to 4.8°C (RCP8.5). Impact of elevated temperature on virtual water footprints (m^3 t^{-1}) of some animal based products under scenario of RCP 8.5 was computed (Table 7).

Table 7. Impact of elevated temperature on water footprints (m^3 t^{-1}) of some animal based products under scenario of RCP 8.5

Products	Current VW (m^3 t^{-1}) 2010	2050 (RCP 8.5)	% increase from current	2070 (RCP 8.5)	% increase from current	2095 (RCP 8.5)	% increase from current
Milk	1212	1253	3.4	1290	6.5	1352	11.2
Milk powder	5611	5824	3.8	6009	7.1	6321	12.2
Cheese	6013	6211	3.3	6421	6.8	6832	13.5
Goat meat	4765	4909	3.0	5096	6.9	5364	13.4
Sheep meat	5590	5802	3.8	5974	6.8	6374	13.8
Chicken meet	5760	5950	3.3	6160	6.9	6485	12.9

Virtual water of rice in different states of India

The term 'virtual water' is also known as 'embedded water', 'exogenous water' or 'ultraviolet water', which refer to the volume of water the buyer essentially imports (virtual) when a commodity (or service) is traded. Since the water outflows like seepage, percolation etc. are not a loss to the catchment, these types of water flows are not included for accounting water footprint. Accordingly, the virtual water of rice for different major rice producing states of India was computed and are presented in Fig. 8. It revealed that virtual water footprint of rice is low (1485 m^3 t^{-1}) in Punjab due to higher productivity, whereas it is higher (3529 m^3 t^{-1}) in Madhya Pradesh owing to lower productivity and higher evapotranspiration.

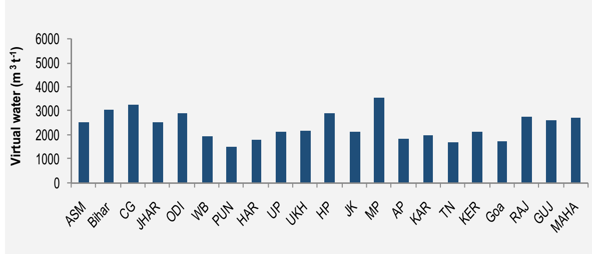


Fig. 8. Virtual water of rice (m^3 t^{-1}) in different states of India

Computation of water footprint when a primary crop is processed into two different products or more

As a case study, water footprints of rapeseed-mustard was computed when it is processed into two different products like crude oil and oil cake. If one tonne of rapeseed produces 0.34 t of crude oil and 0.63 t of oil cake, then the product fraction (α) of rapeseed crude oil is 0.34 t t^{-1} of rapeseed and production fraction of rapeseed oil cake is 0.63 t t^{-1} of rapeseed. Taking the national average market value of rapeseed oil as ₹ 95,000 t^{-1} and rapeseed oil cake is ₹ 40,000 t^{-1}. The total market value of rapeseed oil is, thus, 30,600 ₹ t^{-1} and the market value of rapeseed oilcake is 22,050 ₹ t^{-1}. The total market value produced is ₹ 52,650. Hence the value fraction (β) of rapeseed crude oil is 0.58 and for the rapeseed oil cake it is 0.42. Hence, water footprint of rapeseed crude oil is 6823 m^3 t^{-1}, and water footprint of rapeseed oilcake is 2667 m^3 t^{-1}.

Enhancing Yield and Water Productivity in Rice Fallows of Eastern India through Super Absorbent Polymers (SAP)

Project Code: IIWM/16/182

Investigators: S. Pradhan, O.P. Verma, A.K. Thakur, S.K. Ambast

A field experiment was conducted during the *rabi* season of 2016-17 at the ICAR-IIWM research farm to evaluate the effect of super absorbent polymer (SAP) on growth, yield and water productivity of groundnut (cv. Smruti). The treatments [SAP100 (100 kg SAP ha^{-1}), SAP75 (75 kg SAP ha^{-1}), SAP50 (50 kg SAP ha^{-1}), SAP25 (25 kg SAP ha^{-1}) and C (No application of SAP)] were laid out in randomized complete block design with four replications. The groundnut was grown in a plot size of 5 m × 4 m with a spacing of 30 cm × 20 cm. Soil moisture sampling in the root zone was done through gravimetric sampling at frequent intervals to know the 50% soil moisture depletion at the root zone for irrigation purposes. Irrigation to individual fields was given by pipe using 1hp pump at 50% soil moisture depletion.

Analysis of initial soil samples of the site showed that pH varied between 4.7 to 5.5, EC between 0.05 to 0.09 dS m^{-1}, organic carbon between 0.61 to 0.17%, bulk density between 1.55 to 1.75 Mg m^{-3}, available K between 179 to 128 kg ha^{-1} and available N between 269 to 235 kg ha^{-1} in the 0 to 60 cm soil depth. Root zone soil moisture varied between 49 (SAP25) to 64 (in control) mm at 36 days after sowing (DAS), 38 (SAP25) to 48 (SAP100) mm at 54 DAS, and 48 (SAP100) to 60 (SAP50) mm at 87 DAS. Plant canopy spread ranged between 11 (SAP25) to 12.2 (control) cm at 43 DAS, 25 (SAP75) to 27.3 (SAP100) cm at 66 DAS, and 37.8 (SAP75) to 43.2 (SAP25) cm at 87 DAS. Plant height ranged between 10 (SAP25) to 11.9 (SAP100) cm at 43 DAS, 19.1 (SAP50) to 20.8 (control) cm at 66 DAS, and 31.6 (SAP75) to 34.9 (SAP25) cm at 87 DAS. The percentage of intercepted photosynthetically active radiation by the canopy varied between 18 (control) to 26 (SAP75) at 57 DAS and 53 (SAP100) to 65 (SAP25) at 87 DAS. The leaf area index increased from a mean value of 0.42 at 57 DAS to 2.08 at 87 DAS. The greenness of plants as measured by SPAD 502 plus chlorophyll meter varied between 38.8 (SAP100) to 42.7 (SAP25) at 57 DAS and 34.8 (SAP50) to 38.6 (SAP25) at 80 DAS.

Groundnut crop growth in control (left) and SAP100 treatment (right) at flowering stage

Benchmarking of Public Irrigation Schemes for Improving Performance of Irrigated Agriculture

Project Code: IIWM/16/177

Investigators: A. Mishra, A.K. Nayak, D.K. Panda, P. Nanda and S.K. Ambast

Benchmarking of irrigation schemes though has been recommended as an effective management tool for continuously monitoring the performance using a set of indicators, very little information on time series analysis of the benchmarking data has been found in the literature. There is a need to identify the grey areas and factors which can improve the performance of the schemes based on the analysis. Therefore, during the year under report, the benchmarking data of Maharashtra state was analyzed using few indicators recommended by INCID. The plan group wise number of projects selected for the benchmarking is listed in Table 8. Indicators were analyzed using the data collected for the years from 1999-00 to 2011-12. The indicators used to analyze the historical data on benchmarking are as follows: For System performance [Annual irrigation water supply per unit command area (m^3 ha^{-1}), Annual irrigation water supply per unit irrigated area (m^3 ha^{-1})] and for Agricultural productivity [Agricultural annual output per unit command area (₹ ha^{-1}) and Agricultural annual output per unit irrigated area (₹ ha^{-1}), and Agricultural annual output per unit irrigation water supply (₹ m^{-3})].

Table 8. Plan-wise number of projects selected for benchmarking data analysis

Sl. No.	Plan Group	Water availability (m^3 ha^{-1})	Major	Medium	Minor	Total
1	Highly deficit	<1,500	1	5	5	11
2	Deficit	1,500-3,000	13	9	10	32
3	Normal	3,000-8,000	23	13	13	49
4	Surplus	8,000-12,000	3	2	2	7
5	Abundant	>12,000	10	5	6	21
	Total		50	33	36	119

Indicator 1: Annual irrigation water supply per unit irrigated area

The average annual irrigation water supply per unit irrigated area for major, medium and minor irrigation projects are 12637, 13778 and 10,108 m^3 ha^{-1}, respectively (Fig. 9). All the irrigation projects have higher values than the state norms i.e. 7,692 m^3 ha^{-1} for major and medium projects and 6,667 m^3 ha^{-1} for minor projects. In other words, by adhering to the state norms, the actual irrigated area could be increased in all type of irrigation (major, medium and minor) systems. From 1999-00 to 2002-03, all the projects follows similar trend and the values are in descending order from major to medium to minor. In medium irrigation project the value exceeds that of major projects from 2004-05 to 2011-12 as the irrigation water supply in medium projects increased in surplus and abundant plan groups. In case of minor projects, a smooth trend all over the year is seen and the value remains always lesser than that of major and medium projects. Analysis of this indicator with regard to plan group wise gives better knowledge about the deviation of trends in specific years.

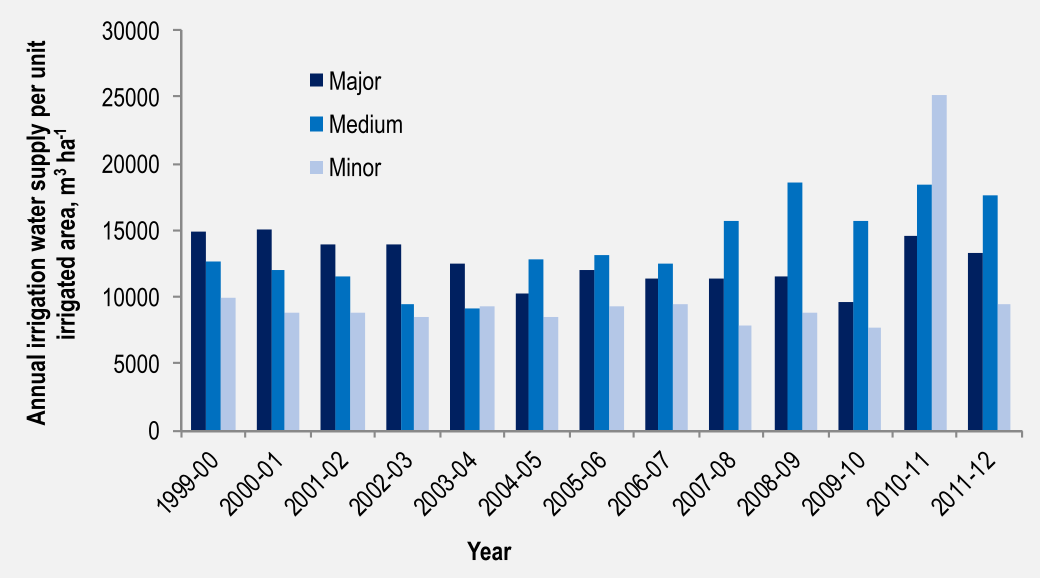


Fig. 9. Annual irrigation water supply per unit irrigated area in major, medium and minor irrigation projects

Indicator 2: Ratio of irrigation potential utilized (IPU) to irrigation potential created (IPC)

The average annual ratio of irrigation potential utilized to potential created for major, medium and minor irrigation projects are 0.84, 0.58 and 0.61, respectively (Fig. 10). There is very large gap between potential created and utilized for all the irrigation projects. The overall reasons for less utilization are (i) low water yield in the reservoirs, (ii) diversion of irrigation water to non-irrigation uses, (iii) tendency of farmers to grow high water intensive crops like sugarcane, banana etc., (iv) low utilization during *kharif* (rainy) season, (v) reduction in storage capacity of reservoirs due to silting, (vi) lapses in assessment of the irrigated area in the command, (vii) non-accounting of irrigated area outside the command (influence area), (viii) poor maintenance of the infrastructure due to financial constraints, and (ix) non-participation of beneficiaries in irrigation management. In case of major irrigation projects, the ratio exceeds 1 in few years due to additional area brought under irrigation because of river lifts, wells and nalas which were not included in created potential of projects. The ratio of IPU/IPC has very little significance in assessing perfromance of irrigation water use within a project. It is estimated using the projections of IPC and IPU, which are based on the expected and acutal water availability in the reservoirs after the monsoon season. Besides these indicators, annual agricultural output per unit command area, annual agricultural output per unit irrigated area etc. were also analyzed.

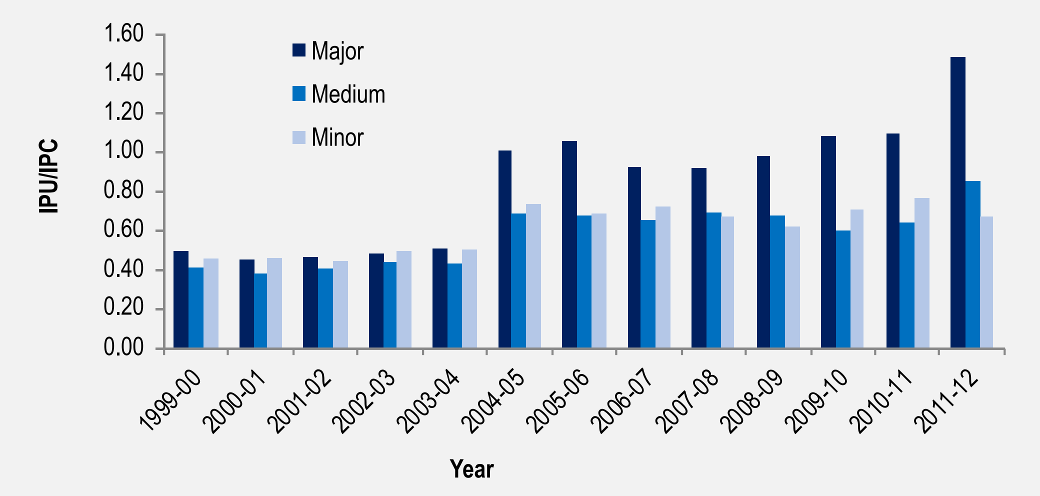


Fig. 10. Annual irrigation potential utilized (IPU) to irrigation potential created (IPC)

GROUNDWATER MANAGEMENT

Impact of Climate Variability and Anthropogenic Factor on Groundwater Resources of India

(ICAR Challenge research project associated with LBS award, 2011)

Investigator: Dileep K. Panda

The human-induced projected global warming and consequent climate variability suggest that the frequency and intensity of dry-hot events would rise in the coming decades. India, home to over 1.2 billion population, mostly engaged in agriculture and outdoor activities would be highly vulnerable. Thus, the heat wave number (HWN), heat wave duration (HWD, days), heat wave frequency (HWF, days), heat wave amplitude (HWA, °C) and heat wave magnitude (HWM, °C) during three periods, viz. 1951-2013, 1981-2013 and 1998-2013, were examined to understand whether and to what extent heat waves and warm spells in India have changed since the mid-twentieth century. HWN represents the total number of heat wave events satisfying the 3-day criteria of extreme temperature, while the length of the longest event is identified by HWD, and that the sum of the participating heat wave days by HWF. The intensity and magnitude of heat wave are represented by the hottest day of the hottest event (HWA) and the average daily magnitude of all the identified heat waves (HWM).

Consistent with the widely reported post-1980 faster rate of warming around the world, present study also shows significant increases in the daytime and nighttime heat waves during 1981-2013, compared to the whole period. A more prominent signal is manifested in HWN, HWD, and HWF, from the prospective of climate change and heat wave detection. Particularly, HWF generates the most robust pattern, followed by HWN, even though it is difficult to determine whether the cumulative change reflected in HWF is due to HWN and/or HWD. This is similar to the characteristics observed the North America and Australian heat waves. Nevertheless, it is important to understand the physical relevance of heat wave intensity (HWA and HWM), although their trends are not statistically significant. Because, even a small increase in amplitude when the atmospheric humidity is high, can trigger panics in human beings and other living organisms.

Results show that most of the recent hot spells have occurred either coinciding the drought year or in the succeeding summer season. Note that the 2002 daytime heat wave aspects exhibit a reasonable spatial agreement of meteorological moisture stress and hot spells over the diagonal strip from northwest to southeast (Fig. 11). Similarly, the spatial extension of the 2009 heat wave suggests a nationwide incidence, with the daytime heat wave number (HWN) and frequency (HWF) registering record values during the study period. Overall, strong coupling of soil water deficit and temperature is likely to have translated into hot extremes, including the record-breaking hot episodes in 2015.

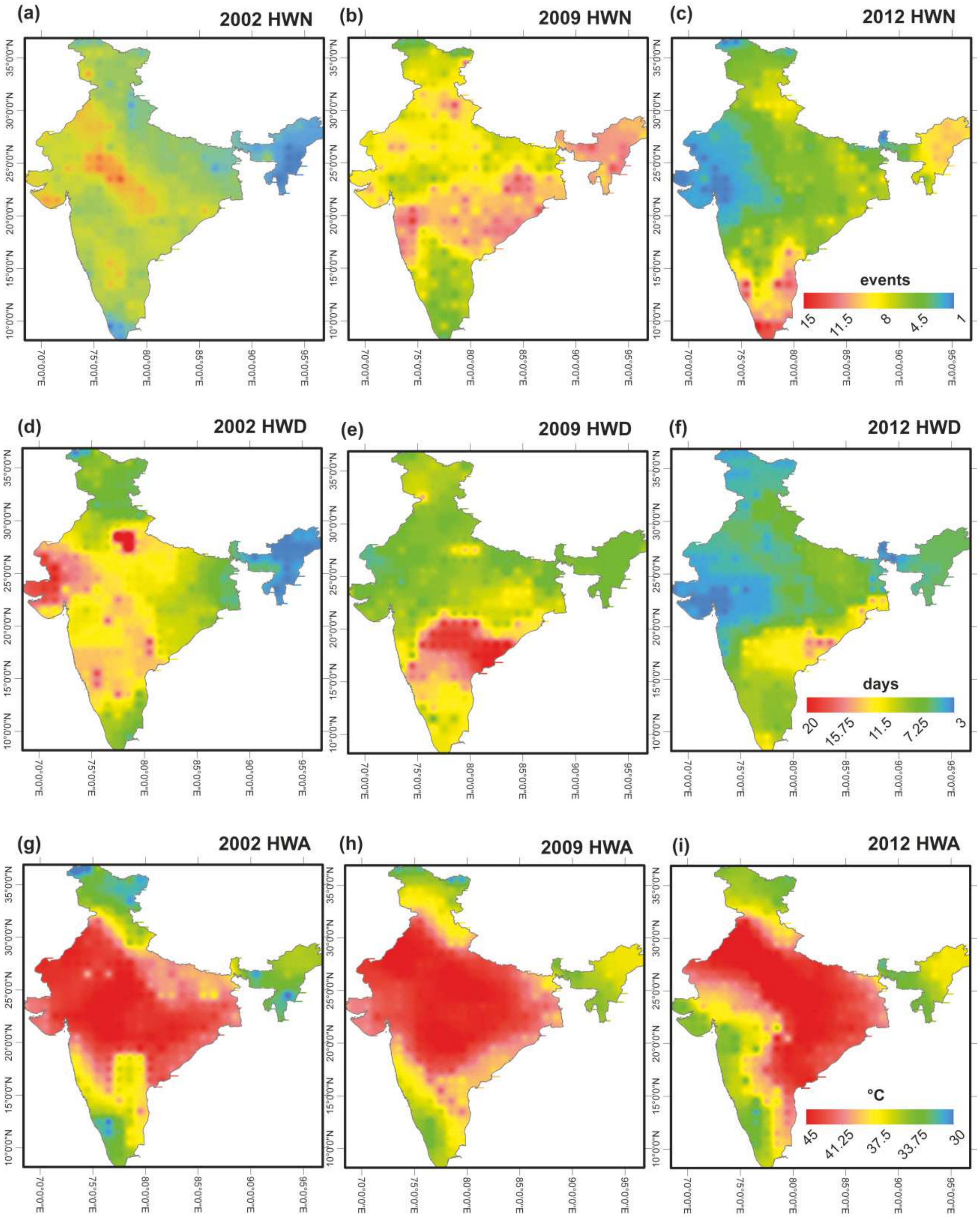


Fig. 11. Spatial distribution of the daytime heat wave number (HWN) (a)-(c), heat wave duration (HWD) (d)-(f) and heat wave amplitude (HWA) (g)-(i) for the drought years of 2002, 2009 and 2012.

Design and Field Evaluation of Groundwater Recharge Structures in Hard Rock Areas

Project Code: IIWM/16/180

Investigators: Ranu Rani Sethi, M. Das, B. Panda and S.K. Ambast

Barghariana la micro watershed (84° 50' 14" E to 84° 52' 14" E; 20° 20' 51" N to 20° 22' 16" N) was selected in Nachipur G.P, Daspalla block in Nayagarh district. The study site belongs to the western central plateau agro-ecological zone of Odisha. The area is dominated by hard rock aquifer. Total geographical area of the watershed is 637.45 ha. Only one stream i.e. Baraghariana la flows through the watershed and joins with Kuanria river. Preliminary survey indicates presence of 38 numbers of farmponds, 14 tube-wells and 29 dug wells within the watershed.

Basic information of the study area was collected from the Department of Soil Conservation and Watershed Management, Govt. of Odisha. The SOI Toposheet (73O/15) includes the Barghariana la micro-watershed boundary, village boundary, contour maps and drainage maps were prepared from the base maps by using ARC GIS 10 software. Land use land cover classification showed that 538.07 ha area is under crop (84.4%) followed by shrub (dense cover land) 64.47 ha (10.11%) and shrub (dense open land) of 15.31 ha (2.42%) (Fig. 12).

Digital elevation model (DEM) was delineated from Shuttle Radar Topography Mission (SRTM) 30 m resolution data from USGS earth explorer site (Fig. 13). Hydrological analysis i.e. flow accumulation, water flow directions and flow length were carried out from DEM. The surface elevation of the watershed varied from 111 to 248 m. Major portion of the watershed is under gentle (<9%) to moderate (9-15%) slope. Forest area has steep slope (15-30%).

In order to design and evaluate the recharge structure, a location was identified in Srirampur village within the watershed. Three numbers of water harvesting structures located in the diversion canal in Srirampur village was selected for detailed study. The storage capacities of these structures were calculated as 7455, 5005 and 1980 m^3. Water level during monsoon, post-monsoon and summer season was monitored and volume of water available during October-December 2016 and January-March 2017 were quantified. A construction of recharge well was proposed in this location for monitoring its effect on groundwater level. In order to study the area of influence of the recharge structure and water harvesting structures, 15 numbers of monitoring well of 6 m depth were installed in 5, 10, 20, 30 and 40 m distance from the recharge structure. Weekly monitoring is being made since January 2017 on water level in monitoring wells and water table depth in dug wells which are located within 100 m distance from the structure.

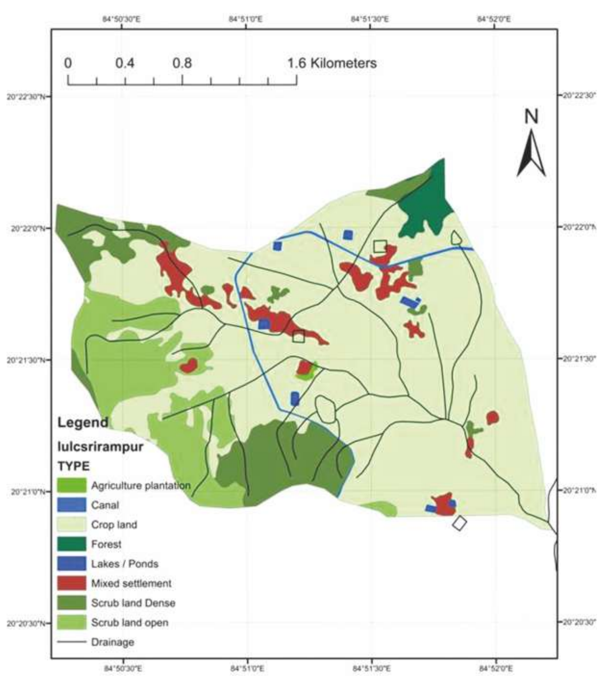


Fig.12. Land use land classification of Barghariana la micro-watershed

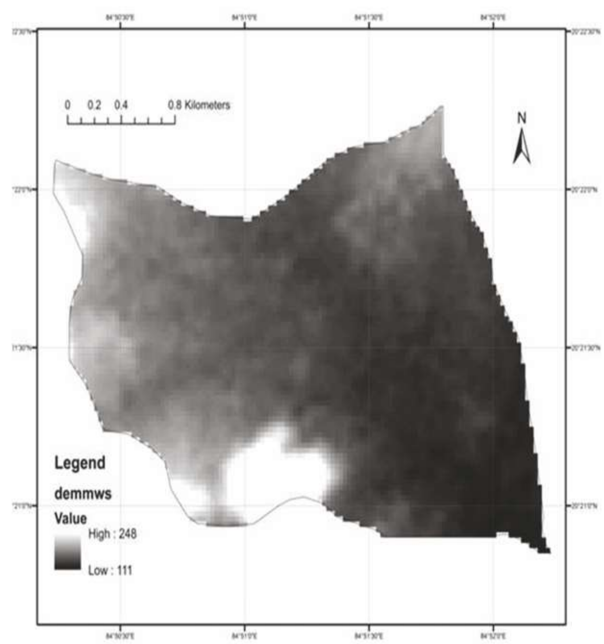


Fig. 13. Digital elevation model (DEM) for Barghariana la micro-watershed

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

Investigators: Mausumi Raychaudhuri and S. Raychaudhuri

A four chambered filter has been developed using coarser and finer materials to reduce turbidity, microbial load, BOD and heavy metals from the wastewater. Batch test was conducted in the laboratory to understand the adsorption and desorption capacity of the designed filter for heavy metals viz. Cd, Cr, Pb and Ni. Five prototype of the filtration system was prepared keeping the components in the same ratio and then charged with 50 ppm concentration of Cd, Cr, Pb and Ni separately and also in combination @ 800 ml $hour^{-1}$ to study the adsorption mechanism. Filtered samples were collected at every 10 minutes till 1 hour and then after every hour. Amount of heavy metal adsorbed by the filtration system when charged in combination was estimated and presented in Fig. 14. It has been observed that the affinity for adsorption was in the order $Cr^{6+} > Pb^{2+} > Cd^{2+} > Ni^{2+}$. Hourly adsorption of heavy metals revealed that maximum adsorption of Cr^{6+} took place for 33 hours, and its quantity was estimated as 1.50 mg g^{-1} of the filtration material. After the filtration beds were saturated with the heavy metals then batch test was conducted and it has been observed that 9.1 litre of fresh water g^{-1} of the filtration bed is required to desorb Cr^{6+} from the filter.

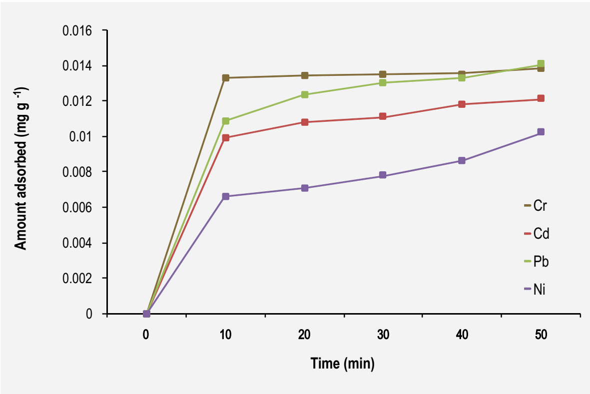


Fig. 14 Adsorption curve of heavy metals in the filtration bed

The filter was evaluated at farmer's field at Jaypurpatna village of Khurda district, Odisha where municipal wastewater was used for irrigation to papaya crop. The discharge from the filter varied from 0.19 to 0.23 ls^{-1}. The average discharge of the dripper was 1.45 lh^{-1} with uniformity coefficient of 95.1%. No clogging in the drippers was reported during February to June, 2016 owing to the use filtered wastewater for irrigation. The same filter was demonstrated to the farmers of peri-urban areas who are using municipal wastewater for cultivation of horticultural crops. This small filter was also demonstrated to the line departments for safe use of municipal wastewater for irrigation.

Filtered wastewater used for drip irrigation to papaya at farmer's field

Developing the Process for Remediation of Chromium from Polluted Water Sources

Project Code: IIWM/15/171

Investigators: Madhumita Das, S. Roy Chowdhury, P.S. Brahmanand and K. Laxminarayana

Exploring the occurrence of Cr (VI) in Sukinda area

Twenty two water samples covering upstream, mid and lower stream portions of outlets (Nallas) of eight micro watersheds delineated at the surroundings of chromites mine areas at Sukinda, Odisha were collected during monsoon season of 2016. On the basis of threshold Cr (VI) concentration level, 82% water samples were found not suitable for agriculture.

Comparative growth of rice in chromite mine areas

The rate of net photosynthesis of rice crop varied from 17.17 to 19.10 µmol CO_2 m^{-2} s^{-1} in the area which was away from wastewater carrying drainage channels, and from 16.73 to 19.10 µmol CO_2 m^{-2} s^{-1} in the area which was close to drainage channel; rate of transpiration ranged from 5.8 to 6.5 and 5.6 to 6.5 mmol H_2O m^{-2} s^{1} in the corresponding areas. However, the leaf area index of rice showed a significant decline from average 3.54 to 2.11 showing the adverse effect on crop growth due to chromium mine wastewater.

Susceptibility of commonly growing aquatic plants to Cr-concentration in sub-humid Odisha

Pot experiment was carried out at varied concentrations of Cr (VI) as $Cr_2O_7^{-2}$ ranged from 0.3 to 1.0 mg L^{-1} by growing

Pistia stratiotes, Water lily*, Hydrilla verticillata, Salvinia minima* and *Ipomoea aquatica* for a period of 38 days of imposing Cr treatments (0, 0.1, 0.5 and 1.0 mgL^{-1}) in water under net house condition. Illustration of plant weight against Cr concentration at different dates of observations revealed as follows: Salient results are presented here under:

Pistia stratiotes reduce Cr concentration of water by 45 to 97% in 38 days; plant biomass reduced by 18 to 30%.

Water lily reduced the Cr concentration only in 38 days; biomass reduction was 47 to 51%; thus this species is not suitable to withstand Cr enriched situation.

Hydrilla verticillata showed 5 to 49% decrease of Cr, reduction of biomass by 71 to 75% within 13 days of imposing Cr treatment in the water; eventually this species was found not suitable for removing Cr from the water.

Salvinia minima conversely indicated a positive growth rate with the application of Cr with 13 to 87% reduction of Cr in water and biomass increase in 38 days.

Ipomoea aquatica revealed a 10 to 89% reduction in Cr with 6 to 20% loss of biomass within the same water culture period.

Threshold level of Cr (VI) for *Pistia stratiotes*

An experiment was carried out with water culture in 0.6 m^3 capacity concrete tank by growing *Pistia stratiotes* with five different concentrations of Cr(VI) viz. 0, 0.2, 0.4, 0.6 2.5 and 6.5 mg L^{-1} as $Cr_2O_7^{2-}$ for a period of 40 days under net house conditions. Plant biomass was increased at different magnitudes up to 25 days of imposing treatments and decreased thereafter irrespective of treatments. A second experiment was again conducted with eleven levels of Cr (VI) for a period of 70 days under net-house situations. Plant biomass was enhanced with time across the levels of Cr up to 2.0 mg L^{-1}, and decreased after 43 days of imposing treatments in general, at different rates and magnitudes with time. But it was decreased beyond 2.0 mg Cr mg L^{-1} and reduced to a minimum after 70 days of imposing treatments (Table 9). The Cr concentration under different treatment was also decreased in a tune of 55 to 92% over its respective initial levels and indicates 2.0 mg L^{-1} as threshold tolerance levels of Cr (VI) in aqueous media.

Table 9. Biomass of *Pistia stratiotes* with time and across the Cr(VI) concentration levels

Cr (VI) conc. (mg L^{-1})	Plant biomass (g pot^{-1})									
	Observation dates									
	Nov. 29, 16	Dec. 6, 16	Dec. 13, 16	Dec. 20, 16	Dec. 27, 16	Jan. 3, 17	Jan. 10, 17	Jan. 17, 17	Jan. 30, 17	Feb. 6, 17
0	44.8	75.9	64.8	62.2	55.9	51.4	51.6	57.7	60.5	65.6
0.5	39.05	50.3	60.55	74.25	74.15	72.2	64.8	70.1	66.1	42.35
0.6	41	46.9	53.95	61.5	61.55	62.6	65.85	50.25	32	21.45
1.0	40.7	46.6	56.95	62.8	75.7	71.45	68.95	54.75	31.5	22.05
1.4	46.7	55.8	64.5	61.55	58.8	45.1	37.7	29.4	20.15	11.45
1.6	46.25	43.25	48.75	47.95	56.35	48.15	48.45	46.75	41.95	38.05
1.8	40.1	42.7	41.65	39.5	45.75	47.45	43.55	44.25	36.8	26.55
2.0	36.45	39.8	41.65	40.3	50.3	51.45	50.4	49.75	46.15	37.35
3.0	47.15	46.55	44.15	43	43.15	24.45	11.6	9.9	7.4	7.3
4.0	40.4	40.05	37.5	32.95	35.75	21.65	20.75	18.15	19.9	10.8
5.0	39.45	35.95	32.1	30.05	32.35	26.3	23.95	14.7	14.1	10.95

Optimization Modeling for Conjunctive Use of Surface and Groundwater

Project Code: DWM/14/165

Investigators: O.P. Verma, R.R. Sethi and A.K. Nayak

The study site and rainfall pattern

The study area, Kendrapada district spreads over 2640 km^2 under the central coastal plain zone of Odisha. The district has the deposits of sediments and alluvial soil due to major river systems viz. Mahanadi, Bramhani, Baitarani, Kharasrota, Luna and Karandia. Rice is the principal crop followed by pulses like greengram, blackgram, kulthi and oilseeds like groundnut, mustard, linseed, sunflower and vegetables etc. Summer rice is usually grown in Pattamundai, Aul, Rajkanika and Rajnagar block in irrigated areas. South-west monsoon (Jun-Oct) contributes almost 87% of total annual rainfall, very meager rainfall in rabi season (Nov-Feb), and 7-10% during summer months (Mar-May).

Rainfall probability analysis at 50, 75 and 90 probability levels for *kharif*, *rabi* and summer season were carried out. Rainfall at 50 percent probability level is found out to be equal to average rainfall and rainfall amount at this probability level (about 1200 mm in different blocks) is sufficient to grow rainfed rice without any risk during *kharif* season. Assured rainfall at 75 percent level is considered as optimum for agricultural crop planning purpose. All blocks except Garadapur block receives 900 mm of rainfall whereas Pattamundai block receives marginally less than 900 mm during June-October period which indicates that rainfed rice can be grown without much risk as this amount of rainfall more or less fulfills the crop water requirement of rice. However, assured rainfall amount at 90 probability level indicates that rainfed rice cultivation can be done in three blocks viz., Aul, Kendrapara and Rajnagar as the rainfall amount above 900 mm. In other blocks it ranged from 495 mm to 771 mm which shows that rainfed rice cultivation is risky unless additional water sources for irrigation is available. Probable rainfall at 75% level in different blocks during *rabi* and summer season is quite less and farmer cannot depend on this amount of rainfall for irrigation. It clearly explains that in Kendrapara district copious rainfall is being received during *kharif* season and farmers can cultivate rice or other crops under rainfed situation without risk and there is possibility to store excess rainwater in water harvesting structures which may helping for taking up short duration pulses or oilseed crops during *rabi* season.

Development of an optimization model

An optimization model was developed with objectives of maximizing net annual return subjected to constraints on land area, water availability from surface and groundwater resources, irrigation water requirement of crops. Block-wise rainfall, cropping pattern, surface and groundwater availability of Kendrapara district of Odisha was considered for solving the optimization model. The objective function was to maximize net profit obtained from different crops grown in *kharif*, *rabi* and summer season with constraints of area and water availability from different sources.

It was observed that rice is extensively cultivated during *kharif* season followed by jute and vegetables (Table 10). For *kharif* irrigated rice, the optimal area allocation should be in the range of 23.9- 51.2% to get maximum net return (Table 11). During *rabi* season, the optimal area of 28.5%-81.7% should be allocated for *rabi* oilseeds under rainfed situation in different blocks of Kendrapada district. During summer season pulses and oilseed crops should be cultivated due to their higher net returns.

Table 10. Existing cropped area (ha) in different blocks of Kendrapada district of Odisha

Blocks	Existing cropped area (ha)													
	Kharif season							*Rabi* season					Summer	
	K-Paddy -irr	K-Paddy -rainf	K-Coarse C-rainf	K-Pulse -rainf	K-Fib -Irr	K-Veg -Irr	K-Veg -rainf	R-Paddy -Irr	R-Coarse C-Irr	R-Pulse -Rainf	R-Oil -Rainf	R-Veg -Irr	S-Pulse -Irr	S-Oil -Irr
Kendrapada	16075	0	0	0	257	2223	5	0	13	3042	157	4080	7935	528
Derabish	11026	0	5	0	385	1723	2297	40	44	8230	210	3390	2580	595
Marshaghai	6374	2236	9	5	680	1764	165	10	43	5400	235	1925	1540	1045
Mahakalapada	5245	18470	9	0	250	1341	2710	490	43	13031	2340	6662	100	5
Garadpur	3650	3145	5	5	135	1707	469	5	33	4423	753	2320	70	632
Pattamundai	11530	0	0	5	175	3004	298	1170	43	2209	685	3375	5395	1780
Aul	5447	1918	8	5	2	2057	863	1853	18	3604	480	1700	1655	560
Rajkanika	5170	8940	19	5	80	851	2966	3030	12	8293	1800	4308	195	40
Rajnagar	3941	19556	10	5	0	1020	1970	720	10	10162	380	2953	680	288

Irr- Iriigated, Rainf-Rainfed, K-*kharif*, R-*rabi*, S- summer, C-Cereals, Fib-Fibre crops, Veg-Vegetables, Oil-Oilseeds

Table 11. Optimal cropped area (ha) in different blocks of Kendrapada district of Odisha considering surface and groundwater availability

Blocks	*Kharif* season							*Rabi* season					Summer	
	K-Paddy-irr	K-Paddy-rainf	K-Coarse C-rainf	K-Pulse-rainf	K-Fib-Irr	K-Veg-Irr	K-Veg-rainf	R-Paddy-Irr	R-Coarse C-Irr	R-Pulse-Rainf	R-Oil-Rainf	R-Veg-Irr	S-Pulse-Irr	S-Oil-Irr
Kendrapada	8421	-	-	-	3457	2683	1897	-	-	-	4448	2844	-	3152
Derabish	7936	-	-	-	5772	3087		915	-	-	7267	2020	-	2403
Marshaghai	5572	3429	-	-	4541	2198	48	643	-	356.3	4644	1123		1480
Mahakalapada	9689	6246	16815	-	-	5605	2195	-	-	13765	5605	-	1013	-
Garadpur	4511	2776	-	-	4185	1649	174	520	-	-	9693	1651.2	-	702
Pattamundai	7713	578	-	-	6606	3002	-	-	-	-	4564	979	-	1321
Aul	5244	3227	-	-	5398	1194	866	605	-	-	2363	2060	1693	-
Rajkanika	9285	5713	-	-	3530	3606		1071	-	-	10640	1452	-	235
Rajnagar	11660	6671	-	4537	-	5300		1250	-	-	8677	5548	-	968

Irr- Iriigated, Rainf-Rainfed, K-*kharif*, R-*rabi*, S- summer, C-Cereals, Fib-Fibre crops, Veg-Vegetables, Oil-Oilseeds

Design and Evaluation of a Portable Drum Based Drip Irrigation System for Sub-marginal Family Farming System

Project Code: IIWM/15/167

Investigators: S. Mohanty and P.K. Panda

The portable drum based drip irrigation system was evaluated with ladies finger crop in research farm (March-June, 2016) and with brinjal crop in farmer's field (January-April, 2016). The average height of the brinjal plants were 33.75 cm, 45.75 cm, 64.25 cm and 68.82 cm at 30 days, 60 days, 90 days and 120 days after planting respectively. Similarly, average number of leaves plant^{-1} were 17.25, 38.75, 63.75 and 71.9 at 30 days, 60 days, 90 days and 120 days after planting, respectively. On an average, there were 5 primary branches and 4 secondary branches per brinjal plant. The average plant height of the ladies finger were 19.3 cm, 36.4 cm and 63.9 cm at 30 days, 60 days and 90 days after sowing, respectively. Average number of leaves plant^{-1} were 4.2, 8.6 and 12.4 at 30 days, 60 days and 90 days after sowing respectively. A yield of 24.8 t ha^{-1} in brinjal and 9.4 t ha^{-1} in ladies finger was observed with the system. The analysis of crop water requirement and capacity of the system indicated that about 100 m^2 of area under vegetables can be irrigated using the system. For the above area, the drum need to be filled daily about twice in winter season and 4-times in the summer season.

Efficient Groundwater Management for Enhancing Adaptive Capacity to Climate Change in Sugarcane Farming System in Muzaffarnagar district, UP

Funded by DoAC&FW, Ministry of Agriculture & Farmers Welfare, Government of India

Investigators: A. Mishra, S. Mohanty, R.R. Sethi and P. Panigrahi

The work of ICAR-IIWM was primarily focused on the installation of climate resilient irrigation systems (underground PVC pipe and drip system), analysis of water requirement of major crops of Muzaffarnagar district, UP and water budgeting of Rasulpur Jattan village of the district during 2016-17 under the project. The installation of underground conveyance pipeline system was carried out in 45 farmers' field and installation of drip irrigation system was nearing completion in three farmers' fields of Rasulpur Jattan village.

Estimation of water requirement and groundwater recharge in Muzaffarnagar

The monthly crop water requirement, net irrigation water requirement for all the major crops, and annual water requirement for domestic and livestock purposes were estimated for the Muzaffarnagar district, UP. About 22% of total crop water requirement was observed to be met from rainfall and the remaining 78% from irrigation either from surface water or groundwater sources. The amount of annual groundwater recharge from rainfall in monsoon and in non-monsoon season was estimated using the historical groundwater table and rainfall data. The monsoon recharge was about 80% of the total annual recharge whereas the recharge during remaining period was only 20% (Table 12).

Analysis of water budget for Rasulpur Jattan village

Analysis of daily rainfall data of 19 years (1997-2015) shows that the average annual rainfall of the area is 768 mm with a standard deviation of 173 mm. The effective rainfall in the village was 545 mm. Highest monthly rainfall was received in July (214 mm) followed by August (189 mm). Rainfall amount of 520 mm was received during Monsoon (July to September).

The average reference evapotranspiration (ET_0) estimated using Penman-Monteith method was1737 mm for the village. The monthly crop water requirement and irrigation water requirement for different major crops (sugarcane, paddy, wheat, black gram, mustard, jowar and berseem) computed on annual basis indicates that about 25% of total crop water requirement was met from the rainfall and remaining 75% was supplemented from groundwater source. The trend analysis of the maximum temperature, minimum temperature, average temperature and ET_0 were also carried out.

The analysis of groundwater table data for 7 years period (2007-2013) in the study village indicates that depth of water table in pre-monsoon depleted at a rate of 0.355 m yr^{-1}, whereas in post-monsoon, the water table rose at the rate 0.014 m yr^{-1} (Fig. 15). The estimate of annual groundwater recharges from rainfall and irrigation return flow indicates that the monsoon recharge was about 75% of the total annual recharge whereas the non-monsoon recharge was only 25%. The total irrigation return flow from the cropped field to aquifer is 785935 m^3 which was about 31% of the total annual draft for irrigation.

Installation of climate resilient irrigation system (underground PVC conveyance pipeline system) was done for conservation and efficient utilization of irrigation water in the crop field of the area. The installation was carried out in 45 farmer's field in Rasulpur Jattan village (15 each in sector 5, Ghari and Jhanduwala). Installation of drip irrigation system in three farmer's field is nearing completion. Other partner Institutes of the project had also constructed/installed two recharge cavities, one water harvesting masonry structure and one drip irrigation system operated by solar pump at the study site. Under capacity building program, one workshop-cum-training and nine training programs were conducted for farmers and stake holders at the study site.

Table 12. Annual water requirement and groundwater recharge for Muzaffarnagar district and Rasulpur Jattan village of the district

	Annual water requirement (m^3)				Annual groundwater recharge from rainfall (m^3)		
	Domestic	Livestock	Irrigation	Total	Monsoon	Non-monsoon	Total
Rasulpur Jattan	108916	22539	2553627	2685081	547200	185482	732682
Muzaffarnagar	65697744	14328841	2836661900	2916688485	462268933	118260537	580529470

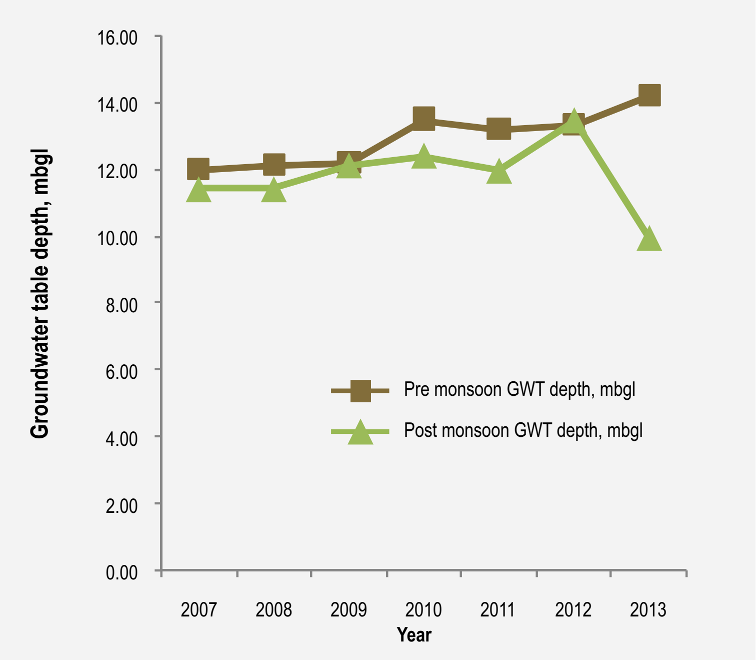


Fig. 15. Depth of groundwater table in pre- and post-monsoon for Rasulpur Jattan

Socioeconomic and Environmental Linkages of Groundwater Irrigation in Coastal Aquifers of Eastern India

Project Code: IIWM/16/178

Investigators: D.K. Panda, S. Mohanty, M. Das and O.P. Verma

India is the largest user of groundwater to irrigate over 0.4 million km^2 annually (i.e., more than double the surface water irrigated area), which has resulted in large-scale depletions. Here, we investigate the climatic projections of the current century to understand the anticipated groundwater crisis in major river basins of India. Basin scale analysis is important from the prospective of hydro-climatic homogeneity, necessary for aquifer management. Six river basins Ganga, Godavari, Krishna, Mahanadi, Brahmani and Subernarekha were included in this study.

The monthly rainfall and mean temperatures during 1981-2095 (Fig. 16), modelled by the Co-ordinated Regional Downscaling Experiment (CORDEX) for south Asia, indicates that most of the years of the current century would be dryer and hotter, with the annual rainfall anomalies ranging from 0 to -350 mm and the annual mean temperature anomalies ranging from 0 to 4.5°C. Although physical mechanism of a hotter environment suggests more rainfall due to accelerated evaporation, the projected climate signals the predominance of droughts in comparison to co-occurrence of wet-hot (WH) events. This supports the reported findings that global warming increases the drought risks. During 1981-2095, rainfall is going to decrease by 8 mm per decade, accompanied by a warming rate of 0.34°C. Under this scenario, the groundwater resources would be highly stressed by climate-induced anthropogenic demands to meet the drinking and irrigation requirements.

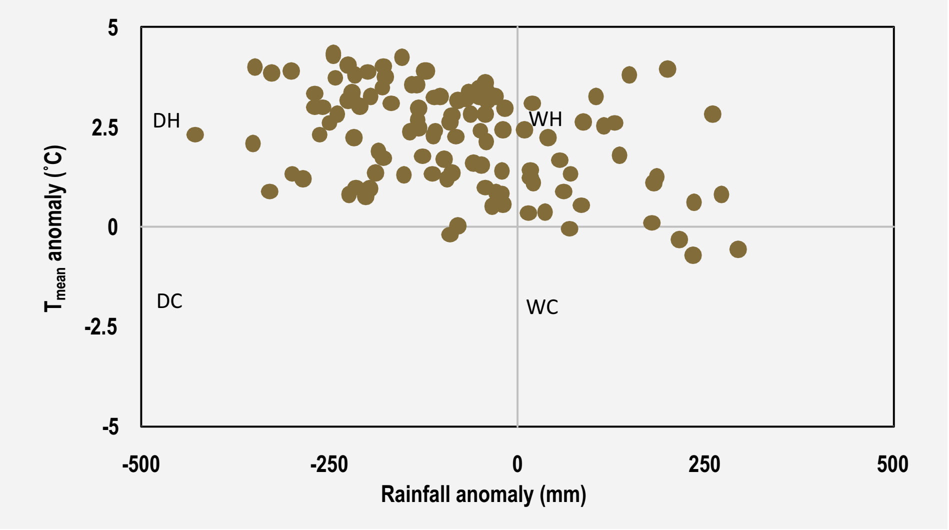


Fig. 16. Scatter plot indicates the distribution of dry-hot (DH), wet-hot (WH), dry-cold (DC) and wet-cold (WC) years during 1981-2095.

Impact Assessment Study of Using Industrial Wastewater on Sunflower (*Helianthus annus* L.) and Mustard (*Brassica nigra* L.) Grown in Peri-industrial Area of Angul, Odisha

Project Code: IIWM/15/170

Investigators: Rachana Dubey, Mausumi Raychaudhuri and P.S. Brahmanand

Earlier studies conducted on wastewater from industrial area of selected sites *viz.,*Kulad, Kulad culvert, CPP-Bonda, Bonda village culvert, Nuahatta and Digi in Angul, Odisha showed more contamination during monsoon season, hence monthly water samples were collected from the site during June to September, 2016 and analyzed (Table 13). Phosphorous content in wastewater in the month of July was low revealing the release of effluents containing flyash which is a potential absorbent of phosphate. High concentration of bicarbonate in the month of August and September (243.9-264 mg L^{-1}) may be due to higher dissolved organic matter that releases CO_2 leading to formation of bicarbonate ions. But the site near captive power plant with a capacity of 1080 MW and discharge of 10 MLD effluent showed significant variation in pH and dissolved oxygen (DO) in the month of July which also coincides with the peak time for release of effluents. The probable cause of lowering of pH may be due to the sulphites released (from flue gas desulphurization process) and gets oxidized to sulphate and then to sulphuric acid which lowers the pH and hence DO.

Besides, the discharged effluents collected from periphery of power plants showed pH and DO ranging from 3.42 to 5.89 and 1.65-7.32 mg L^{-1}, respectively in the months of August and September. This implies that effluent discharge continued till the month of August; therefore, it is suggested not to use nala water for the purpose of irrigation to crops during *kharif* season.

A pot experiment was conducted at the Institute Research Farm, Mendhasal, Bhubaneswar to investigate the effect of irrigation with industrial wastewater of Angul area on sunflower. The wastewater contained pH 7.88, EC 0.39 dS m^{-1}; NH_4, NO_3, P and K as 11.2, 22.4, 2.85 and 3.73 mg L^{-1}, respectively. Conjunctive use of wastewater (WW) and different proportion of freshwater (FW) was tested in sunflower using two methods: cyclic and mixing with different proportions *viz.,* T1: 0% WW, 100% FW; T2: 25% WW, 75% FW; T3: 50% WW, 50% FW; T4: 75% WW, 25% FW and T5:100% WW, 0% FW. The results revealed that head diameter, 1000-achene weight and head weight of sunflower were not influenced significantly by method of application of water i.e., mixing or cycling of industrial wastewater and freshwater. However, the conjunctive use of fresh water and wastewater affected yield attributes significantly (Table 14). Conjunctive use of 75% of wastewater and 25% of fresh water was found to be significantly superior in terms of head diameter, 1000-achene weight and head weight compared to other treatments.

Table 13. Temporal variation in surface water quality during monsoon season in Angul industrial area, Odisha

Month	June	July	August	September
pH	8.15	7.57	7.77	7.97
EC (dS m^{-1})	0.67	0.64	0.56	0.57
DO (mg L^{-1})	8.44	6.82	7.36	7.92
BOD (mg L^{-1})	6.34	5.32	6.69	5.80
NH_4-N (mg L^{-1})	21.90	22.90	21.40	23.60
NO_3-N (mg L^{-1})	56.57	52.55	50.23	54.40
P (mg L^{-1})	5.20	1.40	4.50	6.90
K (mg L^{-1})	6.20	6.80	4.10	5.20
Na (mg L^{-1})	49.39	52.03	59.58	65.87
$CaCO_3$ (mg L^{-1})	100.00	108.00	103.20	155.30
Ca (mg L^{-1})	31.30	32.30	33.50	24.80
Mg (mg L^{-1})	5.20	4.84	4.58	7.85
HCO_3 (mg L^{-1})	150.80	150.82	243.90	264.00
SAR	0.50	0.52	0.58	0.62
TDS (ppm)	426.70	837.33	360.32	361.60
Mg/Ca ratio	0.28	0.25	0.23	0.53
RSC (mg L^{-1})	0.15	0.24	0.53	0.97

Monthly variation during monsoon season in pH and DO in Bonda site in Angul, Odisha

Table 14. Effect of industrial wastewater in conjunction with freshwater on yield attributes of sunflower

Treatments	Head diameter (cm)	1000-achene weight (g)	Head weight (g)
100 % FW	13.0	36.8	14.7
75% FW + 75% WW	13.2	41.7	17.2
50% FW + 50% WW	13.7	46.5	19.4
25% FW + 75% WW	14.6	50.5	21.9
100% WW	15.0	53.0	22.4
LSD (P= 0.05)	0.5	3.7	0.6

Pot experiment at ICAR-IIWM research farm

Enhancing Water Productivity through Intensive Horticultural System in Degraded Land

Project Code: IIWM/15/176

Investigators: Prativa Sahu, S. Pradhan, K.G. Mandal and P. Panigrahi

The experiment was conducted to generate profits in pre-bearing orchard of mango intercropped with papaya and pineapple under drip irrigation and paddy straw mulch. In a 6 m x 6 m spaced mango orchard, planted during July 2015 with papaya and pineapple were grown as intercrops with spacing of 2.0 m × 2.0 m and 0.45 m×0.60 m, respectively. The texture of soil was sandy loam (45% sand, 24% silt and 31% clay) with bulk density of 1.5 g cm^{-3}. The experimental soil was acidic in nature (pH, 5.7). The EC and organic carbon content of soil were 0.11-0.13 dS m^{-1} and 0.55%, respectively. The mean soil (0-15 cm) available N and K in different crops were 280 kg ha^{-1} and 259 kg ha^{-1}, respectively.

The hydraulic performance of drip system was found satisfactory with emitter flow rate variation (Q_v) of 4%, co-efficient of variation (CV) of 5% and distribution uniformity (DU) of 95%. Water was applied to mango, papaya and pineapple crops once in every two days using drip irrigation system during December, 2016 to March, 2017. The amounts of water applied in mango, papaya and pineapple were 306 mm, 260 mm and 204 mm, respectively. The volumetric soil water content in top 0.60 m soil in mango, papaya and pineapple plants were 17.0-25.0%, 15.3-22.0% and 18.2-26.9%, respectively.

The different parameters of vegetative growth of mango, papaya and pineapple, and fruit set of papaya are given in Table15. The higher plant growth was observed with the mango plants grown without any intercrops. However, plant height, canopy diameter and trunk girth of young mango plants were not affected significantly either by papaya and/ pineapple intercropping. In papaya, the canopy diameter was affected significantly due to intercrops and mulching. The effect of different treatments on vegetative growth of pineapple was not significant.

Papaya and pineapple intercropped with pre-bearing mango under drip irrigation

Table 15. Incremental vegetative growth of plants and water used under different treatments

Treatments	Mango			Papaya			Pine-apple			Water applied (mm)
	Plant height (m)	Canopy diameter (m)	Trunk girth (cm)	Herb height (m)	Canopy diameter (m)	Fruit set (No.)	Shrub height (cm)	No. of leaves	No. of suckers slips^{-1}	
Mango + Papaya+ Pineapple	0.76	1.21	2.8	1.75	0.52	20	39.7	31	10	770
Mango + Pineapple	0.81	1.38	2.9	-	-	-	42.3	36	10	510
Mango + papaya	0.79	1.30	3.1	1.78	0.55	23	-	-	-	566
Mango + Papaya + Pineapple + Straw mulch	0.79	1.49	3.0	1.77	0.60	22	42.5	34	12	693
Mango + Pineapple + straw mulch	0.84	1.61	3.1	-	-	-	46.9	38	11	459
Mango + papaya + Straw mulch	0.82	1.38	3.3	1.80	0.65	26	-	-	-	510
Mango + Straw Mulch	0.88	1.41	3.5	-	-	-	-	-	-	276
Mango	0. 85	1.41	3.3	-	-	-	-	-	-	306
CD (p=0.05)	ns	ns	ns	ns	0.03	ns	ns	ns	ns	—

WATERLOGGED AREA MANAGEMENT

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/13/162

Investigators: S. Roy Chowdhury, P.S. Brahmanand, A.K. Nayak, R.K. Mohanty and S.K. Ambast

The georeferenced satellite P6- LISS-III imagery (path 106 and row 54) for both pre-monsoon (May) and post-monsoon period (November) was processed for delineation of waterlogged area with the help of ground truthing and topo-sheet maps obtained from Survey of India, Dehradun. Thematic maps were prepared for pre-monsoon and post-monsoon period for different districts. The supervised classification of images were done for fitting in different crops and cropping system in study area.

The study of satellite data of pre-monsoon period (May 15, 2014) and post-monsoon period (November 23, 2014) suggested that Bhagalpur district had 12,967.31 ha during pre-monsoon period under waterlogging which in post monsoon period increased to 35,721.82 ha *i.e.* an increase in waterlogged area of 17,081.24 ha (excluding perennial waterlogged bodies). Katihar district had 10,671.45 ha during pre-monsoon period which in post-monsoon period increased to 33,258.38 ha *i.e.* excluding perennial waterlogged bodies the waterlogged area increased by 15,786.31 ha. In Purnea district in post-monsoon period excluding perennial waterlogged bodies, the waterlogged area showed an increase of 11,118.12 ha. In Kishanganj district during pre-monsoon period had 1,991.09 ha under waterlogging which in post-monsoon period increased to 5,225.89 ha. Sahibganj district in pre-monsoon period showed 7,432.9 ha under waterlogging which in post monsoon period increased to 18,777.36 ha. Excluding perennial waterlogged bodies, there was an area increase of 8,680.2 ha under waterlogging. Godda district in post monsoon period showed an area increase under waterlogging in additional 954.77 ha area excluding perennial waterlogged bodies. Banka district showed an area increase under waterlogging in additional 1,474.92 ha (excluding perennial waterlogged bodies) area. Madhepura district showed an area increase under waterlogging in additional area of 9,328.32 ha (excluding perennial waterlogged bodies). Munger district had 5628.15 ha during pre-monsoon period which in post monsoon period increased to 12,547.4 ha *i.e.* an increase in waterlogged area of 3,960.99 ha (excluding perennial waterlogged bodies). The district wise maps of pre- and post-monsoon waterlogged areas as well as their digital elevation map of Katihar district, a representative district, are given in Fig. 17.

For fitting in suitable crops in identified waterlogged areas, in tidal waterlogged areas on the both bank of Rup Narayan river the waterlogged areas were delineated which is suitable for cultivation of *Typha*. The total study area was 2,86,100 ha having 2,715 ha waterlogged area and out of which 928 ha area was found suitable for *Typha* cultivation. Apart from cultivation of *Typha*, the processing units for preparing mats and the expertise are also available in the Panskura block I and Panskura block II along the side of Rupnarayan river, so that a complete chain of value added product (mats) development *i.e.,* from cultivation of *Typha* to knitting of mats from *Typha* leaves are feasible from delineated waterlogged area.

Similarly, in Odisha, in the waterlogged areas of Baleswar district, (study area: 92,452.61 ha), the areas feasible for water chestnut cultivation were delineated (607.87 ha) keeping in consideration of close proximity to highway and railway track side. Both the availability of waterlogged area and transport facility of the fresh harvested fruits were among main criteria of selection of delineated areas for cultivation of water chestnut in Baleswar district of Odisha. The cultivation of water chestnut integrated with aquaculture in a delineated 1.5 ha at Haldipada gave a net profit of ₹ 1,17,000 ha^{-1} with water productivity of ₹ 7.31m^{-3} of water.

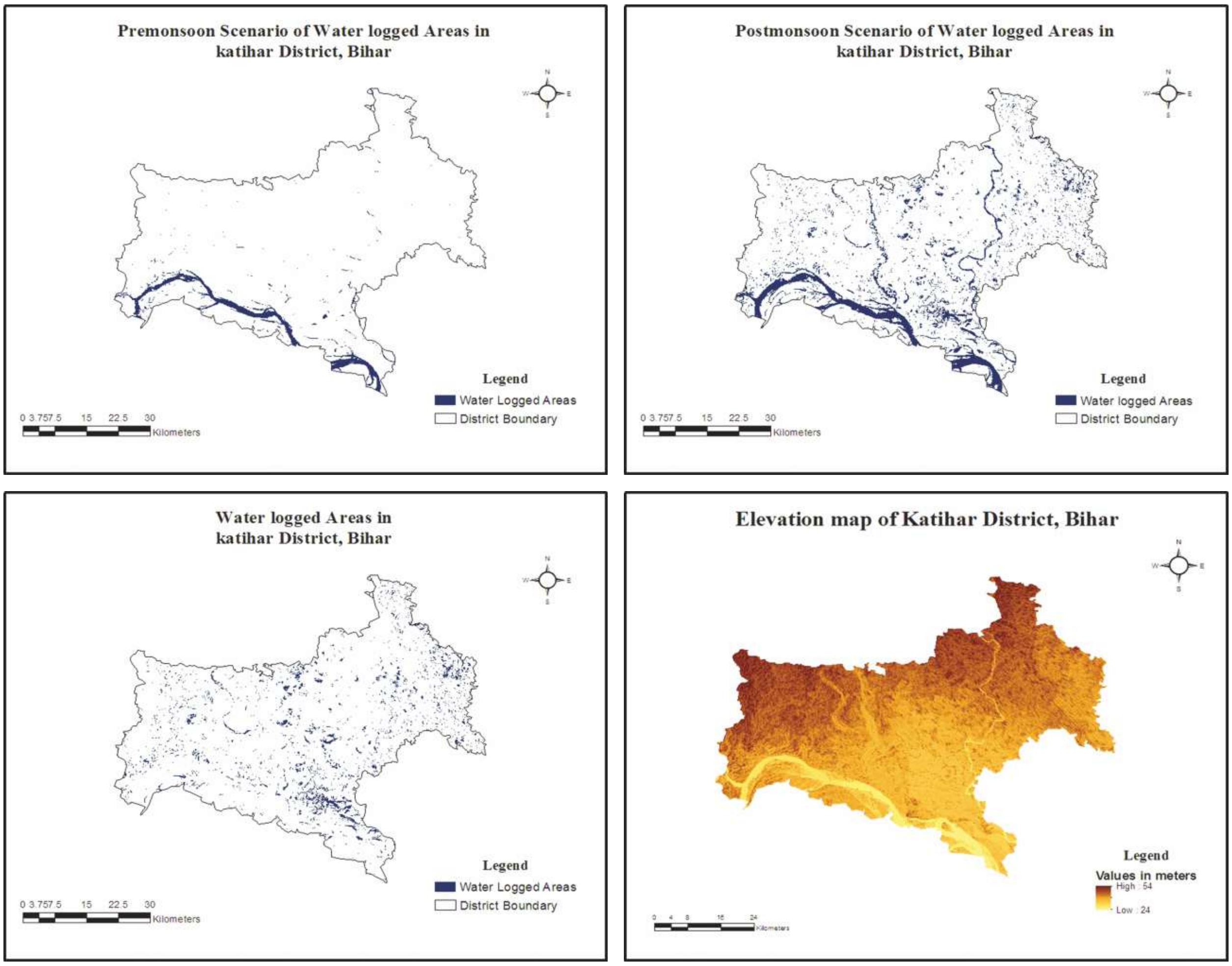


Fig. 17. Thematic maps of pre- (May 15, 2014) and post-monsoon (November 23, 2014) period for Katihar district

Water Use Efficient Practices for Successful Establishment and yield Enhancement of Pulse Crops in Rice Based Cropping System

Project Code: IIWM/16/179

Investigators: P.S. Brahmanand, S.Roy Chowdhury, P. Panigrahi, P. Nanda and S. Raychaudhari

A field experiment was conducted during 2016-17 in the research farm of the Institute at Mendhasal, Khurdha district of Odisha to investigate the effect of irrigation using sprinklers (M_1: no irrigation; M_2: one sprinkler irrigation at flowering stage; M_3: sprinkler irrigation twice at flowering and pod formation stages) and nitrogen treatments (S_1: no nitrogen; S_2: N @ 20 kg ha^{-1} through urea; S_3: *Rhizobium* inoculation and N @ 20 kg ha^{-1} through urea; S_4: N @ 40 kg ha^{-1} through urea) on growth performance of greengram in a rice-based cropping system. The experiment was conducted in a split-plot design with three replications. Moreover, six levels of irrigation (FI: full irrigation, 120% FI, 80% FI, 60% FI, 40% FI, 20% FI and control (without irrigation) were imposed in different growth stages of crop under both surface and sprinkler irrigation to develop water production function in greengram. The quantity of irrigation water applied and volumetric soil water content within top 0.6 m soil depth under different treatments were 90–150 mm and 15.5–27.2%, respectively. Soil of the experiment site was slightly acidic, and had moderate level of organic carbon (6.32 g kg^{-1}) which was not congenial for microbial activities. The available N (110 kg ha^{-1}) and K (71 kg ha^{-1}) were also low and available P (29 kg ha^{-1}) was moderate. No native rhizobia population was detected.

Crop growth parameters *viz.*, plant height and drymatter accumulation were recorded at 15, 30 and 45 days after sowing (DAS) and crop growth rate was computed for 15-30 and 30-45 DAS. The results revealed that plant height and dry matter accumulation were found on par among the irrigation treatments at 15 and 30 DAS as the irrigation treatment was applied at flowering stage (33 DAS).

However, sprinkler irrigation twice (M_3) resulted in significantly greater plant height (28.3 cm) compared to single irrigation (M_2) and no irrigation (M_1) at 45 DAS. Similarly, crop growth was better with N application @ 40 kg ha^{-1} applied through urea (S_4) compared to the N @ 20 kg ha^{-1} through urea (S_2) and no nitrogen application (S_1). However, rhizobium inoculation and N application @ 20 kg ha^{-1} (S_3) was statistically similar to S_4 (Fig. 18). The Soil and Plant Analyzer Development (SPAD) value (23.7-43.7) were higher with irrigation at two critical growth stages of the crop.

Gas exchange traits for the crop was also monitored *viz.*, net photosynthesis rate, stomatal conductance and rate of transpiration at 20, 30, 40 and 45 DAS. Upto 20 DAS irrigation treatments showed no effect on rate of photosynthesis but N application showed significant variation at 20 DAP itself. However, the irrigation x N interaction was significant at 40 and 45 DAS. The highest net photosynthesis was obtained at I_3F_3 at both 40 and 45 DAS, which was statistically similar to I_3F_4 combination, the values ranged from 13-14 μ mol m^{-2} s^{-1} (Table 16). In different irrigation treatments imposed in different growth stages of the crop under surface and sprinkler irrigation, the plant vegetative growth at 40% FI, 20% FI and control were significantly lower compared with that in FI. The quantity of irrigation water applied and volumetric soil water content within top 0.6 m soil depth in different treatments were 58–257 mm and 13.8–28.7%, respectively. The higher SPAD (29.3–51.6), leaf photosynthesis rate, transpiration rate and stomatal conductance were observed with higher level of irrigation.

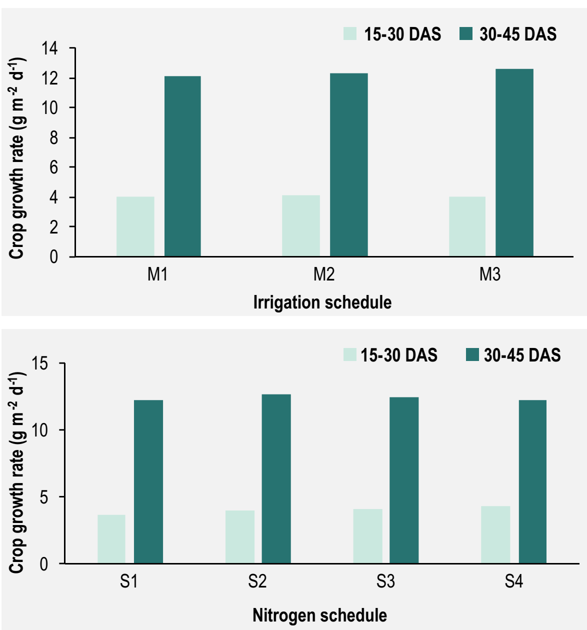


Fig.18. Crop growth rate (g m^{-2} d^{-1}) of greengram as influenced by irrigation and nitrogen schedule

Table 16. The effect of both irrigation (main) as well as different N applications (sub) on net photosynthesis rate (µmol CO_2 m^{-2}s^{-1}) at 45 DAS on mung bean grown under different irrigation levels

Treatment	S1	S2	S3	S4	Mean
M1	7.5	7.5	7.8	7.6	7.6
M2	8.2	9.0	9.9	9.2	9.08
M3	8.0	10.5	14.0	13.0	11.38
Mean	7.9	9.0	10.6	9.9	
LSD (p=0.05)	M-1.96; S-1.2; MxS- 2.7				

View of experimental field at research farm, ICAR-IIWM

Sprinkler irrigation in greengram field

Drainage Planning of Eastern Coast Delta using Geoinformatics

Project Code: IIWM/15/169

Investigators: S.K. Jena, S. Roy Chowdhury, P.S. Brahmanand and A.K. Nayak

Drainage planning of eastern coast delta in Bhargabi-Daya doab was taken up using geoinformatics. Satellite imageries were used for assessment of extent of waterlogging in the study area. LANDSAT images were obtained from United States Geographical Survey records for the year 2015. After browsing the available satellite images cloud free image of September 30, 2015 was chosen along with another image of October 16, 2015 with partial cloud. False color composite maps of the images were extracted showing the area under waterlogging. The images were classified and it was observed that surface waterlogged area on September 30, 2015 was 355.1 km^2 (Fig. 19a) and same shrunk to 259.3 km^2 by October 16, 2015 (Fig. 19b).

Ground truthing of above information was done in the study area with hand held GPS recording the latitude, longitude and elevation data. Observations were taken in river bridges, culverts, originating points of canals and drains from river, on the top of the barrage for easy verification on satellite images. The land use land cover of the adjacent areas close to the point of observation were noted and compared with the classified information for verification and accuracy.

The total length of perennial stream was found to be 297.24 km (Fig. 19c). The drainage density was 0.235 km km^{-2} and the constant of channel maintenance was 4.260 km. For estimation of drainage coefficient, 40 years historical rainfall data (1976-2015) was analyzed to determine the amount of water to be removed from the paddy field in different return period. For 10 year return period the 289.9 mm of water warranted removal in 6 days. If a paddy variety at a particular stage of growth is tolerant to submergence for 6 days, then an amount of 48 mm depth water should be removed from the field per day. Similarly for a 5 year return period it was found to be 42 mm per day. The variation of total depth for 6 days duration for return period varying between 2 to 20 years varied between 192.9 mm to 320.2 mm. Similarly if a rice variety at a particular stage is tolerant to submergence for 4 days, then the amount of water to be drained per day is 62 mm for a return period of 10 years. The drainage coefficient table has been developed for different return period and different days of tolerance (Table 17). As stated above drainage coefficient and water congestion for different return period and different duration were estimated; effect of water congestion on crop growth and yield was assessed and crop planning was done for the Bhargabi-Daya doab.

Table 17. Design drainage coefficients (mm d^{-1}) for different crop tolerance to excess water

Return period	Crop tolerance to excess water (d)					
	1 d	2 d	3 d	4 d	5 d	6 d
5 years	120.81	86.34	66.24	58.32	49.63	42.55
10 years	142.05	108.51	79.37	62.55	52.8	48.33

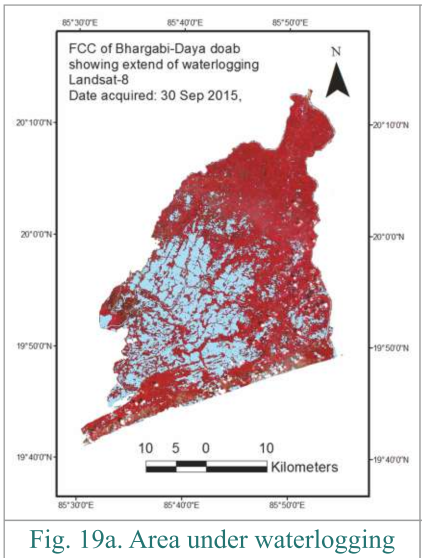


Fig. 19a. Area under waterlogging on 30.09.2015

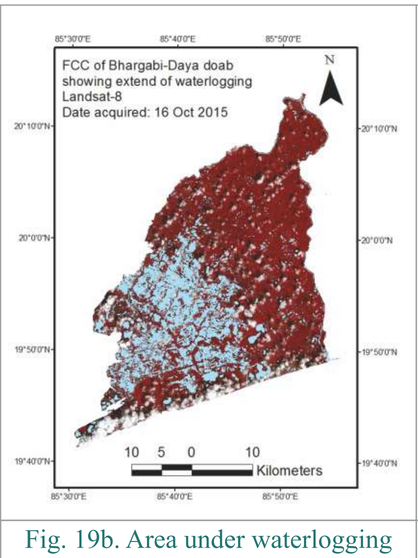


Fig. 19b. Area under waterlogging on 16.10.2015

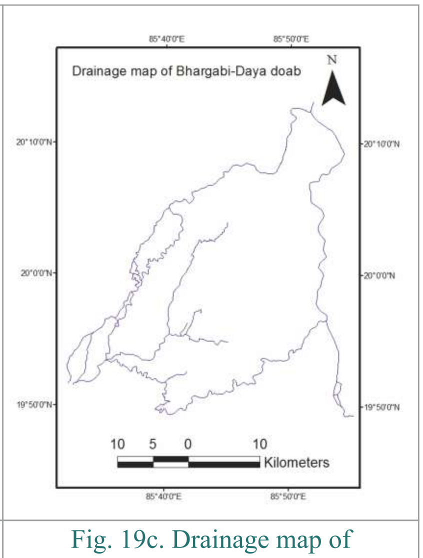


Fig. 19c. Drainage map of Bhargabi-Daya doab

The existing cropping pattern, major popular rice varieties grown, crop yield loss at different levels of submergence and contingency crop planning in Delanga, Kanas, Pipli, Satyabadi and Brahmagiri blocks of Puri district of Bhargabi-Daya doab was analyzed. In Delanga block under Daya-Bhargavi doab, rice is the dominant crop in *kharif* season (16,700 ha) and greengram, blackgram and groundnut are the main crops in *rabi* season. Kanas block, Pipli block, Satyabadi block and Brahmagiri blocks have about 11,300 ha, 16,300, 10,100 ha and 9,400 ha respectively under rice during *kharif* season. 15 to 45% of the decline in grain yield of rice was noticed due to submergence of water (15-60 cm depth) in Delanga block of Puri district. Pooja, CR-1014, CR-1018, *Durga, Sarala* and *Panidhan* are popular varieties in this block. Similar scenario is noticed in other blocks of Puri district, however the yield loss proportion is higher in Brahmagiri and Kanas blocks due to higher extent and duration of water submergence during *kharif* season. Contingency measures/ remedial measures such as cultivation of waterlogging tolerant varieties like *Hanseswari,* flash flood tolerant varieties of rice such as Swarna *sub-1*, cultivation of over-aged seedlings of 60-d old and cultivation of okra, bitter gourd, sunflower under zero-tillage during post-flood season etc. are suggested for this scenario.

Identification of Suitable Crops for Waste-water Irrigation

Project Code: DWM/12/159

Investigators: S. Raychaudhuri, M. Raychaudhuri, S.K. Rautaray and S. Roy Chowdhury

Determination of die off period of pathogens in laboratory

During 2016-17, laboratory experiments on survivability of microbial load on different vegetables showed a mean reduction of 1.29, 2.08 and 1.66 log cfu/g vegetables after 10-d for total coliform, *E. coli* and other bacteria, respectively. The bacterial load decreased to its maximum during 5-7 days after wastewater irrigation. Therefore, minimum seven days gap is required between wastewater irrigation and harvest for safety purpose.

Periodic analyses of soils

Total uptake and build-up of Cd and Cr in soil were estimated from wastewater irrigated farmers field and presented in Table 18. The paddy-amaranth or paddy-radish systems showed very little accumulation of Cd and Cr in soil. However both radish and amaranth are not safe for consumption. The paddy-okra or paddy- ridge gourd or paddy tomato systems appeared safer due to lower accumulation of Cd and Cr in edible part. Therefore, wastewater irrigated root or leafy vegetables are found not safe for consumption whereas fruit bearing vegetables were found safer due to lesser accumulation of Cd and Cr in the edible part. The buildup of Cd and Cr in waste water irrigated soil in farmers field is given in following table.

Table 18. Uptake of cadmium and chromium from soil to different plant parts of vegetables and paddy

Crops	Cd uptake (mg ha^{-1})				Cr uptake (mg ha^{-1})			
	Root	Shoot	Fruit	Total	Root	Shoot	Fruit	Total
Okra	455	2866	151	3472	627	22212	2002	24841
Tomato	447	3188	270	3905	2720	30348	5077	38145
Ridge gourd	421	2988	218	3627	218	6372	2849	9439
French Bean	1423	5408	530	7361	12572	40169	7397	60138
Radish	8626	11647	0	20273	13662	20068	0	33730
Amaranths	6098	12892	0	18990	129222	90996	0	220218
Paddy	-	11040	7970	19010	0	78800	14800	93600

Global Yield Gap and Water Productivity Atlas (GYGA)

Collaborative Project: ICAR with University of Nebraska, Lincoln, USA

Investigators: P.S. Brahmanand, N. Subash, S.K. Ambast and A.S. Panwar

This project aims to collect and compile the data on actual yields, potential yield and yield gaps in India to prepare an atlas, for five major crops namely maize, rice, wheat, sorghum and pearl millet. The quality control exercise of The Agricultural Production Systems Simulator (APSIM) for assessing potential yield of rice and wheat was completed and yield gap of rice and wheat was estimated for different climatic buffer zones.

The yield gaps of rice and wheat were estimated based on the difference between actual yield and potential yield estimated through APSIM model. As per the protocol of GYGA, the yield potential of rice of Amritsar climatic buffer zone of Punjab was estimated as 8.48 t ha^{-1} using APSIM and its mean actual yield (av. of 10 years) was 2.89 t ha^{-1}, hence the yield gap of about 5.59 t ha^{-1} was obtained in this climatic buffer zone which accounts to 65.9% of the potential yield (Fig. 20). Similarly, the yield potential of rice of Kalyani climatic buffer zone of West Bengal was estimated as 7.12 t ha^{-1} and its mean actual yield (average of 10 years) was 2.29 t ha^{-1}, hence the yield gap of about 4.83 t ha^{-1} was obtained in this climatic buffer zone which accounts to 67.8% of the potential yield (Fig. 20). The actual yield, potential yield and estimated yield gap of rice in some other climatic buffer zones of India is presented in Table 19. For wheat, potential yield from Palampur climatic buffer zone of Himachal Pradesh was estimated as 4.32 t ha^{-1} using the same APSIM and its mean actual yield (average of 10 years) was 1.37 t ha^{-1}, hence the yield gap of about 2.95 t ha^{-1} was obtained in this climatic buffer zone which accounts to 68.2% of the potential yield (Fig. 21). Similarly, the yield potential of wheat of Patiala climatic buffer zone of Punjab was estimated as 5.92 t ha^{-1} and its mean actual yield was 4.59 t ha^{-1}, hence the yield gap of about 1.33 t ha^{-1} was recorded in this climatic buffer zone which accounts to 22.5 % of the potential yield (Fig. 21).

Table 19. The yield potential, mean actual grain yield (2002-2011) and yield gap of rice in different climatic buffer zones of India

Name of climatic buffer zone	Actual grain yield of rice (t ha^{-1})	Potential yield of rice (t ha^{-1})	Yield gap of rice (t ha^{-1})	Yield gap of rice (%)
Maruteru	2.86	6.64	3.78	56.9
Modipuram	2.34	7.68	5.34	69.5
Patiala	3.94	8.32	4.38	52.6
Kurnool	3.11	8.16	5.05	61.9
Patna	1.22	7.36	6.14	83.4
Bhubaneswar	1.42	6.00	4.58	76.3

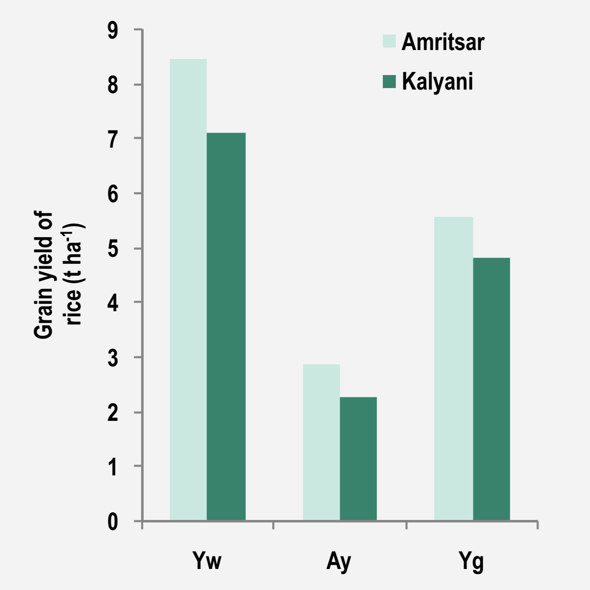


Fig. 20. The yield potential (Yw), mean actual grain yield (Ay) (2002-2011) and yield gap (Yg) of rice in Amritsar climatic buffer zone of Punjab and Kalyani climatic buffer zone of West Bengal, India

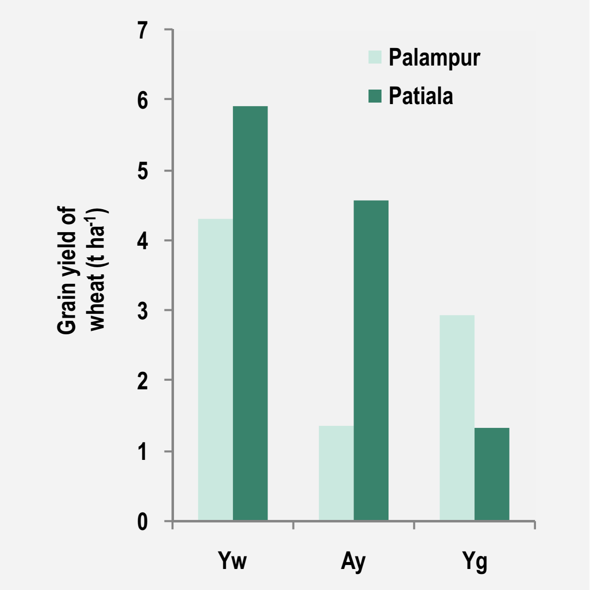


Fig. 21. The yield potential (Yw), mean actual grain yield (Ay) (2002-2011) and yield gap (Yg) of wheat in Palampur climatic buffer zone of Himachal Pradesh and Patiala climatic buffer zone of Punjab, India

Development of Web-based Expert System on Agricultural Water Management

Project Code: IIWM/16/181

Investigators: A.K. Nayak, P.K. Panda and R.K. Mohanty

The advantage of expert systems would raise the performance of the average worker to the level of an expert. The system will allow farmers and other stakeholders to interact and can get the solution over the defined problem. An expert system in agricultural water management has been initiated to categorize water management practices in agriculture, horticulture, high value aquaculture and animal husbandry. A comprehensive database is being developed to store relevant information on requirement of water management in various crops. So the web-based water management expert system will be use of different stakeholders like farmers, NGO, extension personnel and officers. The data on water management aspects in cereal crops were collected and compiled in the form of web pages. The web page formats for cereal crop was developed in open access PHP language for better user friendliness and on WampServer platform. The snapshot of expert systems for searching water management techniques is shown in Fig. 22 & 23. The major crops under four main headings of agriculture, horticulture, fisheries and animal husbandry has been created in the expert system. The decision rules for different modules in agriculture like pulses, oilseeds, commercial crops have also been designed in development of expert system. The end-user can select an option from the given list of options to find out detailed water management practices for the selected crop. Menu options were created for various cereal crops like rice, wheat, maize, pearl millets, jawar and ragi crops. Options also created for pulses, oilseeds and commercial crops like cotton, sugarcane etc.

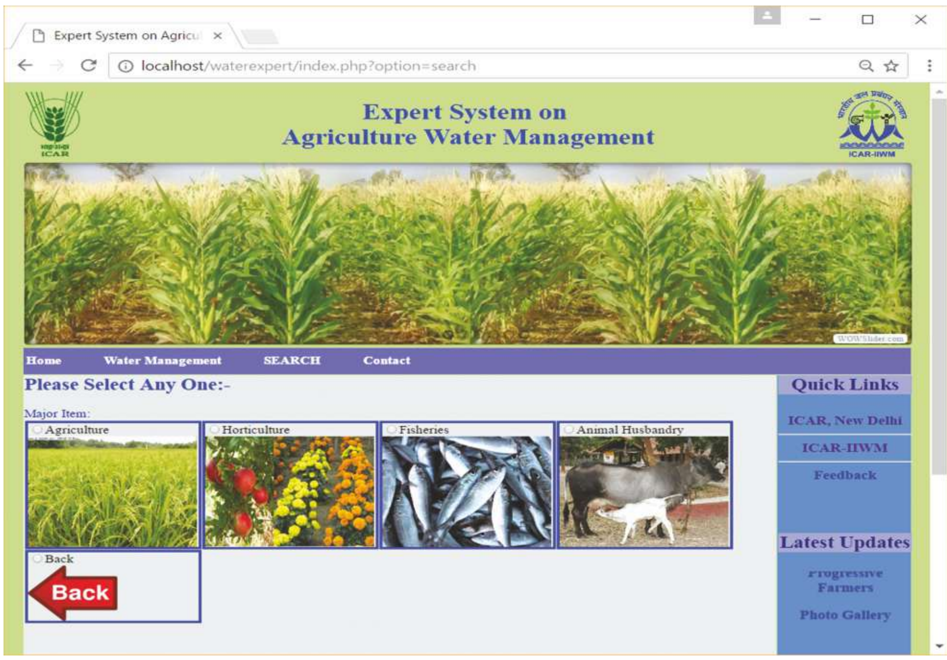


Fig. 22. Expert system on agriculture water management.

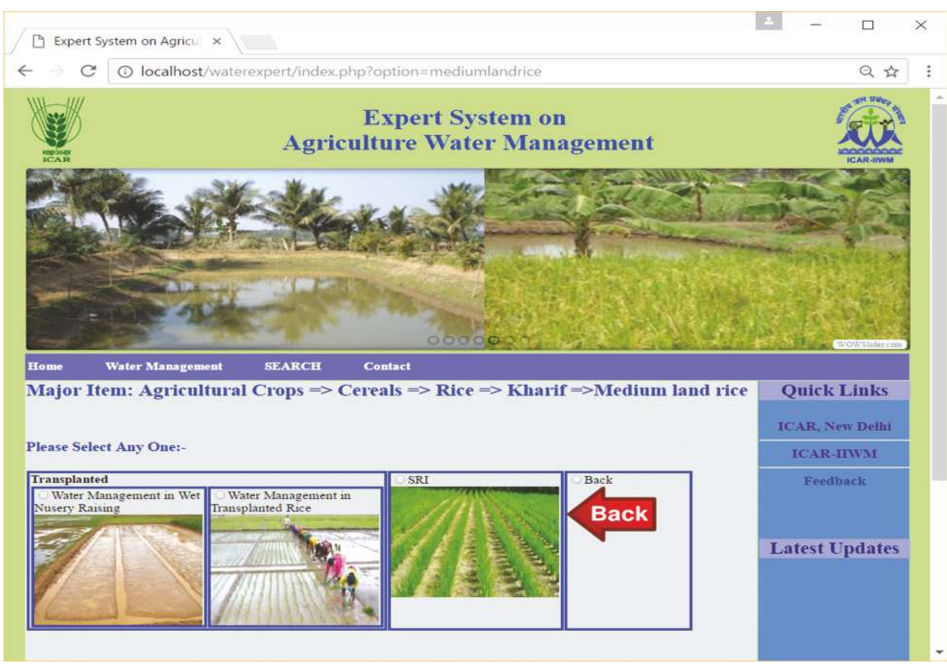


Fig. 23. Options of water management in medium land for rice.

ON-FARM RESEARCH & TECHNOLOGY DISSEMINATION

Assessment of Technological Intervention on Water Management for its Adoption and Sustainability

Project Code: IIWM/15/166

Investigators: M.K. Sinha, G. Kar, R.K. Mohanty, P.S.B. Anand, S. Mohanty, D.K. Panda and M. Das

Impact assessment study on created water management interventions were carried out at respective project sites of two stage rainwater-harvesting techniques at Sadeiberini village, crop diversification in rainfed upland rice area at Arnapunnapur village of Dhenkanal district, tank cum well system at Daburchua village of Khendujhar district and sub-surface water harvesting structure at Ambiki village of Jagatsinghpur district of Odisha. Mixed response of farmers was observed on the physical status of the irrigation structures, their present day utilization and existing field practices.

It reveals that the benefit gained through two stage rainwater harvesting by the farmers due to utilization of additional water resources was quite good and the sustainability of the lowland pond is significant. In case of refuges, little damage has been observed. The farmer gets increased yield of rice from 1.6 to 3.5 t ha^{-1} i.e., 119% increase over pre-adoption period. The lowland pond is also maintained. Some farmers in refuges are also practicing fish culture. After witnessing the success of these farmers, some more farmers got motivated and adopted the similar structures in faraway villages in Dhenkanal district.

Field assessment of sub-surface water harvesting structures at Jagatsinghpur district revealed that the created structures are being maintained even after 12 years of construction of the same. Benefits in *rabi* rice yield is about 7.1% (from 6.7 to 7.18 t ha^{-1}) with 108% increase in fish yield (from 0.28 to 0.58 t ha^{-1}) compared to pre-adoption period. The technology has also been expanded in other fields, it increased productivity of *rabi* and summer crops, cropping intensity and farm income through pisciculture (Fig. 24). There was improvement in farmer's assets from 52 to 86% across the study village and maximum gain (86%) was recorded at sub-surface water harvesting structure at Jagatsinghpur.

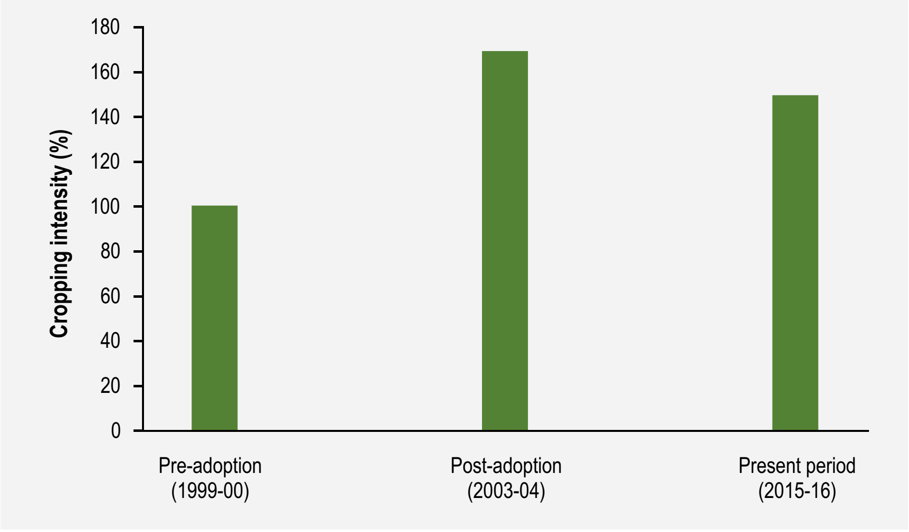


Fig. 24. Cropping intensity trend during pre- and post-adoption period at Sadaiberini village project site

Enhancing Land and Water Productivity through Integrated Farming System (Tribal Sub-plan Project)

Investigators: R.K. Panda, R.R. Sethi, S.K. Rautaray and R.K. Mohanty

Under TSP project, Farmers'-scientists' interaction was made in Mahulijore village (a newly adopted village under TSP project), Sundargarh district on May 6, 2016 to initiate the TSP project activities. A dug-well along with pipe conveyance and pressurized irrigation system in the village was developed. Total 2.1 ha area brought under piped irrigation with pressurized irrigation system. The irrigation intensity increased by 164% and profitability increased by around 6-folds from ₹ 17,000 ha^{-1} (pre-intervention period) to ₹ 1,10,272 ha^{-1}. During the reporting period, three numbers of two-days each farmers' training programs were organized at Mahuljore village and Birjaberna village during July 26-27, 2016, December 8-9, 2016 and March 23-24, 2017. Total 270 farmers including 132 women farmers participated the training programmes. State Govt. functionaries like Plant Protection Officer from KVK, Sundargarh; Executive Engineer, Assistant Engineer and Junior Engineer from Minor Irrigation Department; Agricultural Engineer from Horticulture Department, Govt. of Odisha attended the programs. During the training programs, emphasis was given on different aspects of water conservation and irrigation methods, role of *pani panchayat*, horticultural schemes and drip/sprinkler irrigation systems. Field demonstrations were made on use of paddy transplanter, farm implements, drip-irrigation in pomegranate and sprinkler in mango orchard farm to the farmers. A farmers' exposure visit was arranged to Aonlajore model watershed located in Sundargarh sadar block, where farmers were exposed to different soil and water conservation structures and their impact on agriculture. Farmers of Birjaberna village were distributed with fertilizers and facilitated with cement ring based vermi-compost pits to encourage organic farming.

Capacity building training program for the farmers

Dugwell under construction at the project site

Enhancing Water and Livelihoods Security and Improving Water Productivity in Tribal Dominated Paddy Fallow Rainfed Agro Ecosystem of Odisha (Farmer's First Program)

Investigators: P. Nanda, A. Mishra, S. Mohanty, M. Das, R.K. Mohanty, P.S. Brahmanand, A. Das and B. Das

This project was started from December 2016 with following objectives:

i) to intervene and improve livelihoods through rain water management and its multiple use for higher water productivity and improved on farm and off farm income of the farm households, and

ii) to have farmer-scientist interface enabling involvement of researchers for continuous interaction with farm conditions, facilitating innovations, participatory knowledge enrichment and sustainable management of farming at individual household, farm community and village level.

AICRP ON IRRIGATION WATER MANAGEMENT

The AICRP on Irrigation Water Management (AICRP-IM) scheme is in operation in nineteen agro-ecological regions on the country. Twenty six centers of AICRP-IM carried out research and extension work in the field of assessment of water availability, groundwater recharge, groundwater use at regional level, evaluation of pressurized irrigation system, groundwater assessment and recharge, water management in horticultural and high value crops, basic studies on soil, water, plant relationship and their interaction, conjunctive use of canal and underground saline water, drainage studies for enhancing water productivity, enhancing productivity by multiple use of water, and rainwater management in high rainfall areas.

Salient achievements :

- Relative water supply (RWS) study at Sriganganagar of Rajasthan for Khetawali distributary of IGNP command revealed to be 0.58 during *rabi* 2016, when maximum area was covered by wheat followed by mustard, barley, fodder, gram and vegetables. During *kharif* 2016, RWS was 0.60, when maximum area was covered by American cotton followed by guar and paddy. As the water supply was deficit in both the seasons, there is need to replace part of the area under wheat by mustard or barley and part of area under American cotton by guar and moong bean in order to match water supply with water requirement in all the irrigation systems.
- At Junagadh, recharge basin of about 3,281 m^3 storage capacity constructed and the catchment area of 98,600 m^2 recharged 12,906 m^3 of groundwater at the cost of ₹ 0.17 m^{-3} of groundwater recharge. Therefore, recharge basin was found as an effective recharge technique for an area where groundwater is depleting fast.
- Study on low pressure drip irrigation system at Rahuri, Maharastra showed that an increase in operating pressure from 0.2, 0.4, 0.6, 0.8 and 1 kg cm^{-2} resulted in increase in discharge to 2.13, 3.12, 4.11, 4.25 and 4.58 lph for emitters, and 5.65, 6.81, 7.52, 8.46 and 9.2 lph for micro-tubes, respectively. The discharge exponent 0.49 for the emitters and 0.30 for the micro-tubes indicated non-pressure compensating nature of both. The overall emission uniformity ranged from 86.9 to 93.9% for the emitters and ~92% for the micro-tubes.
- At Dapoli, treatment combinations of drip irrigation (80% ET_c) with crop spacing 120 cm - 45 cm x 15 cm and 100% RDF recorded highest fresh pod yield of okra (17.41 t ha^{-1}) and WUE (81.01 kg ha-mm^{-1}), indicating optimum use of water and fertilizer. Pod yield and WUE in control (furrow irrigation applied @ 50 mm depth at 7 days interval) was 8.75 t ha^{-1} and 10.7 kg ha-mm^{-1}, respectively. Total water applied for the treatment was 214.9 mm with 64.2% water saving compared to control (600 mm).
- At Belvatagi, maize grown under drip at 1.0 ET_o recorded significantly higher grain yield (11.94 t ha^{-1}) and saved 42.1% water compared to yield (9.74 t ha^{-1}) obtained by farmers' method of applying flood irrigation at critical growth stages of the crop. The *rabi* crops, wheat (3.53 t ha^{-1}), bengal gram (2.93 t ha^{-1}) and avare (1.52 t ha^{-1}) also performed better under drip at 1.0 ET_o as compared to the farmers' method with respective yields 3.12, 2.21 and 1.20 t ha^{-1}. This also saved 27%, 36% and 31.75% water in wheat, bengal gram and avare crops, respectively.
- At Sriganganagar, transplanted (TP) cotton crop with drip irrigation on 30th May, 10th June and 20th June gave 15.4, 24.2 and 47.0% higher seed cotton yields (3.06, 2.71, 2.32 t ha^{-1}) than direct sowing (DS)(2.65, 2.18, 1.58 t ha^{-1}), respectively. Yields with DS on 15th May (3.43 t ha^{-1}) and TP on 30th May (3.47 t ha^{-1}) with drip were at par. Highest net seasonal income of ₹ 1,00,591 and highest water expense efficiency (WEE) of 3.69 kg ha-mm^{-1} were obtained with DS on 15th May amongst all the dates and methods of sowing. Thus, when timely sowing is not possible due to canal closure, cotton crop may be raised in plastic bags and transplanted in field up to 30th May with drip irrigation without yield loss.
- At Shillong, zero tillage for both *kharif* and *rabi* crops resulted in significantly higher grain yield of rice by 33.8% (5.93 t ha^{-1}) and succeeding *rabi* crops,

viz., pea by 14.6% (5.35 t ha^{-1}), toria by 50.5% (1.40 t ha^{-1}) and buckwheat by 21.3% (1.68 t ha^{-1}) compared to conventional tillage practice (rice-4.43 t ha^{-1}; pea-4.67 t ha^{-1}; toria- 0.93 t ha^{-1}; buckwheat- 1.39 t ha^{-1}). Similarly, the WUE was also higher with zero tillage (rice- 10.1 kg ha-mm^{-1}; pea-76.9 kg ha-mm^{-1}; toria-20.1 kg ha-mm^{-1}; buckwheat- 24.2 kg ha-mm^{-1}) compared to conventional tillage (rice- 7.5 kg ha-mm^{-1}; pea- 67.0 kg ha-mm^{-1}, toria- 13.4 kg ha-mm^{-1}, buckwheat- 19.9 kg ha-mm^{-1}).

- At Udaipur, low cost groundwater recharge structures constructed were effective in augmenting groundwater table in semi-arid regions of Rajasthan, especially the hard rock areas. Groundwater recharge structures of capacity 260 to 3489 m^3, 450 to 8966 m^3 and 1145 m^3 were constructed at Doongri Para, Jhanpa and Punjpur villages of three districts, respectively. The structures were also utilized to store rainwater and provide life-saving irrigation to *kharif* wheat (0.70 ha) suffering from longer dry spells, and *rabi* wheat and gram cultivated over 7 ha in the villages. This also helped in improving socioeconomic status of tribal farmers of the region. The benefit-cost ratios of the structures were 1.05:1 in Doongri Pada and 1.91:1 in Jhanpa.
- At Rahuri, chilli-watermelon crop sequence recorded highest net income (₹ 32,00,855 ha^{-1}) and WUE (1425.56 kg ha-cm^{-1}), when both crops in sequence irrigated at 70% ET_c with 125% RDF fertigation.
- Based on the three seasons experiment at Pantnagar, the Kc values were determined for mustard and cowpea crops. Average Kc (crop coefficient) for mustard (cv. Pant Yellow Sarson-1) was 0.62 and 0.57 for cowpea. For yellow sarson, it ranged from 0.14 (1^{st} week after sowing) to 1.04 (7^{th} week after sowing). For cowpea, the Kc value was near to 0.4 during the initial phase. It was the maximum in the 8^{th} week of sowing (0.83) and declined thereafter.
- Cotton (var. RCH 650 BG-II) grown with only treated domestic sewage water (TSW) irrigation showed significantly higher seed cotton yield of 3.22 t ha^{-1} and water expense efficiency (WEE) of 36.7 kg ha-cm^{-1} compared to that with CW alone and other treatment combinations at Bhatinda. Yield and WEE were lowest with CW alone (2.84 t ha^{-1} and 32.2 kg ha-cm^{-1}).
- At Shillong, zero tillage resulted in higher maize equivalent yield (MEY) (6.1 t ha^{-1}) and WUE (9.6 kg ha-mm^{-1}) as compared to conventional tillage. Among the intercropping system/residue management treatments, MEY and WUE were highest under maize + groundnut paired row (residue retention) (7.18 t ha^{-1} and 11.3 kg ha-mm^{-1}), which were 32.7 and 32.9% higher compared to sole maize crop.

Masonry water harvesting structure at Jhanpa, Udaipur

Low cost water harvesting structure at Punjpur, Dungarpur

Maize and groundnut under different tillage at Shillong

AGRI-CONSORTIA RESEARCH PLATFORM ON WATER

Development and Management of Integrated Water Resources in Different Agro-ecological Regions of India (Theme-I)

Investigators: S.K. Jena, S. Mohanty, P.S. Brahmanand, R.R. Sethi and S.K. Ambast

Collaborating Institutes: ICAR-IISWC, Dehradun; ICAR-CRIDA, Hyderabad; ICAR-RC NEHR, Barapani; ICAR-NBSSLUP, Nagpur; IIT, Kharagpur; PDKV, Akola

Under this project, installation and evaluation of innovative water harvesting structures like rubber dams in different agro-ecological regions were done. For installation of ICAR flexi-check dams (rubber dams) in different agro-ecological regions of the country, desired rubber composite sheets were procured and installed in Maharashtra, Uttarakhand, Himachal Pradesh, Meghalaya, Tamil Nadu, Gujarat, and Odisha states. The rubber dams were installed in the following locations.

Region of installation	Number of units installed	Place of installation
Konkan region of Maharashtra	3	Dapoli
Tehri Grahwal region of Uttarakhand	1	Bhatoli
Doon Valley, Uttarakhand	3	Pasauli, Sirwalgarh and Selakui
Dhauladhar range of Himachal Pradesh	2	Palampur
Khasi hills of Meghalaya	1	Pyllun in Khasi hills
Nilgiri hills of Tamil Nadu	1	Sillala watershed of Ooty
High rainfall zone of south Gujarat	3	Navsari
Deccan plateau of Maharashtra	2	Kanse (Ambegaon), Pune
Eastern ghat region of Odisha	2	Semiliguda and Jogiput, Koraput district
Coastal plain region of Odisha	3	Sugo, Balasore; Kaushalyagang & Deras, Khurda district

The analyses of impact of installed rubber dams on agricultural performance in Chandeswar-1 and Chandeswar-2 sites of Khurdha district of Odisha showed increased the rice grain yield from 4.14 t ha^{-1} during pre-installation period to 5.05 t ha^{-1} during post-installation period mainly due to optimum time of transplanting and assured irrigation during mid-season dry spells. During *rabi* season, the pod yield of greengram enhanced from 0.72 t ha^{-1} (pre-installation) to 0.92 t ha^{-1} (post-installation). Yield of brinjal and ridge-gourd were enhanced from 7.4 t ha^{-1} to 10.4 t ha^{-1} from 6.1 t ha^{-1} to 9 t ha^{-1} respectively, due to assured irrigation from water resource created through installation of rubber dams. The farmers could irrigate *rabi* crops using water from rubber dam at critical crop growth stages of flowering and pod formation.

The rubber dam installation also improved productivity of summer vegetable crops such as okra (29%), brinjal (35%), watermelon (28%) and cowpea (26%). The fruit yield of okra was enhanced from 4.5 t ha^{-1} during pre-installation stage to 5.8 t ha^{-1} during post installation of rubber dam and the fruit yield of brinjal was enhanced from 4.8 t ha^{-1} during pre-installation stage to 6.48 t ha^{-1} during post installation of rubber dam. Similarly, the fruit yield of watermelon and cowpea has witnessed an increase from 9.4 t ha^{-1} and 5.2 t ha^{-1} to 12 t ha^{-1} and 6.55 t ha^{-1} respectively during corresponding period due to additional available water after installation of rubber dam at Chandeswar. Similarly, the yield of ridge-gourd and pumpkin was found to be enhanced by 36% and 29% respectively due to assured water supply from the installed rubber dams compared to their average productivity in the absence of rubber dam. The fruit yield of ridge-gourd and pumpkin was enhanced from 5.5 t ha^{-1} and 6.3 t ha^{-1} during pre-installation stage to 7.48 t ha^{-1} and 8.13 t ha^{-1} during post installation of rubber dam respectively. The installation of rubber dam resulted in improvement in cultivated land utilization index (CLUI) from 43.3% to 58.2% during 2016-17.

The socio-economic impact of rubber dams was also conducted in downstream areas in Chandeswar, Khurda district of Odisha. The ephemeral (seasonal) stream (Sagadianala) at Chandeswar became a perennial stream after the installation of rubber dam creating an additional water storage of about 8,550 m^3 and command area of 10 ha during *kharif* and 5 ha during summer seasons and the farmers could grow pulses and oil seeds during *rabi* and vegetables during summer season in watershed resulting in higher cropping intensity, crop productivity thereby resulting in better socio-economic status. The rice-pulse-vegetable cropping system has potential to contribute additional net returns of ₹ 19220 ha^{-1}. The benefit: cost (B:C) ratio of the system was worked out to be 2.16. The migration rate of the farmers (to urban areas) was found reduced by 28.5% during post installation phase of rubber dam compared to the pre-project phase.

Groundwater recharge structures such as water harvesting structures, check dam cum rubber dam and injection well were constructed in the hard rock region (Dhenkanal sadar block) of Odisha after conducting geo-resistivity survey in that area. These structures would be evaluated for its efficacy.

ICAR Flexi-check dams installed in different agro-ecological regions of the country

Evaluation of Irrigation System and Improvement Strategy for Higher Water productivity in Canal Commands (Theme-II)

Investigators: R.K. Panda, S.K. Rautaray, P. Panigrahi, S. Raychoudhuri, M.K. Sinha, A.K. Thakur, R.K. Mohanty, O. P. Verma and S.K. Ambast

Collaborating Institutes: ICAR-RCER, Patna; ICAR-CSSRI, Lucknow Centre; ICAR-NRRI, Cuttack; ICAR-IISR, Lucknow; ICAR-IIWBR, Karnal

This project has been initiated under the Agri-Consortia Research Platform on Water with the objective to assess the performance of the existing irrigation system and to improve the irrigation efficiency and water productivity through water resources development and it's efficient management in canal command. Nagpur minor under Puri main canal system in Balianta block, Khurda district, Odisha was selected for the study and sensitization training program was organized at the study site. The canal schedule remained seasonal (15^{th}

July–15th November) with actual irrigated area of 132.6 ha and actual discharge rate of 0.07 m^3s^{-1} as compared with design command area of 156 ha and design discharge of 0.31 m^3s^{-1}.The initial soil properties of the experimental fields were determined. The pH of the soil was 6.6–7.3, whereas the organic carbon, available N, available P, available K and water holding capacity were 2.77-4.45 g kg^{-1}, 178-209 kg ha^{-1}, 25.3-31.0 kg ha^{-1}, 126-161 kg ha^{-1} and 47.2-61.2%, respectively.

Benchmarking of the minor in terms of system performance, agricultural productivity and financial performance was studied. The seasonal irrigation water supply per unit command area was found 73% lower than the designed supply (20,970 cum ha^{-1}). Under agricultural productivity for paddy crop, as expressed in market based output versus supplied water, was 18% less (₹ 9.9 cum^{-1} with MSP of paddy of ₹ 1410 qt^{-1} during 2015-16); average crop yield of 3.9 t ha^{-1}; and actual water supply of 5565 cum ha^{-1}. Similarly, under financial performance expressed as cost-recovery ratio was 0.1 only, when water charges and cost of providing the water in the command were ₹ 0.39 lakh (₹ 250 ha^{-1} for *kharif* season as per Gazette No. 494 dated April 5, 2002) and ₹ 4.0 lakh (Dept. Water Resources, Govt. of Odisha), respectively.

PVC pipe conveyance, drip and sprinkler irrigation systems have been installed in three different reaches (upper, middle and tail) of the minor to improve the system performance.

View of project site

Automatic Irrigation and Fertigation in Drip-irrigated Banana (Theme-III)

Investigators: P. Panigrahi, S. Raychaudhuri, A.K. Thakur, A.K. Nayak, P. Sahu and S.K. Ambast

Collaborating Institutes: ICAR-IIHR, Bangalore; ICAR-IIVR, Varanasi; ICAR-NRCP, Solapur

This project has been initiated under the Agri-Consortia Research Platform on Water (Theme-III- Efficient Water Management in Horticultural Crops) with the objectives: i) to quantify the optimum wetted soil volume under drip irrigation in banana, ii) to study water and nutrients dynamics in soil and plant under different automatic irrigation and fertigation scheduling in banana, and iii) to evaluate the effect of different automatic irrigation and fertigation scheduling on yield, quality of fruits and water productivity in banana. The long term objective of this study is to develop a water and nutrient efficient and profit oriented automatic drip irrigation system for banana.

Field experiments were carried out to study the performance of different automatic irrigation and fertigation scheduling under drip irrigation in banana cv. Grand Nine (G-9) at ICAR-IIWM research farm at Mendhasal, Bhubaneswar. Different automatic irrigation schedules: at 80% ET_c with 60 min. interval 3 times daily (I_1), at 80% ET_c with 90 min. interval 2 times daily (I_2), at 60% ET_c with 60 min. interval 3-times daily (I_3), at 60% ET_c with 90 min.

Drip irrigation in banana plantation

interval 2-times daily (I_4), at 20% ASMD with soil water sensor (I_5) were compared with 100% ET_c (FI) operated manually. In another experiment, the interaction of three irrigation regimes (50% ET_c, 75% ET_c and 100% ET_c) and three fertigation levels (50% RDF, 75% RDF and 100% RDF) were imposed at different stages of the banana crop was evaluated. In third experiment, different planting technique (1 sapling per pit at 1.5 m, 2 saplings per pit at 2.0 m and 3 saplings per pit at 3.0 m) with irrigation at different soil volume (30%, 40%, 50%, 60% and 70%) were studied. The water applied under different treatments was 220-460 mm with different doses of N, P and K fertilizers. The mean volumetric water content in 0-0.15 m, 0.15-0.30 m, 0.30-0.45 m and 0.45-0.60 m soil layers were 18-24%, 16-22%, 20-25% and 19-23%, respectively. The average plant height, canopy diameter and girth diameter under different treatments were 0.95 m, 1.1 m and 125 mm, respectively. The hydraulic performance of the drip system was studied and found satisfactory with emitter flow rate variation (Q_v) of 5%, co-efficient of variation (CV) of 4% and distribution uniformity (DU) of 97%.

Eco-friendly Wastewater Treatment for Re-use in Agri-sectors: Lab to Land Initiative (Theme-IV)

Investigators: S. Raychaudhuri, M. Raychaudhuri S.K. Rautaray,S.K. Jena and Rachana Dubey

Collaborating Institutes: ICAR-IARI (WTC), New Delhi

To develop a wastewater treatment system, temporal variation in rate of wastewater discharge into the Chandrasekharpur drain near ICAR-IIWM gate and heavy metals, BOD, microbial loads in drain water were studied. The maximum rate of discharge (7.2 ls^{-1}) into the drain was observed between 7.30 to 10.30 AM. An inverse relationship between the drain wastewater discharge and microbial load was observed. However, a contrasting result is seen as well where concentration of heavy metals (Cr, Cd, Pb, Ni) varied proportionally with the discharge. Suspended solids also increased with higher discharge of wastewater into drain.

A prototype (1) was designed and developed with three gabion structures. The dimension of the prototype was 3.6 m long, 0.2 m height and 0.34 m wide. It was fitted with three number of gabion walls at 60 cm apart placed perpendicular to the longitudinal direction of the prototype, made with stones filled in gabion cages. Three different filtration materials placed in the middle of the three stone walls, having the same dimension (20 x 34 cm) but 4 cm thickness. The developed prototype has four chambers, where raw wastewater is discharged into the first chamber and the wastewater is passed through gabion 1, 2 and 3 to the fourth chamber which is treated water. The salient features of the designed prototype are: i) *in-situ* landless system, ii) removable/adjustable structure, iii) no use of non-renewable energy, and iv) easily operable and maintainable by local community.

Prototype 1 with treated filtration materials

Prototype 2 with spillway

The prototype was tested with controlled discharge of wastewater from syntax tank filled with continuous lifting of wastewater from the identified Chandrasekharpur drain. A valve was fitted at the bottom of the tank and the discharge rate was fixed at 0.24 $l s^{-1}$ which was equivalent to the 6 ls^{-1} in the main drain. Two prototypes were tested. In prototype 1 (treated), the filtration materials used were pretreated to modify surface charge characteristics of the filtration materials.

Both the prototypes were tested for 20000 liter of water, and the water quality at different chambers were tested and compared. The prototype 1 (treated) showed much improved performance in terms of pollutant reduction in the treated wastewater. The reduction in total dissolved solids (TDS) and suspended solids (SS) increased from <5 and 50% to 35 and 75%, respectively. In prototype 1 (treated), microbial and BOD reduction were more than 98 and 60%. Heavy metal reductions were more than 90%. Another design of the prototype (2), where 5% of the gabion surface was kept open to avoid stagnation of water at the upstream during heavy rainfall or excessive flow of wastewater into the drain.

The extent of reduction of BOD and heavy metal was less for prototype 2 as compared to prototype 1. The reason for lower efficiency in prototype 2 is that the experiment was conducted with high discharge of raw wastewater (8 ls^{-1}) to spill through the spillway. A pot experiment was conducted to study the impact of treated wastewater in comparison to untreated wastewater on few crops *viz*., one cereal (maize), two fruiting vegetable (okra and tomato), two root vegetables (carrot and radish), two leafy vegetables (spinach and amaranth) and one flower plant (marigold). There was an increase in biomass of okra, spinach, amaranth and radish by 12, 14, 8 and 4%, respectively when these were irrigated with treated wastewater.

Banana and papaya on-dyke of pond

Water Budgeting and Enhancing Water Productivity by Multiple Use of Water in Different Aquaculture Production Systems (Theme-V)

Investigators: R.K. Mohanty, P. Panigrahi, P. Sahu and S.K. Ambast

Collaborating Institutes: ICAR-CIFA, Bhubaneswar

During 2016-17, experiments were continued on (i) grow-out production of IMC with different production level and with varied input schedule, (ii) exploring possibility of enhancing water productivity through dual culture of minor carps, magur, pungas, murrels and koi along with IMC, (iii) fry production of IMC, murrels, koi with varied intensity and water volume, (iv) fingerling production of IMC with different inputs, and (v) fry production of magur and murrel at varied density. An IFS model (aquaculture, on-dyke horticulture, agriculture, duckery) has also been developed at ICAR-IIWM research farm with special emphasis on water budgeting. A pond of 900 m^2 has been stocked with Indian major carps at the rate of 5000 fingerlings ha^{-1} (*C. catla, L. rohita* and *C. mrigala*) with a stocking composition of 30:30:40 (surface feeder: column feeder: bottom feeder). On-dyke horticulture includes 140 plants of banana (G-9) in two rows and 90 papaya plants (Red lady) in single row planting. After harvest of *kharif* rice (3.42 t ha^{-1}), green gram, ladies finger, and pumpkin are grown in the adjacent area of 1.5 acre. Ducks (White Pekin) have also been introduced as an integrated component in the system. Life saving irrigation to on-dyke horticulture and adjacent agriculture crops is carried out using the pond water. System-wise water budgeting and water productivity (gross water productivity, net water productivity, consumptive water use index) will be estimated after harvesting.

Integrated farming system model at ICAR-IIWM research farm

Institutional and Market Innovations Governing Sustainable Use of Agriculture Water (Theme-VI)

Investigators: P. Nanda and A.K. Nayak

Collaborating Institutes: UAS, Bangalore; NLSIU, Bangalore

This project has been initiated under theme Water Governance and Policy with the objectives: i) To estimate the role of water markets in bringing efficiency and equity in water use for irrigation, and ii) To evaluate the effect of irrigation extension on awareness in improving water literacy. Irrigation extension is demonstrated through action research on farmers' fields, fixing water meters and energy meters, educating farmers in water and energy budgeting in conjunctive use areas.

The sample survey of pump owners/sellers and buyers of groundwater irrigation in two districts of Balasore and Cuttack revealed that about 70% of the pump owners were engaged in selling the water at fixed rate (varying between ₹ 1,500 to as high as ₹ 3,000 crop^{-1} ha^{-1}). The average open well users/ irrigators were found to be 10.8 numbers per open well and 11.50 for the bore wells. The average area irrigated per well was highest for bore well (4.8 ha) and lowest with average 2.6 farmers for dug wells. In general farmers use two types of pumps; electric, kerosene / diesel. The cost of establishment of irrigation well with an electric motor is much higher than diesel or kerosene motorized well. It was found that the cost of investment under electrified bore well was ₹ 71,500 (20 to 25 m depth) as against dieselized bore well cost of ₹ 23,100 with varying depth (10 to 13 m under diesel pumps). It is evident from the data that more number of sellers used electric pumps than the diesel or kerosene pump. The average number of self-users and buyers were found to be 13 under electric pump and for diesel pump it was found to be only 6 no and the average water rate per ha under dieselized system was found to be ₹ 1,750 as against ₹ 1,450 for electric pump and irrigated area per seller was higher (6 to 8 ha) in case of electric pumps as against 3 ha to 5 ha for diesel pumps. With respect to agricultural income through use of groundwater, it was estimated that the groundwater income has an elasticity of about 0.59 and is significant at 1% level. With respect to dynamics of water institutions under different sources of income, the water institutions under minor irrigation lift system was studied during the reporting year. The performance of the Water User Associations (WUAs) for government lift system indicates that the water users have been effective in allocation of water as per demand and the performance was found to be more than 4 in a scale of 5. The frequency of meetings, problem solving approach and the revenue realization was found to be varying between 2 to 4 for different WUAs under a performance scale of 5.

WEATHER REPORT OF RESEARCH FARM

The weekly rainfall and open pan evaporation data was recorded at ICAR-IIWM Research Farm, Deras Mendhasal, Khurda and were analysed, presented in presented Fig. 25. The total annual rainfall was 1030.6 mm during 2016-17 and standard meteorological week (SMW) 26 received the highest rainfall of 175 mm. Almost every week between SMW 20 to SMW 43 received rainfall, however there was no rainfall in between SMW 44 to SMW 16. The highest evaporation was observed during SMW 18 (58.5 mm) and thereafter it declined during monsoon period.

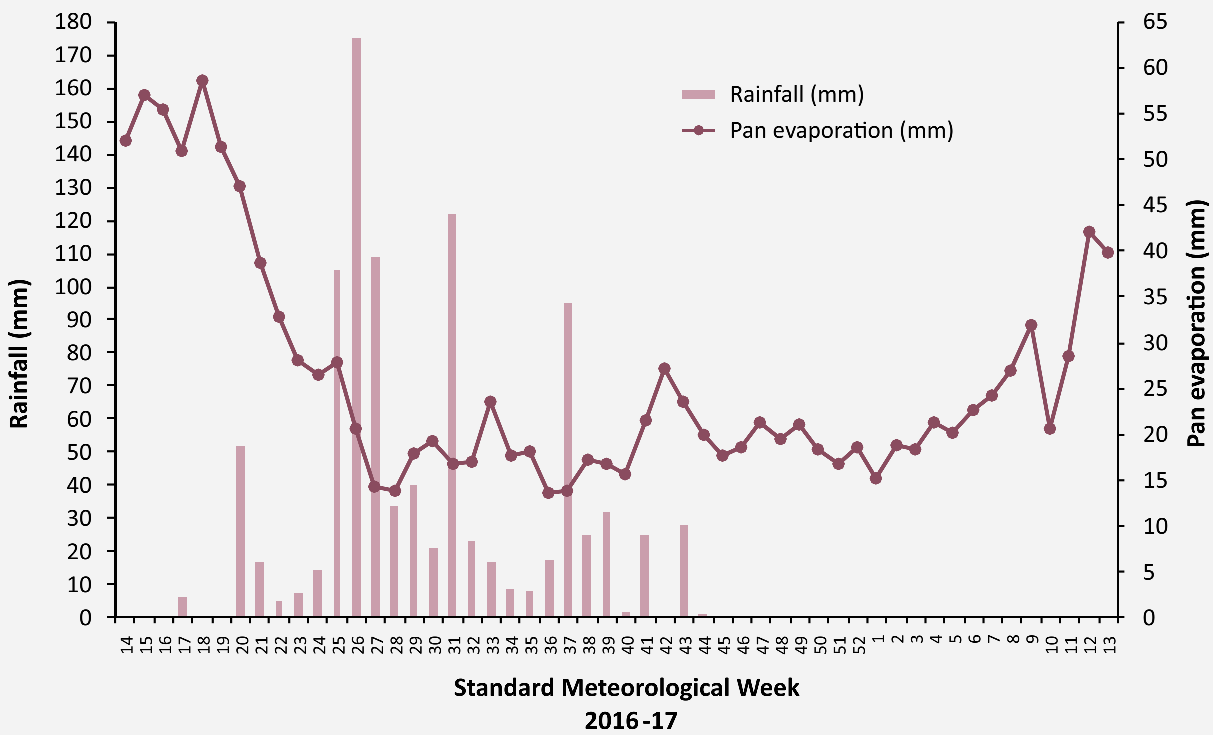


Fig. 25. Weekly rainfall and pan evaporation during April 2016-March 2017 (SMW14-SMW13)

PUBLICATIONS 2016-2017

Peer reviewed articles

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RESEARCH PROJECTS

IN-HOUSE PROJECTS (2016-17)

COMPLETED PROJECTS

Sl.No.	Project Code	Project Title	PI Name
1.	DWM/12/157	Development of runoff recycling model for production and profit enhancement through alternate land and crop management practices	Dr. P.K. Panda
2.	DWM/12/158	Evaluating deficit irrigation under drip system for rice based cropping sequence in canal command area	Dr. P. Panigrahi
3.	DWM/12/159	Identification of suitable crops for wastewater irrigation	Dr. S. Raychaudhuri
4.	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
5.	DWM/12/167	Design and evaluation of a portable drum based drip irrigation system	Dr. S. Mohanty / Dr. R.C. Srivastava
6.	DWM/13/162	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. S. Roy Chowdhury
7.	IIWM/15/165	Optimization modelling for conjunctive use of surface and groundwater	Dr. O.P. Verma
8.	IIWM/15/166	Assessment of technological intervention on water management for its adoption and sustainability	Dr. M.K. Sinha

ONGOING RESEARCH PROJECTS

Sl.No.	Project Code	Project Title	PI Name
1.	IIWM/15/168	Water and nutrient self-reliant farming system for rainfed area under high rainfall zone	Dr. S.K. Rautaray
2.	IIWM/15/169	Drainage planning of eastern coast delta using geo-informatics	Dr. S.K. Jena
3.	IIWM/15/170	Impact assessment study of using industrial wastewater on sunflower (*Helianthus annus* L.) and mustard (*Brassica nigra* L.) grown in peri-industrial area of Angul, Odisha	Dr. Rachana Dubey
4.	IIWM/15/171	Developing the process for remediation of chromium from polluted water sources	Dr. M. Das

Sl.No.	Project Code	Project Title	PI Name
5.	IIWM/15/172	Evaluation of feasibility of enhancing irrigation efficiency in canal command through improved surface and pressurized irrigation methods by adding adjunct service reservoir and open dug well	Dr. R.K. Panda
6.	IIWM/15/173	Inter-regional virtual water trade in India through agro-based products	Dr. G. Kar
7.	IIWM/15/174	Water management in medium and minor canal commands for rice-rice systems to enhance water use efficiency and nutritional water productivity	Dr. K.G. Mandal
8.	IIWM/15/175	Density dependent water use in coastal aquaculture of *Litopenaeus vannamei*	Dr. R.K. Mohanty
9.	IIWM/15/176	Enhancing water productivity through intensive horticultural system in degraded land	Mrs. Prativa Sahu
10.	IIWM/16/177	Benchmarking of public irrigation schemes for improving performance of irrigated agriculture	Dr. A. Mishra
11.	IIWM/16/178	Socio-economic and environmental linkages of groundwater irrigation in selected aquifers of India	Dr. D.K. Panda
12.	IIWM/16/179	Water use efficient practices for successful establishment and yield enhancement of pulse crops in rice based cropping system in seasonal waterlogged ecosystem	Dr. P.S. Brahmanand
13.	IIWM/16/180	Design and field evaluation of groundwater recharge structures for hard rock region	Dr. R.R. Sethi
14.	IIWM/16/181	Development of web-based expert system on agricultural water management	Dr. A.K. Nayak
15.	IIWM/16/182	Enhancing yield and water productivity of rice-fallow areas of eastern India through Super Absorbent Polymers (SAP)	Dr. Sanatan Pradhan

NEW RESEARCH PROJECTS

Sl.No.	Project Code	Project Title	PI Name
1.	None		

RESEARCH PROJECTS

EXTERNALLY FUNDED (2016-17)

Title	Budget (₹ in lakh)	Duration	P.I. / CCPI	Sponsored by
All India Co-ordinated Research Project on Irrigation Water Management	Dr. S.K. Ambast, Project Coordinator			ICAR, New Delhi
Agri-Consortia Research Platform on Water	Dr. S.K. Ambast, Lead Center Platform Coordinator Dr. P. Panigrahi, Deputy Lead Center Platform Coordinator			ICAR, New Delhi
I. Development and Management of Integrated Water Resources in Different Agro-ecological regions of India	119.80	2015-2018	Dr. S.K. Jena	Agri-Consortia Research Platform on Water, ICAR, New Delhi
II. Evaluation of Irrigation System and Improvement Strategy for Higher Water productivity in Canal Commands	45.30	2015-2018	Dr. R.K. Panda	Agri-Consortia Research Platform on Water, ICAR, New Delhi
III. Automatic Irrigation and Fertigation in Drip-irrigated Banana under Efficient Water Management in Horticultural Crops	54.60	2015-2018	Dr. P. Panigrahi	Agri-Consortia Research Platform on Water, ICAR, New Delhi
IV. Eco-friendly Wastewater Treatment for Re-use in Agri-sectors: Lab to Land Initiative	38.10	2015-2018	Dr. S. Raychaudhuri	Agri-Consortia Research Platform on Water, ICAR, New Delhi
V. Water Budgeting and Enhancing Water Productivity by Multiple Use of Water in Different Aquaculture Production Systems	46.40	2015-2018	Dr. R.K. Mohanty	Agri-Consortia Research Platform on Water, ICAR, New Delhi
VI. Institutional and Marketing Innovations Governing Use of Agriculture Water	7.70	2016-2018	Dr. P. Nanda	Agri-Consortia Research Platform on Water, ICAR, New Delhi
National Initiative for Climate Resilient Agriculture (NICRA)	600.00	2012-2018	Dr. G. Kar	ICAR, New Delhi
Impact of Climate Variability and Anthropogenic Factor on Groundwater Resources of India	35.00	2012-2016	Dr. D.K. Panda	LBS ICAR-Challenge project
Efficient Groundwater Management for Enhancing Adaptive Capacity to Climate Change in Sugarcane Based Farming System in Muzaffarnagar district, Uttar Pradesh	459.00	2015-2018	Dr. A. Mishra	Ministry of Agriculture, Govt. of India

Enhancing Land and Water Productivity through Integrated Farming System (Tribal Sub Plan Project)	20.00	2014-2017	Dr. R.K. Panda	ICAR, New Delhi
Enhancing Water and Livelihoods Security and Improving Water Productivity in Tribal Dominated Paddy Fallow Rainfed Agro Ecosystem of Odisha (Farmer's First Program)	18.00	2016-2017	Dr. S.K. Ambast, Nodal Officer Dr. P. Nanda (PI)	ICAR, New Delhi

COLLABORATIVE

Title	Budget (₹ in lakh)	Duration	Co-P.I.	Sponsored by
Global Yield Gap and Water Productivity Atlas (Collaborative project of ICAR with University of Nebraska, Lincoln, USA)	$56,000	2013-2017	Dr. P.S. Brahmanand	University of Nebraska, USA and Bill & Melinda Gates Foundation, USA
Assessment of Soil Fertility and Preparation of Soil Fertility Maps for Various Agro-Ecosystems of Odisha (with ICAR-CTCRI Regional Center, Bhubaneswar)	84.53	2014-2017	Dr. M. Das	RKVY, Office of the Director of Horticulture, Odisha

CONSULTANCY

Title	Budget (₹ in lakh)	Duration	P.I. / CCPI	Sponsored by
Preparation of District Irrigation Plan for 5 districts of Odisha	20.00	2016	Dr. S.K. Ambast	Odisha Watershed Development Mission, Bhubaneswar
Advanced Capacity Building Programme with special emphasis on Soil & Water Conservation activities in Watersheds for PIAs of the Directorate of Soil and Water Conservation and Watershed Development, Govt. of Odisha under PMKSY	24.00	2016	***Course Director:*** Dr. S.K. Ambast ***Course Coordinators:*** Dr. R.K. Panda Dr. S.K. Jena Dr. R.R. Sethi Dr. P. Nanda Dr. S. Mohanty Dr. P. Panigrahi	Odisha Watershed Development Mission, Bhubaneswar

AWARDS, HONOURS, RECOGNITIONS

Dr. S.K. Ambast with associates received 'Dr. Rajendra Prasad Puruskar for Technical Books in Hindi in Agricultural and Allied Sciences, 2015'

Dr. S.K. Jena and team received 'ICAR Award for Outstanding Inter-disciplinary Team Research in Agricultural and Allied Sciences 2013-14'

Dr. G. Kar received 'Ekamra Shree Award'

Dr. G. Kar, Principal scientist, ICAR-IIWM received 'Hooker Award' of ICAR-IARI, New Delhi

Dr. K.G. Mandal admitted as Fellow of the Indian Society of Agronomy (ISA)

Dr. K.G. Mandal elected as Fellow of the West Bengal Academy of Science and Technology (WAST)

- Dr. P.S. Brahmanand, Principal Scientist created a new Guinness World Record in the category of 'Fastest time to identify all elements of the periodic table' by identifying 118 elements from Hydrogen to Ununoctium in 3 min. 54.06 sec.

GUINNESS WORLD RECORDS

CERTIFICATE

The fastest time to identify all elements of the periodic table is 3 mins 54.06 seconds, achieved by Srinivasa Brahmanand Pothula (India), in Odisha, India, on 30 September 2016.

OFFICIALLY AMAZING

- Drs. S. Mohanty, P. Panigrahi, M. Raychaudhuri and S. K. Ambast received 'Er. R.C. Patra Memorial Award' from The Institution of Engineers (India), Odisha State Centre for best research paper in the field of 'Innovative Irrigation Management'.

- Dr. P.S. Brahmanand, Principal Scientist recognized as 'Outstanding Scientist Award' in 4th International Conference on Recent Advances in Agriculture and Horticulture Sciences held at Jodhpur during December 30-31, 2016.

- Dr G. Kar, Principal Scientist recognized as 'Outstanding Scientist Award 2016' by society of International Journal of Tropical Agriculture (IJTA), New Delhi. The award was presented during the International Conference on Agriculture, Horticulture and Plant Sciences, June 25-26, 2016.
- Dr. K.G. Mandal, Principal Scientist has received the 'Outstanding Researcher Award-2016' in Agricultural Sciences by Aufau International Awards 2016, CSRL, Research AP.
- Dr. M. Raychaudhuri, Principal Scientist received 'Best Oral Presentation' award during Global Conference on Perspective of Future Challenges and Options in Agriculture organized by the ASM Foundation, New Delhi and Jain Irrigation System Ltd., Jalgaon, held during May 28-31, 2016 at Jalgaon, Maharashtra.

- Dr. Rachana Dubey, Scientist has been awarded 'Best Paper Presentation Award' at International Conference on Sustainable Natural Resource Management from Science to Practice held at Banaras Hindu University, Varanasi, UP during January 12-13, 2017 for the research paper entitled 'Evaluating adaptation options for increasing heat stress tolerance in wheat'.
- Dr. P.K. Panda, Principal Scientist and co-authors received 'Best Poster Award' at 4th International Agronomy Congress held at IARI, New Delhi during November 22-26, 2016 for the paper entitled 'Runoff harvesting and recycling for production and profit enhancement through land modification and crop management practices'.
- Dr. Rachana Dubey, Scientist obtained Ph.D. degree in Environmental Sciences from ICAR-Indian Agricultural Research Institute, New Delhi. Her topic of research was 'Adaptation options for alleviating terminal heat stress in wheat'.

- Shri Ramchandra Raut of Parbatiya village of Dhenkanal district, Odisha, an adopted farmer of ICAR-IIWM, Bhubaneswar received Appreciation Certificate from Sri Radha Mohan Singhji for adopting 'Drip fertigation in vegetable crops' under National Innovations for Climate Resilient Agriculture (NICRA) Project.

- Dr. S. Roy Chowdhury, Principal Scientist and co-authors has been awarded 'Best Paper Presentation' award during 4th International Conference on Recent Advances in Agriculture and Horticulture Sciences held at Jodhpur during December 30-31, 2016.

- Dr. S.K. Ambast, Director has been elected as Vice-president in the Executive Council (2017-18), Indian Society of Coastal Agricultural Research, Canning Town, West Bengal.
- Dr. S.K. Rautaray, Principal Scientist nominated as Vice-President of the Association of Rice Research Workers (ARRW), ICAR-NRRI, Cuttack.
- Dr. S. Raychaudhuri, Principal Scientist co-chaired a session in the 81st Annual Convention 2016, Indian Society of Soil Science, held at Gwalior during October 20-23, 2016.
- Dr. S. Raychaudhuri, Principal Scientist has been elected as Councilor in the Executive Council (2015-2016), Indian Society of Soil Science.
- Dr. K.G. Mandal, Principal Scientist has been elected as Councilor in the Executive Council (2017-18), Indian Society of Coastal Agricultural Research, Canning Town, West Bengal.
- Dr. S.K. Jena, Principal Scientist, has been nominated by ICAR as member, Institute Management Committee (IMC) of ICAR-Indian Institute of Soil & Water Conservation, Dehradun; Chairman of assessment committee for promotion of technical personnel, ICAR-CRIJAF, Barrackpore; expert member, assessment committee for promotion of technical personnel, ICAR-NRRI, Cuttack; external examiner for evaluation of Ph.D. Thesis of OUAT, Bhubaneswar; TNAU, Coimbatore; and JNTU, Hyderabad.
- Dr. R.K. Mohanty, Principal Scientist, has been nominated by ICAR as member, Institute Management Committee (IMC) of ICAR-NRC on Integrated Farming, Motihari, Bihar.
- Dr. S.K. Rautaray, Principal Scientist, has been nominated by ICAR as Member, IMC of ATARI Bengaluru; expert member of Assessment Committee (Agronomy) for promotion of ARS scientists at ICAR-NRRI, Cuttack; expert member, Assessment Committee for promotion of Technical Personnel, ICAR-NRRI, Cuttack; member, Assessment committee for the clearance of probation of Technical Personnel at ICAR-CIWA, Bhubaneswar.
- Drs. K.G. Mandal and A.K. Thakur, Principal Scientists became Associate Editors of 'Agronomy Journal', published by American Society of Agronomy (ASA), USA and 'Irrigation Science', published by Springer, respectively.
- Dr. R.K. Panda, Principal Scientist has been selected as Associate Editor of 'Journal of Agricultural Engineering (ISAE)'.
- Drs. S. Roy Chowdhury and Dr. A.K. Thakur, Principal Scientists have been selected as editor for Indian Journal of Plant Physiology (Springer), ISPP, New Delhi.
- Dr. M. Raychaudhuri, Principal Scientist became women chess champion and women table tennis runners up during ICAR sports meet for eastern zone 2016 at ICAR-NRRI, Cuttack held during March6-9, 2016. Dr. M. Raychaudhuri and Dr. Rachana Dubey became runners up in table tennis (women) team and badminton (women) team events.
- Dr. S. Raychaudhuri, Principal Scientist won table tennis (singles) runners up during ICAR sports meet for eastern zone 2016 at ICAR-NRRI, Cuttack held during March 6-9, 2016. His team became runners up in table tennis (men) events.

ICAR-IIWM sports team

RESEARCH MANAGEMENT & AICRP MEETINGS

Research Advisory Committee (RAC) Meetings

Members of Seventh RAC of ICAR-IIWM, Bhubaneswar

1.	Dr. T.K. Sarkar, Former Project Director, WTC, ICAR-IARI, New Delhi	Chairman
2.	Dr. A.K. Misra, Former Head, Division of Soil Physics, ICAR-IISS, Bhopal	Member
3.	Dr. P.K. Mahapatra, Former Dean, College of Agriculture, OUAT, Bhubaneswar	Member
4.	Dr. M.K. Jha, Professor, IIT, Kharagpur	Member
5.	Dr. S.K. Chaudhari, Asst. Director General (S&WM), ICAR, New Delhi	Member
6.	Dr. S.K. Ambast, Director, ICAR-IIWM, Bhubaneswar	Member
7.	Dr. S. Roy Chowdhury, Principal Scientist, ICAR-IIWM, Bhubaneswar	Member Secretary

The first meeting of 7th Research Advisory Committee (RAC) of ICAR-Indian Institute of Water Management, Bhubaneswar was held during April 22-23, 2016, and second meeting of 7th RAC meeting was held during February 13-14, 2017. Dr. S.K. Ambast, Director, ICAR-IIWM welcomed esteemed Chairman and all members of RAC and presented research accomplishments of the Institute.

During first meeting, Dr. S.K. Chaudhari, ADG (S&WM) suggested linking Agricultural Water Management Portal (AWMP) with *Krishi* website and appraising training details under *Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)* to Council for record. He also urged to link Institute's activities with the work plan of AICRP on Irrigation Water Management. Action taken report (ATR) was presented by Dr. S. Roy Chowdhury, Principal Scientist and Member-Secretary, RAC. The members suggested inclusion of high-value vegetables and diversified farming system for enhancing water productivity. Dr. M.K. Jha advised that a group of inter-disciplinary scientists should be involved in the development of an open-ended surface and groundwater conjunctive use model. Theme-wise presentation was also made by theme leaders of different programmes. Chairman suggested to make Agricultural Water Management Portal more informative and interactive.

Recommendations:

- National level water governance and water use policy related studies need high priority.
- The present research projects need appropriate re-grouping to avoid overlapping and they should be rationally related.
- Rationalization of scientists' involvement in Research, Training and Extension activities are required as per their experience and expertise in specific professional fields and within the permissible norm of work limit.
- Basic studies on soil-plant-water relationships should be continued under changing environment scenarios.
- Exploratory trials need to be conducted prior to implementing innovative/new ideas in the field.
- Studies on interactive effects of irrigation and nutrients under optimal and sub-optimal levels should be conducted to assess their impacts on crop yield and water quality.

- Studies on canal water management should also include investigation for improving delivery and application efficiency of canal systems.
- Water balance modelling should be carried out at a field/ watershed scale for projected different climate change scenarios.
- Socio-economic impacts of rubber dams should be studied with a special reference to downstream areas.
- Field studies need to be carried out on the application of ICT (Information & Communication Technology) in efficient and user friendly on-farm water management.

Institute Research Council (IRC) Meeting

Institute's Research Council (IRC) meeting was organized during June 6-7, 2016. IRC meeting was organized with the Chairmanship of Dr. S.K. Ambast, Director, ICAR-IIWM, Bhubaneswar. The results of the twenty three completed/ on-going in-house research projects (program-wise) were presented and deliberated in the meeting. Also, four new research project proposals were presented and discussed. Director, ICAR-IIWM & Chairman, IRC highlighted the immediate and long-term challenges in the field of agricultural water management. He emphasized upon taking up of problem solving research that should ultimately lead towards its upscaling. He also emphasized that research findings must be disseminated from research farm to farmers' field. There should be a balance between laboratory/ modeling and field work. Dr. S.K. Jena, Principal Scientist and Member Secretary, IRC organized the meeting.

Chief Scientists' Meet of AICRP-IWM

Chief Scientists' Meet of the AICRP on Irrigation Water Management was jointly organized by ICAR-Indian Institute of Water Management, Bhubaneswar *and Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya* (RVSKVV), Gwalior during August 19-22, 2016. Shri Narendra Singh Tomar, Hon'ble Minister of Rural Development, Panchayati Raj, Drinking Water and Sanitation, Govt. of India was the Chief Guest on the Foundation Day Celebration of RVSKVV and inaugural function of Chief Scientists' Meet. He addressed the gathering, and mentioned the challenges to retain farmers in villages due to decreasing profit in agriculture. He also emphasized on the importance of water for efficient use in agriculture by growing more crop per drop of water and cautioned that the water table and quality is decreasing day-by-day and steps should be taken to save water through use of micro-irrigation. Smt. Maya Singh, Hon'ble Minister for Urban Development and Housing, Madhya Pradesh stressed on more research on safer use of domestic and industrial sewage water in agriculture and narrated the benefits of roof-water harvesting for raising groundwater. Other dignitaries present in this occasion were: Dr. N.S. Rathore, DDG (Education), ICAR; Prof. A.K. Singh, Hon'ble, Vice-Chancellor, RVSKVV; Shri Lakhan Singh Yadav, Hon'ble MLA; Dr. A.K. Sikka, In-Charge India Programme, IWMI; Dr. S.K. Chaudhari, ADG

(S&WM), ICAR; Dr. S.K. Ambast, Director, ICAR-IIWM and Dr. J.P. Dixit, Dean, College of Agriculture, RVSKVV, Gwalior. Dr. P. Nanda and Dr. M. Raychaudhari, Principal Scientists coordinated the meet.

Review Meeting of 'Agri-Consortia Research Platform on Water' Project of ICAR

Dr. S.K. Chaudhari, ADG (S&WM), NRM Division, ICAR and Dr. S.K. Ambast, Director, ICAR-Indian Institute of Water Management, Bhubaneswar reviewed the progress and achievements of eight major research themes under on-going 'Agri-Consortia Research Platform on Water' project of ICAR on November 7, 2016 at the Institute. The PIs and CCPIs of all the research themes/ projects from twenty five different Institutes/ Universities presented their technical and financial progress of the first six months of FY 2016-2017 in the meeting. Dr. P. Panigrahi, Senior Scientist coordinated the review meeting.

HRD, TRAINING AND CAPACITY BUILDING

Participation in training (Category-wise)

Official	Subject	Organization	Period
Dr. A.K. Nayak, Senior Scientist Dr. O.P. Verma, Scientist	Training on Landscape Crop Assessment Tool (LCAT)	CIMMYT, New Delhi	May 2-3, 2016
Dr. D.K. Panda, Senior Scientist	BASIN/ HSPE Training Program	IIT, Roorkee	June 6-14, 2016
Dr. R.K. Panda, Principal Scientist	Intellectual Property and Technology Management for Researchers	ICAR-NAARM, Hyderabad	June 13-18, 2016
Dr. S. Mohanty, Principal Scientist	Groundwater Flow and Transport Modeling through Fractured Geologic Media	IIT, Hyderabad	June 27- July 7, 2016
Dr. A.K. Nayak, Senior Scientist	Training program on Implementation of NIC's e-Procurement Solution through CPP Portal	ICAR-NAARM, Hyderabad	September 26-28, 2016
Dr. A.K. Nayak, Senior Scientist	Training program on Public Authority on RTI - MIS Online System	ICAR-NAARM, Hyderabad	October 25, 2016
Mr. Abhijit Sarkar, Scientist	Professional Attachment Training	ICAR-IISS, Bhopal	November 21, 2016- February 14, 2017
Dr. M. Das, Principal Scientist	Training workshop on Competency development for Human Resource Development Nodal Officer of ICAR	ICAR-NAARM, Hyderabad	February 23-25, 2017

Training organized

Subject	Place	Period	Participants
Summer training program for M. Tech. students of CAET, OUAT, Bhubaneswar on various aspects of water management	ICAR-IIWM, Bhubaneswar	May 16-June 15, 2016	3
Summer training program for M. Tech. students of Agricultural Engineering & Post Harvest Technology, CAU, Ranipool, Gangtok on various aspects of water management	ICAR-IIWM, Bhubaneswar	June 1-30 2016	3
Summer training program for M. Tech. students of Gujarat Agriculture University, Junagarh on various aspects of water management	ICAR-IIWM, Bhubaneswar	July 1-31, 2016	2
MTC on 'Climate Change Mitigation and Adaptation Strategies through Efficient Water Management in Agriculture'	ICAR-IIWM, Bhubaneswar	September 20-26, 2016	20
IGNOU Program for 'Diploma Course on Watershed Management' for the session 2016-17	ICAR-IIWM, Bhubaneswar	November 6, 2016 onwards	4

Farmers' training programs organized

Subject	Place	Period	Participants
Farmer's training program on 'Organic Farming'	Bhakarsahi village	April 15, 2016	40
Farmers' Field day on 'Wastewater Filter & Demonstration'	Jaypurpatna Village, Khurda	May 24, 2016	61
Farmers'-Scientists Interaction-cum-Awareness Program on 'Safe use of wastewater in agriculture'	Banarpal, Angul, Odisha	September 16, 2016	60
Farmers-Scientists interaction cum training program	Sarata village	June 18, 2016	35
ICAR-IIWM adopted farmers' visit in Agricultural Festival	ICAR-NRRI, Cuttack	May 9, 2016	52
Training program under TSP project	Mahuljore village, Sundargarh	July 26-27, 2016	108
Training program under TSP project	Birjaberna village, Sundargarh	December 8-9, 2016	64

Farmers-Experts Interaction-cum-Practical Training Programs

Farmers from	Period	Participants
Office of the Agriculture, Potashpur block, Natunpukur, Purba Medininpur, West Bengal	August 19, 2016	20
Office of the Agriculture, Tamluk block, Purba Medininpur, West Bengal	August 27, 2016	20
Egra-I block, Purba Midnapur, West Bengal (PMKSY)	October 3, 2016	25
Khejuri block, Purba Midnapur, West Bengal (PMKSY)	December 16, 2016	40
Egra block, Purba Midnapur, West Bengal (PMKSY)	February 7, 2017	20
Keonjhar, Odisha (Farmers First project of ICAR-IIWM)	March 25, 2017	50
Purulia, West Bengal (ATMA)	March 28, 2017	95

Advanced Capacity Building Program under PMKSY

Trainees	Place	Coordinators	Period	Participants
Project Implementing Agencies (PIAs) of Directorate of Soil Conservation and Watershed Development, Govt. of Odisha	ICAR-IIWM, Bhubaneswar	Dr. S.K. Ambast Dr. R.K. Panda	August 22-25, 2016	20
		Dr. S.K. Ambast Dr. S.K. Jena	September 6-9, 2016	20
		Dr. S.K. Ambast Dr. R.R. Sethi	September 28-October 1, 2016	20
		Dr. S.K. Ambast Dr. P. Nanda	October 3-6, 2016	20
		Dr. S.K. Ambast Dr. S. Mohanty	October 17-20, 2016	20
		Dr. S.K. Ambast Dr. P. Panigrahi	November 2-5, 2016	20

HRD fund allocation and utilization during 2016-2017

Budget Head	Non-Plan		Plan	
	Budget	Expenditure	Budget	Expenditure
H.R.D.	0	0	1.50	1.50

Exhibitions

Institute's achievements was displayed/ showcased in the following exhibitions held in different locations:

Events	Place	Period
70th Foundation Day of ICAR - NRRI, Cuttack	ICAR-NRRI, Cuttack	April 23, 2016
Farmers' Fair organized by ICAR-NRRI	ICAR-NRRI, Cuttack	May 9, 2016
7th *Krishi Fair* 2016 organized by *'Shree Shrikshetra Soochana'*	Shree Gundicha Temple, Puri	June 4-8, 2016
Exhibition	ICAR-CIFA, Bhubaneswar	September 3, 2016
Agriculture exhibition during 4th International Agronomy Congress	ICAR-IARI, New Delhi	November 23-26, 2016
Northern Regional Agricultural Fair on *Tikkau Kheti - Khushaal Kisan*	G.I.C. Ground, Muzaffarnagar, U.P.	November 28-30, 2016
Kishan Mela	Dr. RPCAU, Pusa, Samastipur, Bihar	December 3-5, 2016
Exhibition	ICAR-CIWA, Bhubaneswar	February 17, 2017

WOMEN EMPOWERMENT

Training-cum-Demonstration

A training-cum-demonstration on 'Mushroom cultivation' for farm women self-help groups (SHGs) was conducted in collaboration with KVK, Jagatsinghpur at Hasimnagar village of Jagatsinghpur district on November 19, 2016. A total of 20 women participated in the training program.

A demonstration program on 'Preparation of bio-pesticides' was conducted at Dhinkia village, Tirtol block of Jagatsinghpur district on August 27, 2016. A total of 20 women farmers attended the program. They were also exposed to various topics, viz., water conservation techniques, soil health card, climate change impact on agriculture and use of organic fertilizers in agriculture.

Farmer-Scientists' Interaction-cum-Awareness Program

A farmer-scientists interaction-cum-awareness programmme on 'Safe use of wastewater in agriculture' was organized by ICAR-Indian Institute of Water Management on September 16, 2016 at the Agriculture Block Office, Banarpal, Angul, Odisha. Sixty farmers including twenty seven women farmers from surrounding villages participated in this program. A group of scientists of the Institute and officials of Department of Agriculture, Govt. of Odisha shared their experiences and discussed on problems usually occurring in agriculture due to wastewater use. Dr. Rachana Dubey, Scientist of the institute coordinated this program, and attended by Dr. A. Mishra and other scientists of the institute.

MAJOR EVENTS 2016-17

Secretary DARE and Director General, ICAR, Dr. Trilochan Mohapatra visited ICAR-IIWM on April 24, 2016

Dr. N.K. Tyagi, former Director, ICAR-CSSRI and Dr. P. Jayasankar, Director, ICAR-CIFA on the occasion of ICAR-IIWM's 29th Foundation Day Celebration

ICAR- IIWM celebrated International Yoga day on June 21, 2016

Visit of Hon'ble Union Minister of Agriculture and Farmers' Welfare, Shri Radha Mohan Singh on September 2, 2016

Advanced Capacity Building Training Program under PMKSY at ICAR-IIWM

Brain Storming Meeting of NAAS on September 3, 2016 at ICAR-IIWM

Hindi Pakhwada
at ICAR-IIWM during September 14-28, 2016

Hon'ble Secretary, DARE and Director General, ICAR, Dr. T. Mohapatra visited ICAR-IIWM on October 1, 2016

MTC on 'Climate change mitigation and adaptation strategies through efficient water management in agriculture' at ICAR-IIWM during September 20-26, 2016

Gandhi Jayanti Celebration with Hon'ble Secretary, DARE & DG, ICAR by forming 'Human Chain'

Vigilance Awareness Week 2016 during October 31 to November 5, 2016

ICAR-IIWM celebrated 'Agricultural Education Day' on December 3, 2016

Celebration of World Soil Day on December 5, 2016

ICAR-IIWM celebrated 'National Productivity Week' during February 12-18, 2017

Field visit of RAC chairman, Dr. T.K. Sarkar on February 14, 2017

Celebration of World Water Day on March 22, 2017

MERA GAON MERA GAURAV

Six groups of scientists of ICAR-IIWM adopted thirty villages across seven blocks spreading over five districts of Odisha under the '*Mera Gaon - Mera Gaurav*' program. Farmers' have been given mobile based services for pest and disease control in crops, literature supports for soil collection, water storage and use, *in-situ* rainwater conservation technique along with creating general awareness and imparted need based training on various aspects of farming. Linkages have been established with state government offices (seed production, Organic farming, state agriculture and horticulture departments etc.), OUAT, Bhubaneswar, KVKs, ICAR-CIFA, Bhubaneswar and other allied organizations.

Information on villages adopted under MGMG Program

Group ID	Name of the villages	Name of Block and District	Number of farm families
Group A	Khalibandha, Nuagaon, Sadeiberini, Gajamara, Saptasajyapada	Block-DhenkanalSadar District-Dhenkanal	631
Group B	Bhakrasahi, Poijhari, Haladibasanta, Naranpur, Sarata	Block-Balipatna District-Khorda	439
Group C	Sukalaaisanyapara, Alisha, Churali, Parimanoipur, Sukalapara	Block-Satyabadi and Kanas District-Puri	674
Group D	Chhatabar, Durgapur, Giringaput, Haridamada, Jammujhari	Block- Bhubaneswar and Jatni District-Khorda	755
Group E	Khadal, Irikundal, Hasimnagar, Dinkia, Bindhapada	Block-Tirtol District-Jagatsinghpur	271
Group F	Madana, Naindipur, Chandapalla, Patakura, Jagannathpur	Block-Garadpur District-Kendrapara	820

Information on general awareness created

Sl. No.	Subject matter
i)	Scheduling of irrigation in field crops
ii)	Soil health management, integrated farming systems and pisciculture
iii)	Facilitated supply of tomato (var. *Swarna Sampad*) and brinjal (var. *Arka Nilachal*) seedlings through KVK, Dhenkanal
iv)	Organic farming and skill development
v)	Nutrient management in paddy and pisciculture
vi)	Suitable time of planting / sowing for *rabi* crops like green gram and groundnut
vii)	Pest management in rice, pulses, groundnut and brinjal crops
viii)	Integrated weed management
ix)	*Swaccha Bharat Abhiyan*, Soil health card, *Jai Kisan Jai Vigyan* week awareness campaign

x)	Soil sample collection and water conservation techniques
xi)	Bio-fertlizer application
xii)	Integrated SRI, rainwater conservation and rice-fish farming
xiii)	Pond lining, Integrated fish-water chestnut co-production system
xiv)	Micro-irrigation
xv)	Benefit of quality seed production
xvi)	Benefit of mushroom cultivation
xvii)	Use of seed drills, sprayers and other farm implements

Training and interaction meeting organized under adopted villages

Detail of programs	Place and date	No. of beneficiary farmers
Farmer's training on organic farming	Bhakarasahi April 15, 2016	40
Farmer-Scientist interaction meeting on soil and water management, soil health card, groundwater use in coastal areas, procedure to collect the soil sample, government schemes on farm machineries and implements like seed drill, sprayers etc.	Erikundala village April 27, 2016	20
Farmer-Scientist interaction on quality seed production, vermicompost, management of problematic soils and integrated farming	Satyabadi & Kanas block, Puri May 13, 2016	40
Scientist-farmer interaction meet on rainwater conservation and rice-fish farming	Khalibandha, Nuagaon, Sadeiberini, Gajamara, Saptasajyapada villages May 27, 2016	20
Farmer-scientist interaction meeting on water conservation, soil and crop management i.e., design of bund size in paddy field, development of groundwater resources, nursery bed preparation for paddy, monsoon preparedness, maintenance of soil health, preparation of bio-pesticides and management of crop residues	Bindhapada village June 10, 2016	20
Scientists-farmers interaction meet on integrated SRI	Khalibandha, Nuagaon, Sadeiberini, Gajamara, Saptasajyapada villages June 17, 2016	15
Farmer-scientist interaction-cum-training programme on nutrient management in paddy and pisciculture	Sarata village June 18, 2016	35
Demonstration of paddy transplanter and training oh fertilizer application methods, drainage requirement in paddy crop, *Pradhan Mantri Fasal Bima Yojna*	Khadala village July 30, 2016	30
Farmer-Scientist interaction meeting on fish culture, agricultural marketing and water harvesting	Poijhari village August 6, 2016	40
Farmer-Scientist interaction on fertilizer application, vermicomposting and pond-based integrated farming	Satyabadi, Puri August 23, 2016	35
Farmers' training on preparation of bio pesticides and different water conservation techniques, agriculture water management issues, climate change impact on agriculture and need of organic farming	Bindhapada village August 27, 2016	20

Farmer-Scientist interaction meeting on preparation of soil health card and government schemes in agriculture and horticulture	Bhakarasahi village September 17, 2016	40
Farmer-Scientist interaction cum training program on agricultural water management and government schemes in agriculture	Sarata village October 29, 2016	30
Farmers & Scientists participated in *Swachha Bharat Abhiyan*	Bindhapada village October 29, 2016	35
Training programme on integrated pest management approaches for *rabi* rice and pulses	Jammujhari village November 11, 2016	30
Farmer-scientist interaction and demonstration on mushroom cultivation	Hasimnagar village November 19, 2016	20
A farmer meeting & demonstration on mushroom cultivation method, water management techniques, *rabi* crop planning, mobile use for getting climate information was conducted.	Hasimnagar village November 29, 2016	20
Farmer-Scientist interaction on HYVs of rice, pisciculture, insect-pest problem in rice, hybrid seed production, importance of soil health card and integrated farming systems	Satyabadi, Puri December 23, 2016	35
Distribution of saplings of guava (var. *Allahabad safeda*) and mango (var. *Amrapali*)	Madana, Jagannathpur, Patakura, Chandapalla and Naindipur villages	30
Farmer-Scientist interaction meeting	Dinkia village January 21, 2017	12
Farmers' interaction meet on integrated farming system option, soil management, fish culture, water management in *rabi* and summer crops.	Hasimnagar village March 3, 2017	15
Farmer-Scientist interaction on pisciculture, management of residual soil moisture, hybrid seed production of different crops and *rabi* rice cultivation	Satyabadi & Kanas blocks, Puri March 25, 2017	33

Farmer's - Scientist interaction meeting

SWACHHA BHARAT ABHIYAN

The Director and staff of ICAR-IIWM, Bhubaneswar participated actively in *Swachha Bharat Abhiyan* and fifteen number of cleanliness campaigns were conducted during 2016-17 in the Institute main campus. As a part of fortnightly '*Swachhata Pakhwara*' celebrations during May 16-31, 2016 under the directives of Government of India and ICAR, human chain formation, pledge taking ceremony and a debate competition on "Can *Swachha Bharat Abhiyan* ensure a healthy and wealthy India by the year 2019?" was conducted on May 16, 2016. A monthly Seminar on "Recycling of waste to wealth under *Swachha Bharat Abhiyan*" was also organized on May 28, 2016.

A human chain was formed and pledge was taken by the Hon'ble Secretary, DARE & DG, ICAR, Dr. Trilochan Mohapatra and staff of IIWM for cleanliness of our surrounding on 2nd October, 2015, birth anniversary of Mahatma Gandhi and Lal Bahadur Shastri. Dr. Mohaptra administered pledge on '*Swacchata Abhiyan'* programme to all staff members of the Institute and called on *swacchata* in a holistic manner so that it really fulfills its objective of taking the nation to a newer height.

A lecture on '*Swachha Bharat Abhiyan* with special emphasis on control of obnoxious weed *Parthenium hysterophorus* (carrot grass)' was organized and cleanliness drive for eradication of this weed outside the main campus of the Institute was undertaken during '*Parthenium* Awareness Week' (August 16-22, 2016). As a part of fortnightly *Swachhata Pakhwada* celebrations during October 16-31, 2016 under the directives of Government of India and ICAR, Dr. S.K. Ambast, Director, administered the *Swachhata Shapath* to all the officers and staff of the Institute. An awareness campaign on *Swachha Bharat Abhiyan* and *Parthenium* eradication was organized in Chandpalla village, Kendrapara district, Odisha and a talk on importance of cleanliness and weed eradication was organized for the trainees from Directorate of Soil and Water Conservation and Watershed Development under PMKSY at ICAR-IIWM on October 20, 2016. A cleanliness programme under *Swachha Bharat Abhiyan* was also organized at Bindhapada village, Tirtol block, Jagatsinghpur district, Odisha on October 29, 2016. Dr. P.S. Brahmanand, Principal Scientist of the institute coordinated these programs.

A 3-minutes short film entitled 'Family is the backbone of *Swachha Bharat Abhiyan*' directed and presented by Dr. P. S. Brahmanand, nodal officer, *Swachha Bharat Abhiyan* was awarded with Certificate of Excellence by Ministry of Information and Broadcasting, GoI and National Film Development Corporation Limited for its participation in *Swachha Bharat* Short Film Festival held at New Delhi on October 2, 2016.

A brief account on *Swachha Bharat Abhiyan* at ICAR-IIWM (April 1, 2016 - March 31, 2017)

S. No.	Nature of events	Number of events	Number of hours	Number of staff / farmers/ students participated
1	Institute campus cleanliness	15	30	50 (each event)
2	Revamping of redundant files and old stock in store	2	5	7
3	Human chain formation and pledge taking ceremony on *Gandhi Jayanti* (October2, 2016) and October1, 2016) and *Swachha Bharat Pakhwara* (May16-31, 2016 & October 16-31, 2016)	4	6	50 (each event)
4	Farmers awareness about *Swachha Bharat* cum cleanliness drive at villages (Kendrapara and Jagatsinghpur districts of Odisha)	2	4	160

5	Student awareness training cum cleanliness drive on October 2, 2016	1	5	75
6	Motivating NSS and NCC students to take part in cleanliness drive in remote villages of Odisha (In collaboration with *Pipli Sanskrtika Samiti*, Odisha)	2	6	100
7	Monthly Seminar on 'Recycling of waste to wealth under *Swachha Bharat Abhiyan*' by Dr. P.S. Brahmanand, Senior Scientist	1	1	45
8	Debate on 'Can *Swachha Bharat Abhiyan* ensure healthy and wealthy India by the year 2019?'	1	1	50
9	*Parthenium* weed eradication drive (August 16-22, 2016)	1	4	50
10	Talk on awareness about *Parthenium* eradication to trainees of watersheds under PMKSY	1	1	20
	Total Number	30	63	607

Cleanliness drive in the Institute campus

Swachha Bharat Abhiyan
at Bindhapada village, Jagatsinghpur district, Odisha

Human chain formation at ICAR-IIWM

PARTICIPATIONS

Conferences, Meetings, Workshops, Symposia, Trainings, Deputations

Official	Name of the Seminar / workshop / training / conference	Organized by	Period
Dr. S. Raychaudhuri Dr. M. Raychaudhuri	4th India Water Week	NWDA under MoWR, River Development and Ganga Rejuvenation, GOI	April 4-8, 2016
Dr. S. Roy Chowdhury	Agroforestry for Rehabilitation of Water Congested Ecologies for the Eastern Region	NAAS and ICAR-Research Complex for Eastern Region, Patna	April 5, 2016
Dr. R.R. Sethi	Workshop on Preparation of District Irrigation Plan under PMKSY	Department of Food Security and Agriculture Govt. of Sikkim	April18, 2016
Dr. S. Raychaudhuri	Workshop on Soil Health Card	DOA, Govt of Odisha & IMAGE, Bhubaneswar	April 18-19, 2016
Dr. M. Das	Workshop on MGMG &Presentation of Farmers' First Project	ICAR – ATARI, Zone VII Jabalpur	April 30-May1, 2016
Dr. M. Raychaudhuri	Global Conference on Perspective of Future Challenges and Options in Agriculture at Jain Hills	ASM Foundation, New Delhi and Jain Irrigation System Ltd., Jalgaon	May 28 - 31,2016
Dr. G. Kar	International Journal of Tropical Agriculture, New Delhi.	Society of International Journal of Tropical Agriculture	June 25-26, 2016
Dr. S. Roy Chowdhury	First meeting Steering Committee, Second Green Revolution	ICAR-Research Complex for Eastern Region, Patna	June 27, 2016
Dr. S.K. Ambast Dr. S. Roy Chowdhury	Meeting on 'Constitution of Special Cell for Monitoring of Second Green Revolution Program'	DoA and Farmers Empowerment, Govt. of Odisha	July 12, 2016
Dr. R.R. Sethi	Training program on 'Urban Rainwater Harvesting'	Gopabandhu Academy of Administration, Bhubaneswar	July 14, 2016
Dr. S. Roy Chowdhury	State level Executive Committee meeting on PKVY	DoA and Farmers' Empowerment, Govt. of Odisha	July 19, 2016
Dr. P.S. Brahmanand	Divisional Review Meeting of Foreign-aided Projects	NRM Division, ICAR, New Delhi	August 9, 2016
Dr. R.R. Sethi	Workshop on 'Preparation of DistrictIrrigation Plan' under PMKSY	Department of Food Security and Agriculture Govt. of Sikkim	August 10, 2016
Dr. S.K. Jena	Workshop on 'Recent Advances in Soil and Water Conservation Engineering'	Assam University, Silchar	August 26-27, 2016
All Scientists of ICAR-IIWM	Brain-storming session on 'Minimizing Water Use in Agriculture'	NAAS & ICAR-IIWM, Bhubaneswar	September 3, 2016

Dr. P.S. Brahmanand	Workshop on 'Waterlogging and Salinity in Irrigated Agriculture'	ICAR, Central Board of Irrigation and Power and CWC, Chandigarh, Haryana	September 3-4, 2016
Dr. K.G. Mandal	Second R&D Session of INCSW of CWC, MoWR, River Development and Ganga Rejuvenation, GOI	INCSW (formerly INCID) of CWC, New Delhi	September 5, 2016
Dr. A.K. Thakur	National Consultation on 'System of Crop Intensification/System of Rice Intensification'	NAAS and NCS, New Delhi	September 10, 2016
Dr. S. Raychaudhuri	*Rajbhasha Sammelan*	*Rajbhasha Samity*, New Delhi	September 29 -October 1, 2016
Dr. K.G. Mandal	Workshop on 'Strategizing Pulses Production in Rice-fallow Areas in eastern India' with eastern states	Department of Agriculture and Farmers Empowerment, Govt. of Odisha (sponsored by DAC&FW, GoI)	October 7, 2016
Dr. S.K. Ambast Dr. M. Das Dr. S. Raychaudhuri	81st Annual Convention of ISSS and National Seminar on Development in Soil Science	Indian Society of Soil Science, New Delhi & RVSKV, Gwalior	October 20-23, 2016
Dr. S.K. Ambast Dr. S. Roy Chowdhury Dr. S.K. Rautaray	Water Management Strategies for Optimal Resource Utilization in Eastern Region	Dr. RPCAU, Pusa and ICAR-IIWM	October 26, 2016
Dr. S. Mohanty Dr. P. Panigrahi	International Conference on Integrated Land Use Planning for Smart Agriculture	ICAR-NBSS & LUP, Nagpur	November 10-13, 2016
Dr. A.K. Nayak	International Conference on Statistics & Big Data Bioinformatics in Agricultural Research	ICAR-IASRI, New Delhi & ICRISAT, Hyderabad	November 21-23, 2016
Dr. S.K. Rautaray Dr. K.G. Mandal Dr. A.K. Thakur Dr. P.K. Panda Dr. P. Panigrahi Dr. S. Pradhan	4th International Agronomy Congress	ICAR-IARI, New Delhi	November 21-26, 2016
Dr. M. Das	13th Scientific Advisory Committee meeting of Sonepur KVK, OUAT	KVK Sonepur, Odisha	November 24, 2016
Dr. M. Das	9th Scientific Advisory Committee meeting of Bolangir KVK, OUAT	KVK Bolangir, Odisha	November 25, 2016
Dr. G. Kar Dr. O.P. Verma Mr. N. Manikandan	Workshop on 'Grafting in Solanaceous and Cucurbitaceous Vegetable Crops for Mitigation of Edaphic Constraints'	CHES (ICAR–IIHR), Bhubaneswar	November 30, 2016
Dr. G. Kar	National Symposium on Plant Health Management for Food Security and Food Safety	Plant Pathological Society, BCKV, Kalyani, Nadia	December 8, 2016
Dr. S. Raychaudhuri	International Interdisciplinary Conference on Humanitarian Technology	KIIT University, Bhubaneswar	December 15-17, 2016
Dr. D.K. Panda	XVIII National Conference of Agricultural Research Statisticians at IAR-IIFSR, Modhipuram	ICAR-IASRI, New Delhi	December 16-17, 2016

Dr. K.G. Mandal	26th Annual General Meeting of the West Bengal Academy of Science & Technology (WAST)	WAST, CSIR-IICB, Kolkata	December 22, 2016
Dr. S.K. Ambast Dr. M. Das Dr. R.K. Panda Dr. R.R. Sethi Dr. P. Panigrahi	International Conference on Emerging Technologies in Agricultural and Food Engineering	Agricultural and Food Engineering Department, IIT, Kharagpur	December 27-30, 2016
Dr. S. Roy Chowdhury Dr. P.S. Brahmanand	IJTA 4th International Conference on Recent Advances in Agriculture and horticulture Sciences	International Journal of Tropical Agriculture and Academic Research Journals, New Delhi, India.	December 30-31, 2016
Dr. S. Raychaudhuri Dr. M. Raychaudhuri Dr. M.K. Sinha	104th Indian Science Congress	Indian Science Congress Association, Kolkata at Sri Venkateswar University, Tirupati	January 3-7, 2017
Dr. P. Panigrahi Dr. R. Dubey	International Conference on Sustainable Natural Resource Management: from Science to Practice	ISAE and Institute of Agricultural Sciences, BHU	January 12-13, 2017
Dr. P.S. Brahmanand	Divisional Review Meeting of Foreign-aided Projects	NRM division, ICAR, New Delhi	January, 2017
Dr. S K. Rautaray	25th Gopinath Sahu Memorial Lecture	Association of Rice Research Workers, Cuttack	January 17, 2017
Dr. D.K. Panda	Second Workshop of Nodal Officers of Data Management of ICAR Research Data Repository for Knowledge Management Initiative	ICAR-IASRI, New Delhi	January 24-25, 2017
Dr. R K. Panda Dr. G.Kar Dr. S.Mohanty	9th National Seminar on 'Water Resources Management in the Context of Climate Change for Growing India	'OUAT, Bhubaneswar	February 27-March 1, 2017
Dr. A.K. Nayak	Unit Level Data Repository Workshop for Experts	ICAR-IASRI, New Delhi	February 28-March 1,2017
Dr. S.K. Ambast Dr. O.P.Verma	60th *Ardhvarshik* meeting of *Nagar Rajbhasha Karyanvyan Samiti*	IIT, Bhubaneswar	March 6, 2017
Dr. P.S.Brahmanand	Workshop on Piped Irrigation Networks	Central Water Commission, New Delhi	March 16-17, 2017
Dr. S.K. Ambast Dr. A.K. Nayak Dr. P. Panigrahi	Brainstorming workshop on IT-based real time monitoring of soil, water and atmospheric variables for sustainable surface and groundwater management	IIT, Bhubaneswar	March 25, 2017
Dr. R.K. Panda Dr. R.R. Sethi	Inception Workshop under Neeranchal project, GOI	Project Director (Watershed), Mayurbhanj, Odisha	March 28, 2017

PERSONNEL

As on 31-03-2017

Dr. Sunil Kumar Ambast, Director

SCIENTIFIC

Sl.No	Name	Designation
1	Dr. R.C. Srivastava#	Principal Scientist
2	Dr. Atmaram Mishra	Principal Scientist
3	Dr. M. Das	Principal Scientist
4	Dr. S. Roy Chowdhury	Principal Scientist
5	Dr. P. Nanda	Principal Scientist
6	Dr. R.K. Panda	Principal Scientist
7	Dr. S.K. Rautaray	Principal Scientist
8	Dr. G. Kar	Principal Scientist
9	Dr. S.K. Jena	Principal Scientist
10	Dr.(Mrs.) M. Raychaudhuri	Principal Scientist
11	Dr. S. Raychaudhuri	Principal Scientist
12	Dr. R.K. Mohanty	Principal Scientist
13	Dr. M. K. Sinha	Principal Scientist
14	Dr. K.G. Mandal	Principal Scientist
15	Dr. P.K. Panda	Principal Scientist
16	Dr. A.K. Thakur	Principal Scientist
17	Dr. P.S. Brahmanand	Principal Scientist
18	Dr. S. Mohanty	Principal Scientist
19	Dr. D.K. Panda	Senior Scientist
20	Dr. A.K. Nayak	Senior Scientist
21	Dr. Ranu Rani Sethi	Senior Scientist
22	Dr. P. Panigrahi	Senior Scientist
23	Dr. O.P. Verma	Scientist
24	Dr. Sanatan Pradhan	Scientist
25	Dr. Rachana Dubey	Scientist
26	Mrs. Prativa Sahu	Scientist
27	Mr. N. Manikandan	Scientist
28	Mr. Abhijit Sarkar	Scientist

- on deputation

TECHNICAL

Sl.No	Name	Designation
1	Mrs. Sunanda Naik	Asst. Chief Technical Officer
2	Mr. Chhote Lal	Technical Officer
3	Mr. R.C. Jena	Senior Technical Assistant
4	Mr. P.C. Singh Tiyu	Senior Technical Assistant
5	Mr. S.K. Dash	Senior Technical Assistant
6	Mr. B.K. Acharya	Senior Technical Assistant
7	Mr. S. Lenka	Senior Technical Assistant
8	Mr. P. Barda	Senior Technical Assistant
9	Mr. A.K. Binakar	Technical Assistant
10	Mr. L. Singh Tiyu	Technical Assistant
11	Mr. A. Parida	Senior Technician

ADMINISTRATION

Sl.No	Name	Designation
1	Mr. Vinod K. Sahoo	Finance & Accounts Officer
2	Mr. A. Mallik	Asst. Administrative Officer
3	Mrs. M. Padhi	Private Secretary
4	Mr. Trilochan Raut	Personal Assistant
5	Mr. J. Nayak	Assistant
6	Mr. R.K. Dalai	Assistant
7	Mr. A.K. Pradhan	Upper Division Clerk
8	Mr. N.K. Mallick	Upper Division Clerk
9	Mr. C.R. Khuntia	Lower Division Clerk
10	Mr. B.S. Upadhyaya	Lower Division Clerk
11	Mr. S.C. Das	Lower Division Clerk

SUPPORTING

Sl.No	Name	Designation
1	Mr. Sanatan Das	Skilled Support Staff
2	Mr. B.N. Naik	Skilled Support Staff
3	Mr. B. Bhoi	Skilled Support Staff
4	Mr. S.K. Panda	Skilled Support Staff
5	Mr. B. Dutta	Skilled Support Staff

JOINING, PROMOTION, TRANSFER, RETIREMENT

- Mr. Abhijit Sarkar, Scientist (Soil Science) joined ICAR on July 5, 2016 (FN) and this institute on October 15, 2016 (FN)
- Mr. Vinod Kumar Sahoo, Finance & Accounts Officer (F&AO) joined ICAR on August 1, 2016 (FN) and this institute on November 18, 2016 (FN)
- Dr. P.K. Panda, Dr. A.K. Thakur, Dr. P.S. Brahmanand and Dr. S. Mohanty have been promoted to Principal Scientist through CAS of the ICAR *w.e.f.* 08.09.2014, 23.09.2014, 19.12.2014 and 11.03.2015, respectively.
- Shri N.V.R.N. Murty, F& AO of the Institute relieved from his additional duty on November 17, 2016
- Er. D.U. Patil, CTO has been transferred to The Ginning Training Centre of ICAR-CIRCOT, Nagpur.
- Mr. H.K. Bal, Skilled Support Staff superannuated on June 30, 2016.

BUDGET & EXPENDITURE 2016-17

The Budget & Expenditure under Non-Plan & Plan for the financial year 2016-17 in respect of ICAR-IIWM, Bhubaneswar (Figures in lakhs)

Budget Head	Non-Plan		Plan	
	Budget	Expenditure	Budget	Expenditure
Establishment Charges	579.00	579.00	-	-
O.T.A.	-	-	-	-
T.A.	3.00	2.99	8.00	8.00
Other charges including equipment	29.00	28.83	109.82	106.63
Other charges-IT	-	-	1.97	1.97
Repair & maintenance of building	9.00	8.71	-	-
Works	-	-	54.67	54.67
Library (Books & Journals)	-	-	4.79	4.78
H.R.D.	-	-	1.50	1.50
Others including loan & advances	-	-	-	-
Total	**620.00**	**619.53**	**180.75**	**177.55**
AICRP on Irrigation Water Management	**-**	**-**	**2045.00**	**2044.99**
Agri-CRP on Water	**-**	**-**	**508.68**	**503.34**

AICRP IWM-PC Unit

Budget Head	Sanctioned	Actual Expenditure
Establishment	48.30	48.30
T.A.	1.00	0.99
Other charges including equipment	–	–
Total	**49.30**	**49.29**

Results-Framework Document (RFD)
for
ICAR-Indian Institute of Water Management
(April 2015- March 2016)

Address : P.O. Rail Vihar, Chandrasekharpur Bhubaneswar – 751023, Odisha
Website ID : http://www.iiwm.res.in

Section 1 : Vision, Mission, Objectives and Functions

Vision

Sustainable development of on-farm water management technologies for enhanced agricultural productivity and improved livelihood under different agro-ecological regions.

Mission

Basic, applied and strategic research activities to address diversified water management issues with institutional linkages, infrastructural support and capacity building to achieve sustainability and growth.

Objectives

- Agricultural water management and conservation measures
- Enhancing water productivity
- Capacity building and human resources development

Functions

- To develop efficient utilization, management and conservation of on-farm water resources for sustainable agricultural production.
- To manage excess water in agricultural lands.
- To develop sustainable cropping systems in relation to the availability of water.
- Devising multiple uses of water in agricultural production programmes to enhance water productivity.
- To reuse poor quality groundwater, industrial and municipal waste waters.
- To disseminate technologies through peoples' participation.

Section 2 : *Inter se* Priorities among Key Objectives, Success Indicators and Targets

Sl. No.	Objectives	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria Value				
							Excellent 100%	Very good 90%	Good 80%	Fair 70%	Poor 60%
1	Agricultural water management and conservation measures		Improving irrigation practices	Technologies for enhancing irrigation efficiency to be developed	No.		4	3	2	1	-
			Judicious use of water	Technologies for enhancing water use efficiency to be developed including network projects and adaptive research	No.		4	3	2	1	-
			Water harvesting and groundwater recharge	Technologies for rainwater conservation and augmenting groundwater through recharge to be developed	No.		4	3	2	1	-
2	Enhancing water productivity		Multiple water uses	Models for improved water productivity to be developed	No.		3	2	1	-	-
				Strategies for use of wastewater in agriculture to be developed	No.		2	1	-	-	-
3	Capacity building and human resources development		Transfer of technology	Skill up-gradation of farmers and students	No.		500	450	400	350	300
				Knowledge of the scientists & officials to be updated	No.		6	5	4	3	2

Section 3 : Trend Values of the Success Indicators

Sl. No.	Objectives	Actions	Success Indicators	Unit	Actual values 2013-14	Actual values 2014-15	Target values 2015-16	Projected values 2016-17	Projected values 2017-18
1	Integrated water management and conservation measures	Improving irrigation practices	Technologies for enhancing irrigation efficiency to be developed	No.	2	2	3	3	4
		Judicious use of water	Technologies for enhancing water use efficiency to be developed through network projects and adaptive research	No.	1	2	3	3	3
		Water harvesting & groundwater recharge	Technologies for rainwater conservation and augmenting groundwater through recharge to be developed	No.	3	3	3	3	2
2	Enhancing water productivity	Multiple uses of water	Models for improved water productivity to be developed	No.	1	1	2	2	2
			Strategies for use of wastewater in agriculture to be developed	No.	1	1	1	1	1
3	Capacity building and human resources development	Transfer of technology	Skill up-gradation of farmers and students	No.	15	15	450	475	500
			Knowledge of the scientists & officials to be updated		4	5	5	5	6

Section 4 : Description and definition of success indicators and proposed measurement methodology

S. No.	Success Indicator	Description	Definition	Measurement	General Comments
1	Technologies for enhancing irrigation efficiency to be developed	Pressurized irrigation systems like drip and sprinkler irrigation methods shall be evaluated.	Irrigation efficiency is to characterize irrigation performance, evaluate irrigation water use, and to promote better or improved use of water resources in agriculture.	Irrigation efficiencies will be measured through study of irrigation performance, irrigation water use etc.	Modern irrigation p ractices and management will yield better irrigation water use efficiency over the farmers' practices in agriculture.
2	Technologies for enhancing water use efficiency to be developed through network projects and adaptive research	Engineering with bio-engineering propositions shall be developed to enhance water use efficiency	Water use efficiency is defined as yield of plant product per unit of crop water use.	Water use efficiency will be measured through crop performance against total water use through evapo-transpiration.	This will help in enhancing agricultural crop water productivity and profitability.
3	Technologies for rainwater conservation and augmenting groundwater through recharge to be developed	Low cost location specific ground water recharge techniques shall be developed.	Groundwater recharge is a hydrologic process where water moves downward from surface water to groundwater.	Groundwater recharge measurement will be studied through development of location specific filter systems.	Groundwater recharge technique shall help in augmenting the groundwater table through minimization of surface runoff.
4	Models for improved water productivity to be developed	Models shall be conceptualized, developed and evaluated for multiple uses of water.	Multiple use of water are low-cost, equitable water use models that provide water for both domestic needs and high-value agricultural production including rearing of livestock.	Under multiple use managements total water use agai nst production of various components will be measured.	This system will help in livelihood improvement, assured production in adverse conditions as well as creation of water resources.
5	Strategies for use of wastewater in agriculture to be developed	The use of waste water in agriculture shall be addressed to enhance water productivity.	Waste water is the marginally polluted water having potentiality of reusing in agriculture.	Waste water quality parameters will be measured using standard methods following recommended guidelines.	To reduce dependency on surface and groundwater, use of treated waste water in agriculture can be a viable proposition.
6	Skill up -gradation of farmers and students	In order to disseminate the various developed on -farm technologies, the training programmes for the farmers and students shall be undertaken.	Transfer of technology through training and demonstration is the process of transferring skills, knowledge, technologies, methods etc to a wider range of users.	Impact assess ment of training and demonstration will be measured through systematic questionnaire feedback approach.	Training and demonstration are the effective tools in rapid dissemination of technologies to end user level for enhancing agricultural productivity.
7	Knowledge of the scientists & officials to be updated	Knowledge of the scientists and officials shall be developed on recent advancement techniques through various training programmes.	Human resource development is a framework for the expansion of human capital within an organization through the development of both the organization and the individual to achieve performance improvement	Enhanced knowledge will be measured through aided trainings on new and emerging subjects/tools.	This will update and enhance the existing knowledge level of scientific and other officials of the organization.

Section 5 : Specific performance requirements from other departments

Location Type	State	Organization Type	Organization Name	Relevant Success Indicator	What is your requirement from this organization	Justification for this requirement	Please quantify your requirement from this organization	What happens if your requirement is not met
Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Section 6 : Outcome / Impact of activities of organization ministry

S. No.	Outcome / Impact of organization	Jointly responsible for influencing this outcome / impact with the following organization (s) / departments / ministry (ies)	Success Indicator	Unit	2013-14	2014-15	2015-16	2016-17	2017-18
1	Enhancing agricultural water productivity through multiple uses and improving livelihood	Departments of agriculture / water resources of state Governments	Enhancement in adoption of pressurized irrigation system	%	15	16	17	17	17

भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

भाकृअनुप – भारतीय जल प्रबंधन संस्थान

ICAR-Indian Institute of Water Management

(An ISO 9001:2008 Certified Organization)

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