वार्षिक प्रतिवेदन
ANNUAL REPORT

2012-2013



जल प्रबंधन निदेशालय
Directorate of Water Management

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जल प्रबंधन निदेशालय

(भारतीय कृषि अनुसंधान परिषद)

भुवनेश्वर, ओडिशा, भारत

Directorate of Water Management

(Indian Council of Agricultural Research)

Bhubaneswar-751023, Odisha, India

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Annual Report 2012-13

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PREFACE

It is a matter of satisfaction to present the Annual Report of Directorate of Water Management for the year 2012-13 to report the research achievements of the Institute under five different research programmes, i.e. rainwater management, canal water management, groundwater management, waterlogged area management and on-farm research & technology dissemination and other related information for the said period. There has been several significant research achievements made by Institute by development of several on-farm water management technologies like rubber dam installation in watershed, optimal designing of micro-catchment for water harvesting, energy efficient conservation agriculture in the rainfed ecosystem, understanding growth potential of CAM plant sisal under rainfed situation, enhanced water productivity with climate variability resilient irrigated production systems through integrated water resources utilization, tapping physiological potential of modified rice intensification system for increased productivity in canal command, groundwater management and identification of potential areas for artificial groundwater recharge, industrial waste water characterization for irrigation use, development of contingency crop planning for flooded and flood prone areas, package of practices for non food crops like cat tail in waterlogged ecosystem, exploring scope for reuse of municipal waste water for peri-urban agriculture, characterization of waterlogging and land use system for drainage map development in different coastal districts using modern tools like GIS, etc. Twenty five centres operating under the All India Coordinated Research Project on Water Management have been engaged in research in different themes like evaluation of pressurized irrigation system, management of rain and other natural sources of water, basic studies on soil- water- plant relationships and their interactions, water management for different agricultural production system including horticultural and other high value crops etc. along with transfer of technologies through different training programmes organized for farmers. Nine centres were operating under the All India Coordinated Research Project on Groundwater Utilization, which had undertaken research work in theme areas like regional groundwater assessment and modeling, conjunctive use of surface and groundwater, artificial groundwater recharge, groundwater pollution and transfer of technologies to farmers. The findings of different water management researches in above areas are presented in the report. I wish that content of the report will be useful for the stakeholders at various levels who are engaged in the field of agricultural water management in the country.

The research accomplishment of the Institute has also been recognized by various institutions and organizations through recognition award of 'National Academy of Agricultural Sciences (NAAS) in the field of soil, water and environmental science for the biennium 2011-12', Indira Gandhi Rajbhasha Puraskar (First Prize) for the Year 2010-11 by Honorable President of India Shri Pranabh Mukherjee, Lal Bahadur Shatri Outstanding Young Scientist Award of ICAR, and many other distinctions and Fellowships of different professional Societies.

During the year the Institute published 37 research papers in scientific peer reviewed journals of national and international repute along with four technical bulletins and five training manual / books. The meeting of QRT, Research Advisory Committee meeting and two Institute Research Council meeting were organized during the year. International events like workshop on adaptive governance, exposure visits of Scientists from Bulgaria, Spain and The Netherland was organized by the institute. Institute has organized training for officers in Watershed Management, Consortium meeting on Water Platform, Agribusiness camp, one inception workshop during the period under report. In order to strengthen the statistical computation the Institute provided five trainings to 113 scientists/researchers on "Data Analysis using SAS". One scientist-farmer interactive meet was organized for farmers of waterlogged affected area.

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

May 2013

(Ashwani Kumar)

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कार्यकारी सारांश

वर्षाजल प्रबंधन

- मिट्टी, पानी संतुलन मॉडल का अंशांकन और सत्यापन विभिन्न आकार के माइक्रो कैचमेंटस के लिये किया गया । सबसे अच्छे माइक्रो कैचमेंट के लिए अपवाह गुणांक (वर्ग आकृति में 0.33 और कप आकृति तथा तश्तरी के आकार में 0.51) वर्षा के उपयोग से निर्धारित किया गया । जलग्रहण कैचमेंट क्षेत्र व खेती क्षेत्र अनुपात क्रमश: 24.9:1 वर्गाकार के लिये तथा 16.1:1 कप और तश्तरी के आकार के लिए निर्धारित किया गया । कप और तश्तरी आकार के माइक्रो कैचमेंटस के तहत आम के पौधों की वृद्धि को बेहतर पाया गया ।
- ओडिशा में वाटरशेडों में रबड़ बांधो की स्थापना करके धारा में एक लंबी अवधि के लिए 4500-10000 घन मीटर पानी की अतिरिक्त मात्रा को लंबे समय तक संग्रहीत किया जा सकता है । उस संग्रहीत जमा पानी से सूखे के दिनों के दौरान सिंचाई उपलब्ध कराके उत्पादन और उत्पादकता बढ़ाने में मदद के साथ फसल तीव्रता में महत्वपूर्ण वृद्धि हुई ।
- जलवायु परिवर्तन जांच निगरानी और सूचकांक विशषज्ञ दल द्वारा परिभाषित (ETCCDMI) चरम जलवायु परिवर्तन सूचकांकों जैसे सूखे के सूचकांक (लगातार सूखे दिनों की अधिकतम संख्या और शुष्कता तीव्रता सूचकांक) आदि का सन 1971-2005 की अवधि के दौरान दैनिक वर्षा डाटासेट के उपयोग द्वारा मूल्यांकन किया जो कि बीच में और भीतर के दो सूखे इंडेक्स के बीच मौसमी और उप मौसमी परिवर्तन का सुझाव देते हैं ।
- धान की फसल को सिसबेनिया हरी खाद और रासायनिक उर्वरकों के साथ एकीकृत पोषक तत्व प्रबंधन के साथ उगाया गया तो रासायनिक उर्वरकों के साथ उगायी गयी फसल की तुलना में कम ऊर्जा इनपुट (7.91 गीगा जूल/हे.), उच्च ऊर्जा उत्पादन (145.69 गीगा जूल/हे.), उच्च ऊर्जा आउटपुट-इनपुट अनुपात (18.4) एवं उच्च ऊर्जा उत्पादकता (1.37 गीगा जूल प्रति टन उपज) प्राप्त हुये । एकीकृत पोषक तत्व प्रबंधन (रू 31755/हे.) के तहत, रासायनिक उर्वरक का उपयोग (रू 24400/हे) की तुलना में शुद्ध रिटर्न भी अधिक प्राप्त हुआ । धान की फसल में एकीकृत पोषक तत्व प्रबंधन के अवशिष्ट और सीधे प्रभाव से धान आधारित फसल प्रणाली जैसे सूरजमुखी की फसल उपज में 18.9% और कुलथी की फसल की उपज में 38.9% की वृद्धि हुई ।
- धान- मक्का फसल पद्धति के तहत, बिलकुल जुताई नहीं, न्यूनतम जुताई, पारंपरिक जुताई के साथ 100% अकार्बनिक उर्वरक, 50% अकार्बनिक +50% फार्म गोबर खाद और 50% अकार्बनिक +50% हरी खाद आदि के साथ संरक्षण कृषि पद्धतियों का मूल्यांकन किया गया । पारंपरिक जुताई को न्यूनतम और जुताई नहीं की तुलना में धान और मक्का की उपज के लिये बेहत्तर पाया गया । इसी तरह, 100% अकार्बनिक उर्वरकों के प्रयोग से 50% से अधिक अकार्बनिक +50% FYM और 50% अकार्बनिक + 50% हरे पत्ते खाद के प्रयोग की तुलना में धान एवं मक्का की फसलों की अधिक उपज प्राप्त हुयी । उच्चतम जैविक कार्बन की मात्रा जुताई नहीं और 50% अकार्बनिक + 50% फार्म गोबर खाद के उपचार में पायी गयी ।
- ढेंकानाल जिले में 10 जल संचयन बांधों का निर्माण किया गया जिससे बांध बागवानी, मछली पालन, मुर्गी पालन, और बतख पालन के माध्यम से पानी का एकाधिक उपयोग हुआ । जल संचयन संरचनाओं के भीतर आने वाले धान के खेतों में धान की उपज 6.2 टन प्रति हेक्टेयर जबकि तालाब के कमांड क्षेत्र के बाहर के धान के खेतों में उपज 5.1 टन/हेक्टेयर ही प्राप्त हुयी । विभिन्न जल संचयन संरचना प्रणाली से अतिरिक्त आय रू.9,000 से लेकर रू.38,000 तक प्राप्त हुयी ।
- नियंत्रित कम सिंचाई और आंशिक जड़ क्षेत्र सुखाने की विधियों के साथ आम के पौधों पर क्षेत्र प्रयोग ड्रिप सिंचाई का उपयोग कर आयोजित किया गया । ड्रिप सिस्टम के हाइड्रोलिक प्रदर्शन की क्षमता को भी एमिटर प्रवाह भिन्नता (7%), भिन्नता का गुणांक (8%) और वितरण एकरूपता (93%) के साथ संतोषजनक पाया गया । आम के पौधे के वृद्धि मापदंड जैसे पौधा ऊंचाई, कॅालर व्यास और पत्तों का आयतन आदि को पूर्ण सिंचाई उपचार के तहत उच्चतम पाया गया । अधिकतम फलों की पैदावार 80% आंशिक जड़ क्षेत्र सुखाने की विधि के साथ और उसके बाद पूर्ण सिंचाई उपचार के तहत प्राप्त हुयी ।
- धान की उपज पर सिंचाई और उर्वरक स्तर के प्रभाव का पता लगाने के लिए एक क्षेत्र प्रयोग खरीफ 2012 के दौरान

आयोजित किया गया । उर्वरक की 80% सिफारिश के स्तर के साथ और 100% सिफारिश के साथ अनाज पैदावार समान प्राप्त हुयी । दो अनुपूरक सिंचाइयों ने अनाज की उपज को बढ़ाने में भी मदद की ।

नहरी जल प्रबंधन

- यह अध्ययन एकीकृत जल संसाधनों के उपयोग के माध्यम से जलवायु परिवर्तनशीलता के तहत सिंचित उत्पादन प्रणालियों में पानी की उत्पादकता बढ़ाने के लिए आयोजित किया गया । अध्ययन के तहत चयनित नहरी क्षेत्र में फसल और नहर के पानी की उपलब्धता के पैटर्न का मूल्यांकन भी किया गया और जल संसाधनों को चार स्तरीय बनाया गया जिससे खरीफ के दौरान और डबल फसलों की खेती के लिये कम सूखे के अंतरालों को कम करने में मदद मिली । निर्मित जल संसाधनों की वजह से तालाब आधारित खेती क्षेत्र (0.47-0.82 हेक्टेयर) में आय स्थिरीकरण के रूप में कुल शुद्ध लाभ रू. 47700 से रू. 64300 तक तथा फसल तीव्रता में 200% की वृद्धि हुयी। तालाब आधारित खेती के कारण जल उत्पादकता रू. 1.1-1.42/ घन मीटर से बढ़कर रू. 6.0-7.5 / घन मीटर हो गयी। स्थान विशिष्ट भूजल पुनर्भरण सरंचनायें कोयंबटूर में टपकन तालाब पुनर्भरण शाप्ट की तरह भू - हाइड्रोलॉजिकल स्थितियों के लिए उपयुक्त है । उदयपुर तथा जूनागढ़ केंद्र में टपकन तालाब में कम लागत सूखी चिनाई संरचना का निर्माण किया गया है । ओडिशा में मोडीस टेरा उपग्रह के डेटा से प्राप्त सामान्यीकृत अंतर वनस्पति सूचकांक व बढ़ी हुयी कार्बन डाइऑक्साइड तथा तापमान के प्रभाव का अध्ययन सिंचित मक्का पर DSSAT 4.5 मॉडल का उपयोग करके किया गया ।
- धान की एसआरआई विधि के तहत फसल प्रबंधन करने से बेहतर फसल प्रदर्शन प्राप्त होने के कारण काफी बेहतर जड़ विकास और अधिक कुशल शारीरिक सजीव पौधों की बाहरी संरचना में एक संशोधित परिवर्तन प्राप्त हुआ । कार्बनिक खाद प्रयुक्त फसलें, अकार्बनिक खाद वाले भूखंडों की तुलना में शुरु में बेहतर स्पेड मूल्य व वृद्धि और पत्तियों द्वारा प्रकाश ग्रहण तथा प्रकाश संश्लेषण की दर को दिखाती हैं । हालांकि, फसल वृद्धि की अवस्था में जैविक एसआरआई और पारंपरिक धान रोपित भूखंडों में पोषक तत्वों की आपूर्ति में संभावित सीमाओं के तहत रासायनिक उर्वरको की तुलना में कम गुणवत्ता वाले अनाज उत्पादन में वृद्धि हुई ।
- हीराकुड नहर कमांड क्षेत्र में अपनाये गये सिंचाई जल प्रबंधन के लिये एक निर्णय समर्थन प्रणाली का बहु स्तरित भू-स्थानिक डेटा बेस का उपयोग करके निर्माण किया गया । बरगढ़ कमांड जल वितरण की मालीपली माइनर में उचित फसल पैटर्न का मूल्यांकन सिंचाई के पानी की मांग और आपूर्ति में अंतर की पहचान के माध्यम से प्रस्तावित किया गया । पिछले 11 वर्षों के दौरान रबी सीजन में उपग्रह डेटा का उपयोग कर धान के क्षेत्र में 65 से 91% तक की वृद्धि की जानकारी का पता चला । क्षेत्र वाष्पीकरण, वाष्पोत्सर्जन और टपकन दर क्रमश: 1.3 से 2.3, 3.7 से 4.8 और 1.0-2.0 मिमी/ दिन थी । लाइंड और अन लाइंड नहर में प्रवाह की औसत हानि 4.16 $X10^{-5}$ और 2.27 $X10^{-4}$ घन मीटर प्रति सेकंड प्रति वर्ग गीला क्षेत्र प्राप्त हुयी । अधिकतम अनाज उपज (6.63 टन / हेक्टेयर) नहर के ऊपरी क्षेत्र में प्राप्त हुयी है जो कि मध्य (5.92 टन / हेक्टेयर) और पूंछ क्षेत्रों (5.39 टन / हेक्टेयर) की तुलना में 12% और 23% अधिक दर्ज की गयी ।
- ओडिशा में नयागढ़ जिले के दसपाला ब्लॉक में कुंवारिया मध्यम सिंचाई परियोजना के तहत संरक्षण और अपवाह की रीसाइक्लिंग, सीपेज कम करके, वर्षा पानी तथा टैंकों और कुओं के द्वारा भूजल उपयोग के माध्यम से नहर की सिंचाई पानी की उत्पादकता को बढ़ाने के लिये प्रयोग को आयोजित किया गया और क्षेत्र परीक्षण भी किया गया । संग्रहीत पानी के बहुउद्देशीय उपयोग से फसल विविधीकरण के साथ साथ तालाब में लघु अवधि मछली पालन से क्षेत्र की उत्पादकता में वृद्धि हुयी । संग्रहीत पानी का बहुउद्देशीय उपयोग जैसे सिंचाई, घरेलु उपयोग, मछली पालन और बतख पालन तथा अरहर, पपीता, केला, भिंडी, बैंगन आदि फसलों को बांध के किनारों पर उगाकर एक एकीकृत कृषि प्रणाली विकसित करके किया गया ।

भूजल प्रबंधन

- कर्नाटक में कृत्रिम भूजल पुनर्भरण के लिये उपयुक्त क्षेत्रों को भूविज्ञान, भूमि की क्षमता और भूमि जल निकासी के आधार पर चित्रित किया गया तथा भूजल गहराई के आधार पर प्राथमिकता दी गयी । राज्य में बहुत कम, कम और मध्यम वर्षा क्षेत्रों के आधार पर पुनर्भरण प्राथमिकता वाले क्षेत्रों की पहचान की गई ।

कर्नाटक और तमिलनाडु के बहुत कम वर्षा वाले क्षेत्रों में आवश्यक पुनर्भरण संरचनाओं की संख्या का भी अनुमान लगाया गया ।

- घीबेन - हर्जबर्ग दृष्टिकोण की सहायता से ओडिशा के तट रेखा से 0 से 15 किमी स्थित क्षेत्रों के लिये समुद्र की ओर मीठे पानी का प्रवाह, हाइड्रोलिक ढाल तथा ताजा और खारे पानी की इंटरफेस आदि का अनुमान लगाया गया । चयनित स्ट्रिप्स की औसत चौड़ाई 1 किमी (भूजल के प्रवाह की दिशा के साथ) में पुरी से बालासोर तक सुरक्षित पम्पिंग मात्रा 676 से 10075 घन मीटर प्रति दिन प्राप्त हुयी । भूजल पम्पिंग गहराई को 2 से 24 मीटर तक औसत समुद्र तल ऊंचाई के भीतर प्रतिबंधित किया जाना चाहिये । 1-3 अश्वशक्ति के छोटे पंपों को कुओं के आयतन 3-4 वर्ग किमी के साथ खारा पानी के प्रवेश की जांच करने के लिए इस्तेमाल किया जा सकता है ।
- यूनाइटेड ब्रेवरीज उद्योग, खुर्दा का नाइट्रोजन, फोस्फोरस, पोटासियम, कार्बनिक कार्बन, माध्यमिक और माइक्रोन्यूट्रेंट्स, सोडियम और बाइकार्बोनेट समृद्ध क्षारीय अपशिष्ट जल (उपचारित) प्रवाह को लाल और लैटराइटिक, जलोढ़ तथा लाल और पीले रंग की मिट्टी के प्रकारों में सिंचाई के लिये उपयुक्त पाया गया । शक्ति शुगर्स लिमिटेड, ढेंकानाल के आसवनी अपशिष्ट जल प्रवाह को 60:40 सांद्रता के साथ मृदा में बिना किसी भी लगातार नमक उत्पादन के लाल और लैट्राइटिक तथा लाल और पीले रंग की मिट्टी के प्रकारों में सिंचाई के लिए उपयोगी पाया गया ।
- दया नदी के फैलाव के किनारे 20 किमी की दूरी तक भूजल में औसत आइरन और मेंगेनीज तत्वों की सांद्रता को अनुमेय सीमा से परे क्रमश: 2.65 और 0.237 पीपीएम दर्ज किया गया । एक्टिवेटेड चारकॉल (0.2%) दूषित भूजल से अतिरिक्त आइरन और मेंगेनीज को निकाल सकता है । कैल्शियम और मैग्नीशियम समर्द्ध दया नदी का क्षारीय सिंचाई पानी मिट्टी की पीएच को 5.25 से 6.29 तक बढ़ा देता है और इससे अम्लीय मिट्टी को सुधारा जा सकता है ।
- ओडिशा में भूजल दोहन के लिये विभिन्न हाइड्रोजियोलोजीकल सेटिंग्स के तहत ऊर्जा की खपत का अनुमान लगाया गया । तीस जिलों को क्लस्टर 1 और 3 (हार्ड रॉक क्षेत्र) और क्लस्टर 2 (जलोढ़ क्षेत्र) के रूप में के-मीन्स क्लस्टर विश्लेषण के उपयोग की सहायता से वर्गीकृत किया गया । भूजल दोहन के लिये कुल वार्षिक ऊर्जा खपत $7.37X10^8$ मेगा जूल प्रति वर्ष, जिसमें से 55% ऊर्जा की खपत क्लस्टर 2 में हुयी । गहरे नलकूपों (120 मीटर गहराई तक) द्वारा ऊर्जा की आवश्यकता ऊथले कुओं (5-10 मीटर गहराई तक) की तुलना में 24% अधिक थी । इस प्रकार, उथले या गहरे नलकूपों का ऊर्जा खपत में निवेश करने का फैसला एल्वीफर के गुण, सिंचित क्षेत्र, ऊर्जा स्रोत की प्रकृति और संबन्धित लागत अर्थशास्त्र पर निर्भर करती है ।
- सिंचाई बाजारों की अर्थव्यवस्था का खेत आकार और पानी उपयोगकर्ता समूहों के ऊपर प्रभावों का आकलन करने के लिये नमूने आधारित सर्वेक्षण आयोजित किया गया । नमूनों में से 0.57-1.31 हेक्टेयर जोत के साथ 78.45% छोटी जोत वाले धारक थे । जल प्रभुत्व खरीदारों (53.59%) की संख्या पानी बाजार में अधिक थी तथा छोटी जोत वाले धारक प्रमुखतया पानी के खरीददार थे । जल विक्रेताओं ने कुल लागत और पानी की निकास की कुल परिचालन लागत रू. 25.00 प्रति घंटे पर रू.11.92 प्रति घंटे का शुद्ध लाभ अर्जित किया जो पानी को एक लाभकारी व्यवसाय बनाता है । रबी के फसल क्षेत्र और फसल तीव्रता में खरीदारों के बीच में सुधार भी प्राप्त हुआ ।

जलाक्रांत क्षेत्र प्रबंधन

- ओडिशा में जगतसिंहपुर जिले के एरसामा व कुजंग और केंद्रपाड़ा जिले के मारसाघाई ब्लॉकों में ओडिशा रिमोट सेंसिंग एप्लीकेशन सेंटर, भुवनेश्वर से प्राप्त भूमि उपयोग नक्शे, भूआकृति नक्शा और आईआरएस लिस III सैटेलाइट डेटा की सहायता से जल भराव क्षेत्रों का आकलन किया गया । धान की फसल और अध्ययन के क्षेत्र में जल निकासी की व्यवस्था के लिये नक्शे भी तैयार किये गये ।
- बाढ़ के बाद कुशल प्रबंधन के लिये ओडिशा के पुरी जिले के 11 ब्लॉकों, कटक जिले के 16 ब्लॉकों, जगतसिंहपुर जिले के 8 ब्लॉकों, बालासोर जिले के 11 ब्लॉकों और भद्रक जिले के ५ ब्लॉकों की पहचान करके क्षेत्रों की मिट्टी एवं फसल संबंधित समस्याओं के आधार पर आपात योजना तैयार की गयी । हरे चने की एसएमएल 668 किस्म को बाढ़ की स्थानीय स्थिति के तहत स्थानीय किस्म की तुलना में बेहतर उपयुक्त पाया गया ।
- ओडिशा के केंद्रापाड़ा जिले के पट्टामुंडाइ गाँव के जल भराव क्षेत्र में 29-46 सप्ताह के दौरान लिंक नाली और छोटी नहर में पानी की अस्थायी प्रवाह दर 0.2 से 0.45 और 0.9 से 1.63 घन

मीटर प्रति सेकंड की रेंज में दर्ज की गयी । गहराई अवधि आवृत्ति संबंध का उपयोग करके 162 मिमी/दिन का जल निकासी गुणांक निर्धारित किया गया । कुल 39 तालाबों (1200 से 6000 वर्ग मीटर क्षेत्र के बीच लेकर) जो 6.2% कमांड क्षेत्र को कवर करते हैं वहाँ लिंक नाली को फसल विविधिकरण सुविधा के लिये पुननिर्मित किया गया । पुननिर्मित तालाब में पानी का भंडारण 0.5 से 3.2 मीटर गहराई तक सप्ताह वार मापा गया ।

- गैर खाद्य वाणिज्यिक फसल केटैल (टाइफा स्पिसीज) की उत्पादन फिजियोलोजी का नाइट्रोजन उर्वरक के 0, 30, 60 एवं 90 किग्रा/हे स्तरों के प्रयोग (पौधे की विभिन्न वृद्धि अवस्थाओं जैसे बुआई के समय और बुआई के 3 तथा 6 महीने के बाद) के साथ जल भराव क्षेत्रों में इसकी वृद्धि और उत्पादन के शारीरिक और सस्यीय सिद्धांतों की पहचान के लिए अध्ययन किया गया । नाइट्रोजन का बेसल प्रयोग 60 और 90 किलोग्राम/ हेक्टेयर की दर से करने पर पौधों की ऊँचाई, पत्तियों की संख्या और बेहतर प्रकाश संश्लेषण की दर, नाइट्रेट रिडक्टेज गतिविधि, क्लोरोफिल प्रतिधारण और उच्च उर्वरक उपयोग की क्षमता मे वृद्धि प्राप्त हुयी । नाइट्रोजन के बेसल प्रयोग 90 किलोग्राम/ हेक्टेयर पर करने से पत्ती उपज में 127 पत्तियाँ प्रति वर्ग मीटर तक वृद्धि हुयी ।
- अपशिष्ट जल सिंचाई से मिट्टी सुधार और माइक्रोबियल गतिविधि के साथ भारी धातु संवर्धन मे वृद्धि हुयी। भारी धातु संवर्धन कारक क्रमश: आइरन > जिंक > मेंगेनीज = केडमियम > क्रोमियम > कॅापर क्रम में थे । अपशिष्ट जल सिंचाई के तहत स्थानांतरण कारकों के अध्ययन ने सुझाव दिया कि तुरई, भिंडी एवं करेले की सब्जियाँ, टमाटर, तरबूज एवं चौलाई की तुलना में उपभोग के लिए सुरक्षित हैं। नदी के पानी के साथ अपशिष्ट जल के संयुक्त उपयोग से 50% तक ताजा पानी को बचाया गया और सब्जियों के खाद्य भागों में भारी धातु सांद्रता को अपशिष्ट जल और ताजा जल के मिश्रण के साथ एक निश्चित सीमा के भीतर बनाये रखा ।

खेतों पर अनुसंधान और प्रौद्योगिकी हस्तांतरण

- ओडिशा में कटक जिले के माइनर (लिफ्ट) सिंचाई प्रणाली के तहत बयालीस-मौजा क्षेत्र में 150 सदस्य किसानों वाली 15 जल उपयोग संघो का अध्ययन किया गया । किसान भागीदारी सूचकांक मूल्य 75 से 88% प्राप्त हुआ जो भागीदारी सिंचाई प्रबंधन की प्रभावशीलता का एक संकेत था। किसानों के दृष्टिकोण से सिंचाई के प्रदर्शन से पता चला कि शिक्षणीयता, सुविधा, संभाविता व इक्विटी आदि, रबी मौसम (> 3.0; 5 बिन्दु कंटीनुयम पैमाने पर) की तुलना में अपेक्षाकृत खरीफ सीजन (>4.0) में 197 और 171 हे. सिंचित क्षेत्र के साथ अधिक प्राप्त हुये । जल उपयोग संघो का समग्र प्रदर्शन एक 5 बिन्दु कंटीनुयम पैमाने पर बहुत अच्छे स्कोर 3.77 से 4.37 तक की रेंज में प्राप्त हुआ ।
- ओडिशा के ढेंकानाल और बोलंगीर जिलों में साल भर में नियमित रूप से बार बार गांव के घरेलु डेटा जैसे विश्वसनीय घरेलू उपलब्धता, व्यक्तिगत, विशिष्ट क्षेत्र, कृषि संबंधी डेटा जैसे कि श्रम, व्यय, आय और उपभोग आदि की उपलब्धता बढ़ाने के लिये गांवों में आर्थिक, सामाजिक और संस्थागत विकास की गतिशीलता को संबोधित करने के लिये एकत्रित एवं अध्ययन किया जा रहा है । यह अध्ययन घर और खेत के आकार के समूहों में गांव अर्थव्यवस्थाओं का विश्लेषण करके गरीबी को कम करने की गतिशील प्रक्रिया को समझने के लिये किया गया ।
- SAS का उपयोग कर डेटा विश्लेषण पर 6 दिन के प्रशिक्षण कार्यक्रम के तहत पूर्वी क्षेत्र में राष्ट्रीय कृषि अनुसंधान प्रणाली और एआइसीआरपी (जल प्रबंधन) के 37 वैज्ञानिक और शोधकर्ताओं को प्रशिक्षित किया गया । इसके अलावा, यह प्रशिक्षण 9 अनुसंधान सदस्यों और सहायकों को भी प्रदान किया गया । सॉप्टवेयर स्थापना और प्रशिक्षण कार्यक्रम के तहत 47 शोधकर्ताओं को प्रशिक्षित किया गया । कुल 113 शोधकर्ताओं को वर्ष 2012-13 के दौरान प्रशिक्षित किया गया ।
- ओडिशा के बालासोर और मयूरभंज जिलों में एलडीपीई पॉलिथीन शीट के माध्यम से दो खेत के तालाबों में सिपेज कम करने के लिये लाइनिंग और 11 किसानों के खेतों में पीवीसी पाइप उपलब्ध करवा के पानी को खेत मे ले जाने की हानि के नियंत्रण के माध्यम से जल संचयन करके जल उपयोग दक्षता बढ़ाने हेतु खेत में प्रदर्शन किया गया । विभिन्न बुवाई की दिनांक के प्रभाव से पता चला कि जल्दी बुवाई (22 नवंबर, 2012) से सरसों की उपज (7.21 क्विंटल/हेक्टेयर) और पानी की उपयोग क्षमता (2.83 किलो / हेक्टेयर मिमी) प्राप्त हुयी ।

EXECUTIVE SUMMARY

RAINWATER MANAGEMENT

- The calibration and validation of the soil water balance model for the different shapes of microcatchments was carried out. The runoff coefficient for the best microcatchments (0.33 in square and 0.51 in cup and saucer shape) was determined using sprinkler simulated rainfall. The catchment area to cultivated area ratio of 24.9:1 and 16.1:1 was determined for square and cup & saucer shaped microcatchments, respectively. The physiological performance of mango plants under cup and saucer shape microcatchment was found better.
- Installation of rubber dams in watersheds of Odisha stored water for a longer period in the stream and additional volume of 4500–10000 m^3 water at most of the time. The water stored helped enhancing the production and productivity by providing irrigations at critical dry spells with increase in cropping intensity.
- Using the extreme climate change indices defined by the Expert Team on Climate Change Detection Monitoring and Indices (ETCCDMI), the drought indices, such as the maximum number of consecutive dry days (CDD) and the aridity intensity index (AII) were assessed by utilizing the daily rainfall dataset during 1971-2005 period which suggested seasonal and sub-seasonal differences between and within the two drought indices.
- Rice crop grown with integrated nutrient management with *Sesbania* green manure and chemical fertilizers showed lower energy input (7.91 GJ/ha), higher energy output (145.69 GJ/ha), higher energy output: input ratio (18.4) and higher energy productivity (1.37 GJ per ton yield) compared to the crop grown with chemical fertilizers. The net returns were also higher (Rs 31755/ha) under the INM compared to chemical fertilizer use (Rs 24400/ha). Residual and direct effect of INM in rice based cropping system increased 38.9% yield in horse gram and 18.9% in sunflower.
- Conservation agricultural practices were evaluated under rice- maize cropping systems with no-till (NT), minimum tillage (MT) and conventional tillage with 100 % inorganic fertilizers, 50% inorganic + 50% FYM and 50% inorganic + 50% green leaf manuring. The conventional tillage was superior to minimum tillage and no tillage system for higher rice and maize yield. Similarly, 100 % inorganic fertilizers produced higher rice and maize yield over 50% inorganic + 50% FYM and 50% inorganic + 50% green leaf manuring. Highest organic carbon was found in no till as well as 50% inorganic + 50% FYM treatments.
- Multiple use of water through on-dyke horticulture, pisciculture, poultry and duckery was done in 10 water harvesting structures in Dhenkanal district. The yield of paddy within the command of water harvesting structures was 6.2 t/ha in comparison to 5.1 t/ha in the paddy fields outside the command area of the pond. Additional income from different water harvesting structure systems varied from Rs. 9,000 to Rs. 38,000.
- The field experiment on regulated deficit irrigation (RDI) and partial root zone drying (PRD) on bearing mango trees was conducted using drip irrigation. The hydraulic performance of the drip system like emitter flow variation (7%), coefficient of variation (8%) and distribution uniformity (93%) were found satisfactory. The growth parameters like plant height, collar diameter and canopy volume were highest under full irrigation treatment. Maximum fruit yield was obtained under 80% PRD treatment followed by full irrigation treatment.
- A field experiment was conducted during kharif 2012 to find out the effect of irrigation and fertilizer dose on yield of paddy. Similar grain yields were recorded at 80% of recommended dose of fertilizer as compared to the recommended dose. Two supplementary irrigations helped to increase grain yield.

CANAL WATER MANAGEMENT

- The study was conducted to enhance water productivity in irrigated production systems under climate variability through integrated water resources utilization. Cropping pattern and canal water availability in selected canal commands were assessed and fourth tier of assured water resources were created which helped in mitigating dry spells during kharif and for cultivating double crops. Income stabilization was achieved with the net returns of Rs. 47700 to Rs. 64,300/- from the pond based farming area (0.47 to 0.82 ha) and cropping intensity of 200% due to created water resources. Water productivity of the area enhanced from Rs. 1.1-1.42/m^3 through sole rice to Rs. 6.0-7.5/m^3 through pond based farming. Location specific groundwater recharge structures suitable for geo-hydrological conditions, like recharge shaft with percolation pond at Coimbatore, Low cost dry masonry structure at Udaipur, percolation pond at Junagarh centre were constructed. The drought assessment in Odisha was carried out using Normalized Difference Vegetation

Index (NDVI) of MODIS-TERRA satellite data and impact of elevated carbon dioxide and temperature on irrigated maize was studied using DSSAT 4.5 model.

- Significantly better root development and more efficient physiological functioning due to changes in the plants' morphological structure resulting from a modified crop management under SRI led to superior crop performance. Organically fertilized crops showed initially better SPAD value and growth, light interception by canopy and photosynthesis rate compared to chemically fertilized plots. However, at later stages of crop growth probable limitations in nutrient supply in organic SRI and conventional flooded rice plots resulted into inferior grain production than chemically fertilized plots.
- A Decision Support System (DSS) for real time adoptive irrigation water management in Hirakud canal command area is attempted using multi layered geo-spatial data base. Optimal cropping pattern for Malipali minor of Bargarh distributary under the command is being proposed through performance assessment and identification of the gaps in demand and supply of irrigation water. In-season crop information using satellite data revealed increase in paddy area from 65 - 91 % during last 11 years in rabi season. The field evaporation, transpiration and deep percolation rates were 1.3-2.3, 3.7-4.8 and 1.0-2.0 mm/day, respectively. Average loss of flow in the lined and unlined canal was $4.16X10^{-5}$ and $2.27 X 10^{-4}$ m^3 per sec per m^2 wetted perimeter, respectively. The highest grain yield (6.63 t/ha) was recorded in head region which is 12 % and 23 % higher than that of mid (5.92 t/ha) and tail (5.39 t/ha) regions.
- Improving water productivity under canal irrigation command through conservation and recycling off runoff, seepage, rainwater and groundwater using tanks and wells was implemented and field tested under Kuanria Medium Irrigation Project in Daspalla block of Nayagarh district in Odisha. Crop diversification including short duration pisciculture increased productivity of the area. The harvested water is used as multisource water for irrigation, domestic use, fish rearing and duckery, and on-dyke cultivation of various crops like arhar, papaya, banana, bhindi, brinjal etc along the banks in an integrated farming system approach.

GROUNDWATER MANAGEMENT

- Areas suitable for artificial groundwater recharge in Karnataka were delineated on the basis of geology, land capability and soil drainage and were prioritized depending on groundwater depth. The areas having recharge priority under very low, low and medium rainfall zones in the state were identified. The number of recharge structures necessary in very low rainfall area of Karnataka and Tamil Nadu were estimated.
- Ghyben-Herzberg approach was used to estimate freshwater flow towards sea, hydraulic gradient and fresh and saline water interface for areas located within 0-15 km away from the coast line of Odisha. Average safe pumping volume for the selected strips of 1 km width (along the groundwater flow direction) stretching from Puri to Balasore varied between 676 to 10,075 m^3/day. Groundwater pumping depth should be restricted within 2 – 24 m depending upon elevation of location from MSL. Small pumps of 1-3 hp with well density of 3-4/km^2 could be used to check saline water intrusion.
- Enriching soil with N, P, K, organic carbon, secondary and micronutrients the sodium and bicarbonate rich alkaline effluent (treated) water of United Breweries was found suitable for irrigation in red and lateritic, alluvial, and red and yellow soil types. Without producing any persistent salt build up the distillery effluent of Shakthi Sugars Ltd up to the concentration of 60:40 as effluent:water was useful for irrigation in red and lateritic, and red and yellow soil types.
- Along 20 km stretch of Daya River, average Fe and Mn concentration in ground water was 2.65 and 0.237 ppm respectively beyond the permissible limit. Activated charcoal (0.2 %) could remove excess Fe and Mn from the contaminated groundwater. The calcium and magnesium rich alkaline Daya River water irrigation increased the soil pH significantly from 5.25 to 6.29 and could be an ameliorative for acid soil.
- The energy consumption for groundwater extraction was estimated for different hydro-geological settings in Odisha. Thirty districts were classified into cluster 1 and cluster 3, hard rock region and cluster 2, alluvial region using K-means cluster analysis. The total annual energy consumption for groundwater extraction was 7.37×10^8 M Joule/annum, 55 % of which was consumed in cluster 2. Energy requirement by deep tubewells (upto 120m depth) was 24 times higher than shallow wells (upto 5-10m depth). Thus, the decision to invest in shallow or deep tubewells rests on the aquifer properties, area to be irrigated, nature of energy source and relative cost economics.
- Samples based survey was conducted to assess impacts of irrigation markets on farm economy across farm size and water user groups. 78.45% of samples were small holders with holding size 0.57-1.31 ha. Water buyers dominated (53.59%) the water market and majority of small holder were buyers. Water sellers earned a net profit of Rs 11.92 per hour

over the total cost and Rs 25.00 per hour over the total operational cost of water extraction, making water selling a remunerative business. Rabi crops area and cropping intensities improved among buyers.

WATER LOGGED AREA MANAGEMENT

- The Satellite data of IRS LISS III and Land use map, geomorphology map from Orissa Remote Sensing Application Centre, Bhubaneswar were used in assessing the waterlogged areas of Ersama, Kujang and Marsaghai blocks of Jagatsinghpur and Kendrapara district in Odisha. Thematic maps were prepared for the rice crop and drainage system in the study area.
- Block wise contingency plans for efficient post flood management were prepared for 11 blocks of Puri, 16 blocks Cuttack, 8 blocks of Jagatsinghpur, 11 blocks of Balasore and 5 blocks of Bhadrak districts of Odisha based on the identified soil and crop related problems of these regions. SML-668 variety of green gram was suitable under post flood situation compared to the local variety due to its better adoptability in post flood situation.
- Temporal flow rate in the link drain and minor canal were observed within the range of 0.2-0.45 and 0.9-1.63 m^3/sec, respectively during 29th–46th weeks in the waterlogged area of Pattamundai (Kendrapara), Odisha. Using depth-duration-frequency relationship, the drainage coefficient of 162 mm/day was determined. Total 39 ponds (area ranging between 1200 to 6000 m^2) covering 6.2 % command area were renovated along the link drain which facilitated crop diversification. Week-wise depth of storage water in renovated pond varied between 0.5 - 3.2 m.
- The production physiology of non-food commercial crop cat tail (*Typha* sp.) was studied for identification of physiological and agronomic principle of its growth and production in waterlogged areas by applying N at 0, 30 and 60 and 90 kg/ha rate at three different stages of plant growth i.e. basal, 3 and 6 month after planting. The basal N application improved plant height and number of leaves significantly at 60 and 90 kg/ha level with better photosynthesis rate, nitrate reductase activity, chlorophyll retention and higher fertliser use efficiency. The leaf yield increased significantly up to 127 leaves/m^2 at 90 kg/ha basal application.
- Wastewater irrigation improved soil fertility and microbial activity along with heavy metal enrichment even with long term wastewater irrigation. Heavy metal enrichment factors were in the order Fe > Zn > Mn = Cd > Cr > Cu. The transfer factors study suggested ridge gourd, ladies finger and bitter gourd are safer for consumption than tomato, water melon, amaranthus under wastewater irrigation. The conjunctive use of wastewater with river water saved 50% of fresh water and heavy metal concentrations remained within permissible limits in edible parts of vegetables grown with wastewater and fresh water mixture.

ON-FARM RESEARCH AND TECHNOLOGY DISSEMINATION

- Minor (lift) irrigation systems at 42 Mouza area of Cuttack district in Odisha were studied covering 150 member-farmers representing 15 WUAs. Farmers participation index (FPI) values ranged from 75 to 88% indicating the effectiveness of PIM. Irrigation performance from farmers' perspectives revealed that tractability, convenience, predictability and equity were relatively higher in kharif season (>4.0) than in rabi season (>3.0; on a 5-point continuum scale) with irrigated area of 197 and 171 ha respectively. Overall performance of WUAs was quite well with mean performance score ranging from 3.77 to 4.37 on a 5-point continuum scale.
- Regular high frequency village household data being collected to enhance availability of reliable household, individual, field specific, plot level data on agriculture, labour, expenditure, incomes and consumption throughout the year to address the dynamics of economic, social and institutional development at study villages in Dhenkanal and Bolangir districts of Odisha. The study aims to understand the dynamic process of reducing poverty by tracking the household and village economies across farm size groups.
- Under the 6-days training program "Data Analysis using SAS", 37 scientist and researchers from the National Agricultural Research System in eastern region and that from the AICRP (water management) were trained. In addition, this training was offered to 9 research fellow and assistants. Under the software installation and training program, 20 nodal officers have been trained. Under 3-days sensitization and training program, 47 researchers were trained. A total of 113 researchers of the NARS were trained during 2012-13.
- Efficient water harvesting through control of seepage and conveyance losses for increasing water use efficiency were demonstrated in Balasore and Mayurbhanj districts of Odisha through LDPE lined sheets in two farm ponds and laid out PVC pipes in 11 farmers' fields. The effect of different planting dates on yield and water use efficiency of mustard revealed that early sowing (22 November, 2012) yielded maximum (7.21 q/ha) with water use efficiency of 2.83 kg/ha-mm.

Introduction

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

Mandate

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

Research Achievements

The research activities of the centre are carried out under five different programmes, viz, rainwater management, cannal water management, ground water management, waterlogged area management and on-farm research, extension and training to solve the problems related to agricultural water management. At the national level the researchable issues of Agricultural water management are being addressed by the different centers under the AICRPs on Water Management and Ground Water Utilization. Comprehensive technology for *in-situ* rainwater harvesting through microcatmentment is being designed with suitable crop diversification to enhance and stabilize productivity of rainfed areas. The installation of rubber dam technology for water harvesting in different watersheds and runoff recycling at micro-level have significantly improved crop productivity in its command. Standardization of energy efficient cropping system conservation agriculture in the rainfed ecosystem has potential to improve productivity in rainfed region. In the canal command area, enhanced water productivity with climate variability resilient irrigated production systems through integrated water resources utilization has been achieved. In order to facilitate ground water utilization in a sustainable manner potential areas for artificial groundwater recharge have been identified The industrial waste water characterization was also done for its conjunctive utilization with surface water for irrigation. The contingency crop planning for flooded and flood prone areas, package of practices for non food crops like cat tail was developed with either resilient cropping system or following strategic intervention in to address uncertainties of productivity waterlogged ecosystem. Looking for reuse option of municipal waste water for peri-urban agriculture, identification of safer crops under waste water irrigation, development of drainage map in different coastal waterlogged areas with help of modern tools like geographic information system (GIS) and remote sensing have been done to minimize extent of waterlogging in coastal areas. The multidiscipline approach adopted by DWM in each of the technology development process has added to robustness of these technologies for their application in farmers field.

Infrastructure facilities and Organization

The centre has state-of-the-art infrastructure facilities and has four well-equipped laboratories, *viz*, soil-water-plant relationship laboratory, irrigation and drainage laboratory, hydraulic laboratory, and plant science laboratory with all the latest equipments for research activities. An engineering workshop and photographic laboratory also cater to the needs of the institute. Four field laboratories at farm, *viz*, meteorological laboratory, pressurized irrigation system, solar photovoltaic pumping system, and agricultural drainage system also add to the research related inputs. The institute has a state of-the-art communication facility with an automatic EPABX system and LAN. The institute has its own web server and regularly updated website (http://www.dwm.res.in/). The network

administration of the computers, internet and website update and 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 16 international and 5 national journals. The subscription of electronic journals and its access through LAN to all the scientists is another useful facility of the library. The Video conferencing and IP Telephony System facility have been installed at the Institute as part of the project ICAR net.

The DWM has linkages with various agencies through providing training, consultancy, collaboration or contract research services. It encourages public and private sector institutions dealing with water management research addressing their issues scientifically, monitoring research and development issues and their evaluation in a cost effective manner. The institute has linkages with different state and central government agencies like National Rainfed Area Authority , Watershed Mission (Government of Odisha), CAPART, NABARD, Directorate of Agriculture (Government of Odisha), Central and State Ground Water Board, Command Area Development Agency, Government of Odisha, WALMI to implement farmer friendly water management technologies in the region. Entrusted by NRAA, New Delhi and Watershed Mission, the centre organized training programme on Integrated Watershed Development for officers and stakeholders.

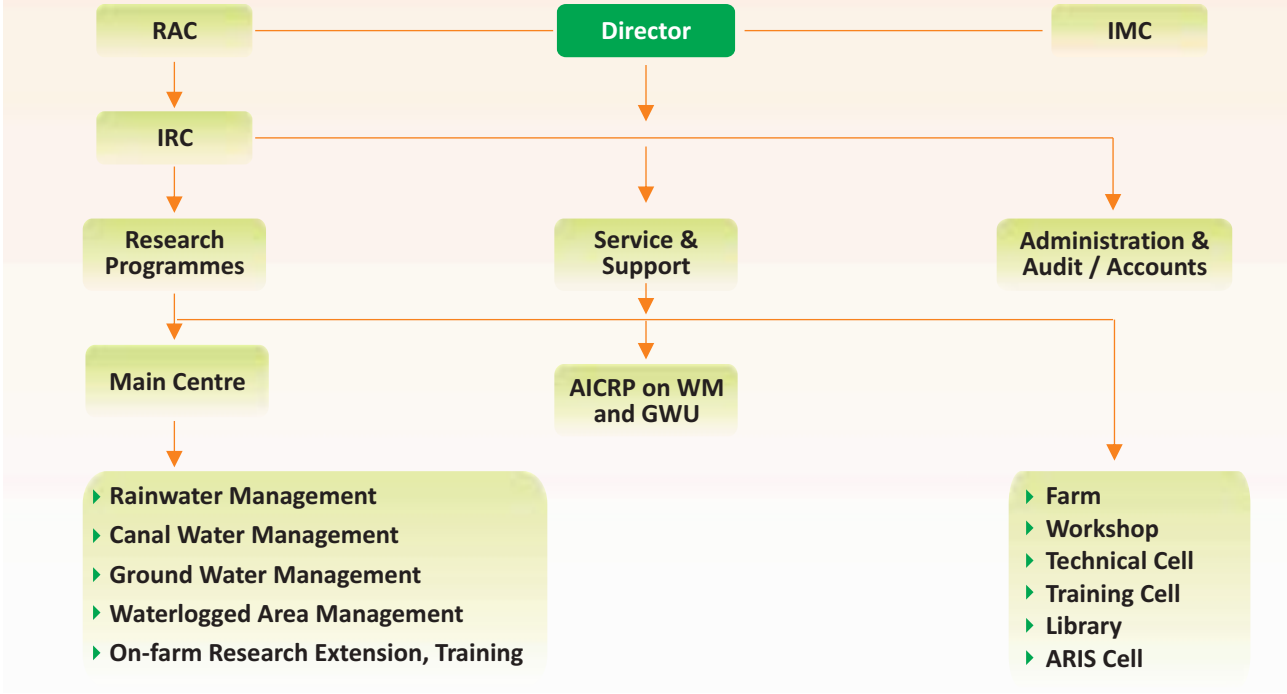
The Institute has conducted ICAR entrance examinations for UG and PG courses in Agriculture and allied sciences at national level. The center has been recognized as nodal center for carrying out research work leading to Ph.D degree under Utkal University and also has been recognized by Indira Gandhi National Open University as Study Center to carry out Diploma in Watershed Management. In addition to ongoing in-house research projects, the institute is awarded with many projects sponsored by various external organizations like Ministry of Water Resources, Department of Science and Technology, ISRO, GOI, Bill and Melinda Gates Foundation, etc.

Staff

At the end of March 2013, DWM had 78 sanctioned posts (including AICRP) out of which 59 are in position. The break up of the posts under different categories is given below:

Cadre	Sanctioned	In Position	Vacant
RMP	01	01	nil
Scientific	35	25	10
Administrative	15	13	02
Technical	16	14	02
Supporting	11	06	05
Total	78	59	19

ORGANOGRAM



RESEARCH ACHIEVEMENTS

Rainwater Management

- Design and development of rubber dams for watersheds
- Micro-catchment water harvesting in the rainfed ecosystem of eastern region
- Sustainable rural livelihood and food security to rainfed farmers of Odisha
- Effect of dry spell occurrence on reduction in paddy yield and optimum design of rainwater harvesting structures for its mitigation
- Water budgeting in high-value shrimp monoculture and carp poly culture under varying intensification levels
- Performance evaluation of drip irrigated mango under deficit irrigation
- Conservation agricultural practices in rice based cropping system for increasing water and nutrient availability in a rainfed agro-ecosystem for eastern India
- Development of water and energy efficient integrated farming system model for the rainfed farmers
- Extreme climatic effects on major cropping systems of Orissa

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

Successful installation of five rubber check dams was done at different watersheds such as Baghamari, Badapokharia, DWM Farm, Chandeshwar–1 and Chandeshwar-2, Odisha under NAIP Project. The Chandeswar and Baghamari check dams were operated and maintained by farmers for paddy cultivation during *kharif* and pulses, oilseed and vegetable cultivation during *rabi* and summer season in the surrounding field. In the period of report various types of evaluations of rubber dams were done regarding water availability analysis and crop productivity. Water remained available in the upstream side of the rubber dam till 1st week of May 2012 at Chandeswar-2. However, it remained up to end of April 2012 at Chandeswar-1, while all the nearby streams became dry by middle of March. There was almost no rain in the months of March, April and May 2012. At all the sites water stored up to the maximum capacity of the rubber dam since third week of June 2012 till end of mid-February 2013. The water stored in the upstream side of the dam up to a length of 800 m to 1.70 km at various locations. The additional volume of water stored in the upstream side due to installation of rubber dam varied between 4800 m^3 to 10000 m^3 at any given point of time during monsoon. Incase this water was used for irrigation; it filled up by the water was from the upper catchment during monsoon.

The stored water in rubber dam irrigated 12 ha of rice fields during critical stages at Chandeswar-I and around 16 ha at Chandeswar-II. The rainfall occurred after south-west monsoon during mid-October till end-November was stored in rubber dam and was used by the farmers for *rabi* pulses and vegetables. The rubber dam at Badapokharia facilitated augmenting groundwater recharge. There was a yield enhancement of paddy by about 16-25% during *kharif* season. During *rabi* season farmers close to the rubber dam sites were growing vegetables water melon, cucumber, tomato, ladies finger, etc. in approximately 5.5 ha area utilizing the water stored in the dam which was otherwise remaining fallow. The economic (pod /fruit yield) yield of vegetables like cucumber, okra, cowpea under rubber dam command area in Chandeswar was enhanced by 28%, 34% and 31% respectively due to assured water supply from the installed rubber dams. The pod yield of greengram under rubber dam command area in Bamadiha and Chandeswar was significantly superior to that of pre-installation period due to longer retention of residual soil moisture. The average productivity of green gram in *rabi* season enhanced from 0.52 t/ha to 0.81 t/ha at Bamadiha. Similarly, the area of the green gram in rabi season increased by 26 % in this village. The pod yield of greengram was found to be 0.75 t/ha at Chandeswar.

The farmers were trained on improved water management and other crop management practices through participatory irrigation management. The biometric observations of rice were recorded at regular intervals for assessing the impact of rubber dam on growth of rice during kharif season at Chandeswar.

For commercialization of technology document with technical specification of rubber composite used for rubber dam was finalized. After reconnaissance survey for selection of sites for rubber dam installation in the states of Uttarakhand, Meghalaya, Maharashtra, Jharkhand and Odisha, drawing, design and estimates were prepared for all the sites. Discussion was made with Rubber Board, Kerala for installation of rubber dam at a rubber plantation area in Kerala. World Bank team members visited the rubber dam installation site on various occasion and interacted with farmers and filled questionnaires collecting information regarding impact of rubber dams on livelihood of the beneficiary farmers.

Dr. A.K. Singh, DDG (NRM) visited rubber dam site and interacted with farmers about its functioning

Project Title	:	Micro-catchment Water Harvesting in the Rainfed Ecosystem of Eastern Region
Project Code	:	DWM/09/138
Funding Agency	:	Institute
Project Personnel:		A.Mishra, S. K. Routray, H. Chakraborty, S. Roy Chowdhury and M.J. Kaledhonkar

The soil water balance model for the microcatchments was calibrated and validated. The runoff coefficient for the best microcatchments was calculated and the catchment to cultivated area ratio was determined. The physiological aspect of plants under different microcatchments was also studied.

Calibration and Validation of Soil Water Balance Model

During last year, a soil water balance model was developed for the microcatchment water harvesting system. This year, the model was calibrated and validated. In the absence of rainfall, the field experiments were carried out using the sprinkler system to simulate the rainfall in the microcatchments. The rainfall intensity data was generated by running the sprinkler system. In microcatchments with mango plant (Square, Cup & saucer and Diamond shapes), the soil moisture content at four depths 0-20, 20-40, 40-60 and 60-80 cm were measured two days after the experimental run. In circular shape microcatchment with mango plant and cup & saucer shape microcatchment with sapota plant, the moisture content at four depths 0-20, 20-40, 40-60 and 60-80 cm were analysed one day after experimental run.

To calibrate the model, the moisture content data was used. The model calibrated parameters are saturated hydraulic conductivity and van-Genuchten model (VGM) parameters α and n. Tables 1 and 2 present the calibrated model parameters at different soil depth for microcatchments with mango plant and sapota plant, respectively. As the soil characteristics were different at microcatchments with mango plant compared to microcatchments with sapota plant, two sets of calibrated model parameters were obtained. The simulated and measured moisture contents for different shapes of microcatchment were plotted. A good agreement between the simulated and measured moisture content was visually observed, with the corresponding values of Nash-Sutcliffe Coefficient (NSC) and mean absolute relative error (MARE) ranging from 0.65 to 0.86 and from -0.006 to 0.01 respectively for microcatchments with mango plant. Similarly for Sapota plants, the Nash-Sutcliffe Coefficient ranged from 0.85 and 0.69 and MARE ranged from 0.0018 and -0.0028. Simulations were made using the calibrated values of parameters (α, n and Ks) to validate the model for remaining selected microcatchments.

Table 1 Calibrated parameters at different soil depths for microcatchments with mango plant

Soil depth (cm)	α (cm^{-1})	n	Ks (m/s)
0-30	0.4010	2.4109	6.78E-06
30-60	0.3431	2.3901	3.95E-06
60-80	0.3312	2.3104	2.56E-06

Table 2 Calibrated parameters at different soil depths for microcatchment with sapota plant

Soil depth (cm)	α (cm^{-1})	n	Ks (m/s)
0-20	0.3801	2.3462	6.78E-06
20-40	0.3334	2.3518	3.95E-06
40-80	0.3356	2.2661	2.56E-06

Microcatchment Design

In order to decide the catchment to cultivated area ratio of the microcatchment, determination of design rainfall, runoff coefficient and crop water requirement were determined as follows.

Design rainfall - Probability analysis

Design rainfall is the amount of rainfall at which catchment area will provide sufficient runoff to meet the crop water requirement. To estimate the design rainfall, the daily rainfall data of 24 years (1985-2008) was analyzed. The probability analysis of daily rainfall data was carried out. To fit the probability distribution to rainfall data, EasyFit software was used with Anderson–Darling test as a goodness of fit criteria. According to Anderson–Darling test, the two parameter gamma distribution was fitted well to rainfall data. After fitting the probability distribution, the frequency factor method was used to estimate the design rainfall. Table 3 presents the descriptive statistics of gamma distribution fitted to daily rainfall. Figure 1 presents the design daily rainfall at 50% probability of occurrence. The frequency factor (K) depends upon the return period (T) and the frequency distribution. The two parameter gamma distribution acts as a Pearson III type distribution. For Pearson III type distribution, frequency factor (K) for 2 years return period and skewness coefficient of 7.99 was found to be –0.249.

Table 3 Descriptive statistics of gamma distribution fitted to daily rainfall

Statistic	Value
Sample size	8766
Range	400.3 mm
Mean	4.33 mm
Variance	211.3 mm^2
Standard deviation	14.5 mm
Coefficient of variation	3.55
Standard error	0.156 mm
Skewness	7.99
Kurtosis	117.8

The values of the Parameters of Gamma distribution are $\alpha = 0.08876, \beta = 48.79$.

Runoff measurement

The runoff measurements were carried out by collecting the runoff water in the drums installed at the centre of the microcatchments. The soil moisture content and crop growth performance showed that square and cup & saucer shaped microcatchments performed better over other shapes. Therefore, the runoff coefficient for square and cup & saucer shape microcatchment was determined (Table 4). For cup and saucer shaped microcatchment with area 23.75 m^2, the runoff coefficient was 0.51 and for square shaped microcatchment it was 0.33.

Table 4 Runoff coefficient for square and cup & saucer shape microcatchment

Shape of microcatchment	Rainfall (m^3)	Runoff (m^3)	Runoff coefficient
Square	0.61	0.2	0.33
Cup & saucer	0.33	0.17	0.51

Catchment area to cultivated area ratio

For appropriate design of microcatchment water harvesting system, it is necessary to determine the ratio between catchment area and cultivated area. The catchment area to cultivated area was calculated by the following equation.

$$\frac{\text{Catchment area}}{\text{Cultivated area}} = \frac{\text{Crop water requirement} - \text{Design rainfall}}{\text{Design rainfall} \times \text{Runoff Coefficient} \times \text{Efficiency factor}}$$

For humid region, there is sufficient rainfall in monsoon season to meet the crop water requirement but in the remaining eight months crop suffer from moisture stress. Therefore, design of microcatchment system for dry season in humid region is necessary. Starting from October to May considered as dry period and catchment to cultivated area ratio was decided using the design parameters for this period. The design rainfall at 50% probability for dry season was 115.7 mm. On the basis of 24 years pan evaporation data, average crop water requirement for dry season was calculated. The crop water requirement for dry season was 828.9 mm. The efficiency factor was taken as 0.75. For better moisture conservation and crop growth square and cup & saucer shaped microcatchments recommended. On the basis of runoff coefficient, the catchment area to cultivated area ratio found 24.9:1 and 16.1:1 for square and cup & saucer shaped microcatchments, respectively (Table 5).

Table 5 Catchment area to cultivated area ratio for square and cup & saucer shaped microcatchments

Shape of Microcatchment	Runoff coefficient	Catchment to cultivated area ratio
Square	0.33	24.9:1
Cup and saucer	0.51	16.1:1

Leaf water status, photosynthesis and water use efficiency

In mango, the leaf water potential (LWP, -MPa) decreased steadily in post monsoon period in all the treatments. However, the decline was slowest in Cup &

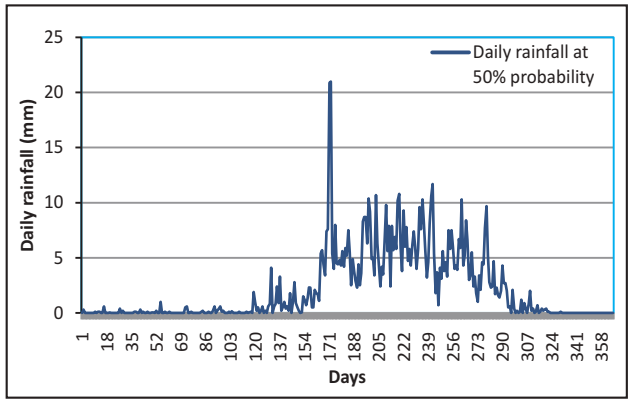


Fig. 1 Design daily rainfall at 50% probability of occurrence

saucer shaped and fastest in farmers practice (Fig. 2). As a result, the former treatment was able to maintain better leaf water status in the month of March. Other treatments showed similar trend with intermediate values. The net photosynthesis was also found highest in Cup & saucer shaped i.e. 14.1 µ mol of $CO_2.m^{-2}.s^{-1}$ fixed compared to 13.05 in farmers practice which was

lowest among five treatments (Fig.3) during month of January and in March it was 13.9 and 12.75 µ mol of $CO_2.m^{-2}.s^{-1}$ fixed respectively. The photosynthesis rate in 'square', 'circular' and 'diamond' shaped microcatchment was lesser than Cup & saucer shaped and did not vary significantly among themselves. The average water use efficiency (WUE), i.e. µ mol of CO_2 fixed per mol of water transpired in mango was 2.53 in January and increased to 2.67 during March in Cup & saucer shape compared to 2.45 and 2.33 during same period in farmer's practice.

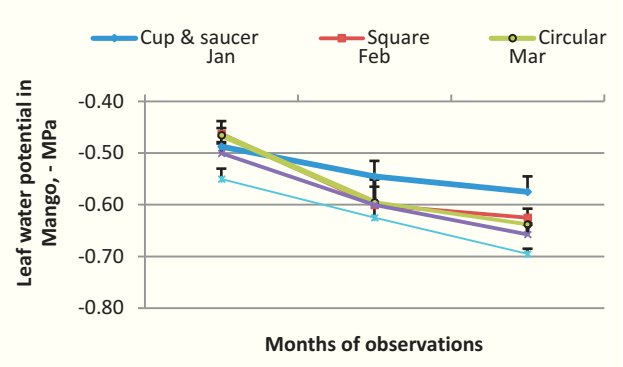


Fig. 2 Leaf water potential in Mango plants during 1st quarter of 2013

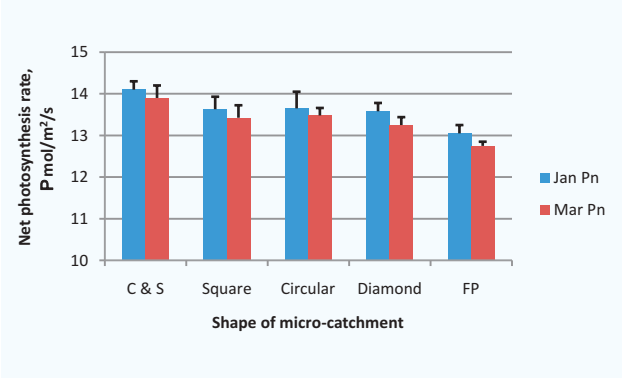


Fig. 3 Net photosynthesis in Mango plants during 1st quarter of 2013

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

The study on livelihood of the rainfed farmers due to technological interventions on water management was carried out in three study villages, i.e. Khallibandha, Nuagaon and Mandapala villages in Dhenkanal Sadar block and Gunadei, Belpada and Kaunriapala villages in Odapada block of Dhenkanal district. In the current year another three villages, i.e. Kotapala, Talagotha and Khamara villages in Dhenkanal Sadar block and Mahadia, PasaSingh and Podapada villages in Odapada block were added to the study villages. Multiple use of water in agriculture, on-dyke horticulture, vegetable cultivation, poultry, duckery and pisciculture was taken up with ten water harvesting structures. The total command areas of the water harvesting structures were 13 ha. The water in the water harvesting structures was utilized for supplementary irrigation to paddy crop in *kharif* season, irrigation of vegetables in post-monsoon season, pisciculture and for duckery. Different vegetables like brinjal, tomato, ladies finger, cauliflower, cabbage, potato, ridge gourd, bitter gourd, cowpea, onion, cucumber, pumpkin etc were cultivated by the farmers. Banana, papaya and drumstick trees were planted on the embankments of the pond. Poultry and duckery were part of some pond-based integrated farming systems.

Horticultural plants on the embankment of the pond

Analysis of the monthly and weekly rainfall data of Dhenkanal Sadar block and Odapada block was done for the year 2012 (Fig.4). The analysis showed that

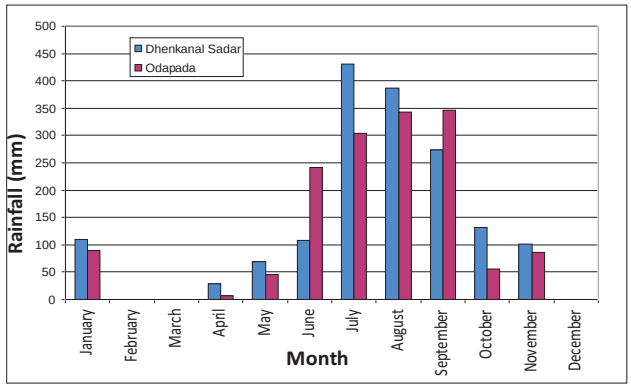


Fig. 4 Monthly rainfall in Dhenkanal Sadar and Odapada block for the year 2012

Dhenakanal Sadar block received a rainfall of 1641 mm which is 14% more than the normal rainfall. The Odapada block received a rainfall of 1518 mm which was 20% more than the normal rainfall. In Dhenkanal Sadar block, maximum rainfall of 148 mm was received in the 31st week whereas in the Odapada block, maximum rainfall of 132.5 mm was received in the 37th week. The yield of paddy within the command of water harvesting structures was 6.2 t/ha in comparison to 5.1 t/ha in the paddy fields outside the command area of the pond.

Out of the ten water harvesting structures, three were of the type of two-stage rainwater conservation technology developed by DWM, Bhubaneswar. The net income from different activities i.e. on-dyke horticulture, pisciculture, poultry, duckery, vegetable cultivation and agriculture for all the 10 water harvesting structures sowed total income ranging from Rs. 13,000.00 to Rs. 38,000.00. Paddy yield in different dyke height treatments were observed and compared. Paddy fields with dyke height of 15 cm height had maximum average yield of 5.45 t/ha in compared to 5.4 t/ha in 20 cm weir height and 5.15 t/ha in case of 25 cm weir height.

Farmer groups were formed to carry out vegetable cultivation by lift irrigation in the post-monsoon season. Pumps were provided to the farmers for lifting irrigation water. Three farmer groups in the Khallibandha and Nuagaon villages were formed for water melon cultivation by river lift irrigation. In total 40 farmers were involved in three groups and 45 ha was put under cultivation. Another farmer group involving six farmers in the Belpada village carried out sugarcane and vegetable cultivation in 1 ha of land. Four 1-day farmers training programs on 'Rainwater management for sustainable agriculture and rural livelihoods' were conducted in the newly adopted study villages. The training sites were Mahdia and PasaSingh villages in Odapada block and Kotapala and Khamara villages in Dhenkanal Sadar block. In total 125 farmers were trained out of which 51 were women farmers.

Integrated farming system model at site of Mr. Sribascha Biswal

Success story

The water harvesting structure constructed in the land of Mr. Sribascha Biswal helped him to shift from paddy cultivation to pisciculture, vegetable cultivation and on-dyke horticulture. Out of the 1 acre area, water harvesting structure was built on almost one fourth of the land. With the technological support from DWM and initiative of the farmer, the farming unit has been developed as an integrated farming system model. The embankment of the water harvesting structure has been used for horticultural plants like banana, papaya and drumstick plants. The unit now also has poultry shed of 100 chicks capacity which was constructed with the help of OUAT, Bhubaneswar. Now this shed is being used for duckery and the farmer himself has constructed a bigger poultry shed of 1500 capacity. A mushroom shed has also been constructed. Plate 2 shows some of the integrated farming system components in the land of Mr. Sribascha Biswal.

Apart from providing supplemental irrigation, the pond is being used for pisciculture. The farmers harvested 160 kg fish in the current and year, and 120 kg last year. Initially, the farmer was irrigating the vegetable and horticultural crops by carrying buckets of water from the pond. After that he constructed a storage tank made out of well RCC rings to develop a gravity fed irrigation system. The low lift hand pump supplied by DWM, Bhubaneswar proved handy for pumping water from the pond to the storage tank. Now, with the help of government scheme, the farmer has constructed a tubewell which is being used for irrigation and filling up of the pond during summer season. Honeybee production has been added as a component of the farming system model. Before the technological interventions, the farmer was getting only a gross return of Rs. 10,000.00. Excluding the cost of cultivation of Rs. 5000.00, the farmer was getting a net return of Rs. 5000.00. But after the development of the farming system model, the gross return of the farmer was Rs. 75,000.00 in the last year. Excluding the expenditure of Rs. 37,000.00, the farmer got a net return of Rs. 38,000.00. Thus, there is an increase in net return to the tune of Rs. 33,000.00 per year due to the farming system model.

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

An experiment was conducted in Directorate of Water Management research farm, Mendhasal in *kharif* 2012 to quantify the effect of fertility level and supplementary irrigation on paddy. The experiment was carried out with a view to calibrate the FAO-AquaCrop model to simulate different climatic scenarios including dry spell occurrence in paddy. The layout of the experiment was split plot in which irrigation was the main plot treatment and fertilizer was sub-plot treatment. The main plot treatments were, (a) rainfed paddy (I_1), (b) rainfed paddy with one supplementary irrigation (I_2), and (c) rainfed paddy with two supplementary irrigation (I_3). The sub-plot treatments were, (a) fertilizer application at recommended dose (80-40-40 kg N-P_2O5-K_2O) (b) fertilizer application at 80% of recommended dose, and (c) fertilizer application at 60% recommended dose. The experiment was conducted with Swarna Mahsuri variety of paddy and transplanting was done on 28th July 2012. Supplementary irrigation of 5 cm depth each were applied during occurrence of dry spell during the experimental period. In the irrigation treatment (I_2), one irrigation was applied on 25th September 2012 and in the irrigation treatment (I_3), one irrigation each on 25th September and 20th October were applied and coincided with panicle initiation and flowering stage of the crop.

Table 6 shows the yield and yield attributes of rice as influenced by fertilizer does and irrigation. The results revealed that similar grain yields were recorded at 80% of recommended dose as compared to full recommended dose. However, grain yields decreased significantly at 60% recommended dose. Two supplementary irrigations increased grain yield over the rainfed situation. Straw yield and biomass yield also increased with each level irrigation and fertilization. However, harvest index was not influenced by fertilizer dose and irrigation level.

View of experimental plot during vegetative and ripening stage

Table 6 Yield and yield attributes of rice as influenced by fertilizer dose and irrigation

	Grain Yield (t/ha)	Straw Yield (t/ha)	Harvest Index	Dry biomass at maturity t/ha
Fert dose				
100%	4.55	7.14	0.388	10.04
80%	4.28	6.60	0.393	9.27
60%	3.90	6.16	0.388	8.56
CD (p=0.05)	*0.29*	*0.24*	*NS*	*0.39*
Irrigation				
Rainfed	3.98	6.25	0.386	8.70
1 irrigation (PI)	4.21	6.66	0.386	9.28
2 irrigations (PI & flowering)	4.53	7.01	0.393	9.89
CD (p=0.05)	*0.39*	*0.16*	*NS*	*0.27*

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

Due to low economic output in grow-out aquaculture, it is imperative to minimize the operational cost by improving water use efficiency. Further, uncertainty in monsoon rain, scarce and limited availability of freshwater resource under changing climate scenario has forced in rethinking wise-use of water in aquaculture sector to increase water productivity. Estimation of the water requirement of commercially important fish and prawn species will ensure higher water productivity and profitability. Therefore, water budgeting is first step towards protocols for best water management practice (BWMP) in commercially important grow-out aquaculture. Therefore, an attempt has been made by DWM since April, 2012 to estimate the consumptive and total crop water requirement and water productivity in commercially important carp polyculture of Indian major carps (Freshwater fish), and monoculture of *Penaeus monodon* (brackishwater shrimp) under different levels of intensification. The main objectives of this study are (1) To study the effect of different stocking densities on the consumptive and total water requirement of Indian major carps in poly culture and black tiger shrimp *P.monodon* in monoculture system, (2) To study the impact of varying intensification levels on water quality, sediment load, water productivity, growth and production performance of Indian major carps and *P.monodon* and (3) To develop protocols for best water management practices (BWMPs) for different levels of intensification.

Study on estimating consumptive and total aquacultural crop water requirement for grow-out operation of carp polyculture and shrimp monoculture is undertaken in earthen ponds (carp polyculture-3 treatments X 3 replications and shrimp monoculture- 3 treatments X 3 replications) in farmer's field at Chandipur, Balasore, Odisha. Stocking density was taken as treatment. Stocking density of 6000, 8000, and 10000 fingerlings/ha have been maintained for composite culture (30 : 30 : 40 :: Surface feeder : Column feeder : Bottom feeder) while 150000, 200000 and 250000 post larvae/ha for Black tiger shrimp culture. Recommended minimum water depth of 2.0 m for composite fish culture and 1.2 m for monoculture of *P .monodon* was maintained in each treatment. Required water depth was maintained on weekly basis either adding or withdrawing water from the experimental ponds. Management practices and inputs were kept same for all treatments and replications. Periodic data collection on amount of water replenishment/ exchange, seepage & percolation loss, depth of water in the pond, rain fall, evaporation, water quality parameters (pH, DO, turbidity, TSS, TDS, total plankton count, total alkalinity, nitrite, nitrate, temperature, H_2S, NH_3) growth parameters (absolute growth, PDI, Kn, PI, PSI, SGR), survivability(%), C-tray monitoring is continuing on regular basis. Growth and production performance, feed efficiency (FE), AFCR, biomass yield (t/ha), water productivity (Rs/m^3) etc. will be estimated at the end of crop cycle.

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

The performance evaluation of drip irrigated mango trees under deficit irrigation was continued at the DWM research farm, Mendhasal, Bhubaneswar during the period April under report. The treatments of the experiment were as follows, (1) Full irrigation @ 100% Etc, (2) RDI @ 80% Etc, (3) RDI @ 60% Etc, (4) RDI @ 40% Etc, (5) Partial root zone drying (PRD) @ 80% Etc, (6) PRD @ 60% Etc, and (7) PRD @ 40% Etc and (8) rainfed control. Water was applied during April and May except the periods when some rainfall occurred. After the end of monsoon season, irrigation application started from 11th December and continued thereafter. The irrigation was withheld from January 15 to mid-February to impose water stress on the trees, which is a pre-requisite for better flowering. The monthly

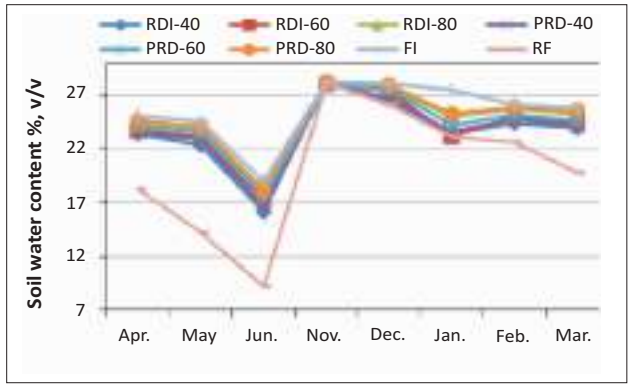


Fig. 5 Mean monthly soil water variation at 0-90 cm depth under various treatments

Table 7 Incremental increase in vegetative growth parameters of mango trees under RDI and PRD treatments

Treatment	January–June			July–December		
	Plant height (m)	Collar diameter (mm)	Canopy volume (m^3)	Plant height (m)	Collar diameter (mm)	Canopy volume (m^3)
100% ETc	0.37	15.9	10.2	0.51	22.4	10.8
80% RDI	0.31	12.0	8.49	0.46	22.0	9.40
60% RDI	0.29	11.7	8.07	0.40	18.5	9.02
40% RDI	0.23	10.1	6.33	0.40	14.6	7.51
80% PRD	0.26	11.5	8.01	0.48	17.9	9.08
60% PRD	0.26	11.2	7.83	0.39	17.2	8.66
40% PRD	0.22	9.7	4.98	0.38	12.4	6.95
Control	0.18	9.2	3.20	0.42	12.2	6.77
$CD_{0.05}$	0.02	NS	0.9	NS	NS	NS

NS: Not significant

irrigation applied under various treatments varied from 10 mm to 100 mm, with maximum amount in May and minimum in January. The hydraulic performance of the drip system was studied from time to time and found satisfactory with emitter flow rate variation (Qv) of 7%, co-efficient of variation (CV) of 8% and distribution uniformity (DU) of 93%.

Soil water variation

The mean monthly soil water content (SWC) observed at 0–90 cm depth during November–June indicated that the full irrigation (FI) should higher SWC compared to other treatments (Fig.5). The improved SWC consistently reduced from November to March and April to June in all the treatments. However, the magnitude of reduction was significantly higher under rainfed treatments over other treatments. The SWC increased during November, due to residual soil moisture of the rainfall that took place during July to October. The mean soil water fluctuation between two consecutive measurements in FI was highest compared to other treatments, reflecting the highest evapotranspiration rate under FI.

Vegetative growth

The half yearly (January-June and July-December) increases of plant height, collar diameter and canopy volume was maximum in fully-irrigated trees in both the periods (Table 7). Moreover, the growth parameters showed a decreasing trend with decreasing irrigation regimes under both RDI and PRD. The magnitudes of the increment were higher during July–December due to adequate soil moisture caused by rainfall in the former period.

Yield parameters

The yield parameters (fruit number, fruit weight and fruit yield) were significantly affected by irrigation (Table 8). The higher number of fruit was observed with full irrigation, followed by irrigation at 80% RDI and 80% PRD. However, the maximum yield was recorded with 80% PRD, followed by FI. The higher yield with 80% PRD attributed to heavier fruits under this treatment compared to other treatment. Overall, the yields under FI, 80% RDI, 80% PRD and 60% PRD were statistically at par. The maximum yield under irrigated treatment was 212% higher than that with the rainfed trees.

Table 8 Yield parameters of mango trees under RDI and PRD treatments

Treatment	Fruit number	Fruit weight(g)	Fruit yield (kg $tree^{-1}$)
100% ETc	44	161.1	7.13
80% RDI	37	181.2	6.73
60% RDI	29	193.3	5.17
40% RDI	18	152.0	2.74
80% PRD	37	198.6	7.41
60% PRD	32	196.5	6.33
40% PRD	19	153.7	2.94
Control	16	142.6	2.37
$CD_{0.05}$	3.7	12.9	1.15

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

The field experiment was conducted in research farm of DWM, Bhubaneswar under split plot design with three replications. The main plot treatments were four conservation agricultural practices viz. No-till (NT), Minimum tillage(MT), Conventional tillage with maize sown in flat bed(CT_1) and Conventional tillage with maize sown in raised bed (CT_2). The sub plot treatments were three nutrient management practices, 100% NPK(F_1), 50%NPK+50% N through FYM(F_2) and 50 %NPK+ 50 % N through green leaf manuring(GLM)- F_3. This practice was evaluated under rice-maize cropping systems. Rice crop was applied with 60,35 and 35 Kg of N, P_2O_5 and K_2O per hectare, respectively during *Kharif*. During *rabi*, maize crop was applied NPK @ 120 Kg N, 60 Kg P_2O_5 and 40 Kg K_2O per hectare, respectively.

Among various tillage treatments, conventional tillage-CT_2 recorded significantly higher rice yield(3.92t/ha) over NT and MT and was found at par with CT_1 (Table 9). Minimum tillage was significantly superior to no till system for obtaining higher rice yield. Among various nutrient sources, 100 % NPK produced significantly higher grain yield (3.4 t/ha) over both F_2 and F_3. Both FYM and GLM with 50 % NPK produced similar rice yield. Interaction effects of tillage and nutrients were nonsignificant. Tillage treatments did influence maize yield during *rabi* season. Conventional tillage with maize sown in raised bed recorded significantly higher yield (4.12 t/ha) compared to others. Similarly, minimum tillage was found superior to no till system. Among various nutrient sources, 100% NPK produced significantly higher grain yield (4.16 t/ha) over F_2 and F_3. Both F_2 and F_3 were found to be at par. The no till system should significantly higher soil organic carbon content (0.54%) over all other treatments and was highest (0.60%) in F2.

Table 9 Rice and maize yield under conservational agriculture set up

Treatments	Rice yield	Maize yield	Organic
Main plots(M)	(t/ha)	(t/ha)	carbon (%)
NT-. No-till	2.10	2.80	0.54
MT- Minimum tillage	2.64	3.24	0.51
CT_1. Conventional tillage with maize sown in flat bed	3.50	3.64	0.48
CT_2. Conventional tillage with maize sown in raised bed	3.92	4.12	0.47
CD(5%)	0.50	0.36	0.05
Sub plots(S)			
F_1- 100% NPK	3.4	4.16	0.46
F_2-50%NPK+50% N through FYM	2.8	3.60	0.60
F_3-50 %NPK+ 50 % N through green leaf manuring(GLM)	2.7	3.40	0.59
CD(5%)	0.38	0.40	0.12
Interaction(MXS)	NS	NS	NS

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

Rice variety Surendra was grown during *kharif* 2011 under recommended dose of chemical fertilizers (CF) alone (80 N, 40 P_2O_5 and 40 K_2O/ha) or integrated nutrient management (INM) involving *sesbania* green manure. After harvest of *kharif* rice, each main plot was divided into 6 sub-plots. Different crops viz., sweet corn (S_1), sunflower (S_2), horsegram (S_3), Babycorn (S_4), cabbage (S_5), and tomato (S_6) were gorwn in sub-plots during *rabi* 2011-12 to evaluate 6 different rice based cropping systems. Winter season crops were grown under two main plot treatments viz., recommended chemical fertilizers alone and integrated nutrient treatments using vermicompost and chemical

Table 10 Yield, Net Returns (Rs) and energy input (MJ/ha) of different crops under chemical fertilizers and INM

Crops	Yield (t/ha)			Net Returns (Rs)			Energy output:input ratio		
	CF	INM	Mean	CF	INM	Mean	CF	INM	Mean
Tomato	15.54	17.14	16.34	7337	13784	10561	1.18	1.44	1.31
Cabbage	22.93	24.05	23.49	35707	38694	37201	2.10	2.66	2.38
Baby corn	5.14	5.67	5.41	38355	45551	41953	1.98	2.51	2.25
Sweet Corn	5.87	6.23	6.05	29962	33048	31505	2.51	3.20	2.86
Sunflower	1.15	1.36	1.26	3432	5799	4616	7.76	12.54	10.15
Horse-gram	0.86	1.19	1.02	930	5651	3291	6.68	12.50	9.59
CD(0.05) crops		0.42				2379			-

CF: Residual & Direct effect of Chemical fertilizers;
INM: Residual & Direct effect of Integrated nutrient management

fertilizers. Horse-gram received vermicompost at 1 t/ha due to low rate of fertilizer recommendation, while the remaining 5 crops having high fertilizer requirements received @ 2 t/ha. Vermicompost contained 1.85% N, 1.83 % P_2O_5 and 0.84% K_2O. The yield of cabbage was highest (23.49 t/ha) followed by tomato (16.34 t/ha), sweet corn (6.05 t/ha), baby corn (5.41 t/ha). The two seed crops (sunflower 1.26 t/ha and horse gram 1.02 t/ha) yielded low. The increase in yield under INM compared to chemical fertilizers was high for seed crops (18.9 to 38.9%) and was low for the remaining four crops (4.9 to 10.3%). Energy input for tomato cultivation under CF treatment was 18.54 GJ/ha and it was 15.94 GJ/ha under INM with resource conservation technology. Thus, the energy input was higher by 14% under the CF treatment for tomato was highest (30%) in horse gram. Total energy input was low for sunflower (6.69 GJ/ha) and horse gram (4.05 GJ/ha) mainly due to use of less fertilizer and irrigation. Energy efficient crops based on energy output:input ratio and net energy were sunflower and horsegram. Low energy efficient crops were tomato, baby corn, cabbage and sweet corn(Table 10).

Net returns were highest under baby corn Rs 41953/ha, followed by cabbage Rs 37201, sweet corn Rs 31505, tomato Rs 10561, sunflower Rs 4616 and lowest with horse gram Rs 3291. Net income under INM was always higher than under the CF treatment. Composite pisciculture was practised in fish pond (900 m^2 area) using surface feeders (*catla*), column feeder (*rohu*) and bottom feeder (*mrigal*). Fish yield was 204 kg with gross return of Rs16320 and net return of Rs 8078. The dyke surrounding the pond was utilized for growing banana, papaya and coconut. Net return of Rs1800 was generated from 45 papaya plants, Rs 3475 from 60 banana plants and Rs2000 from 40 bottle gourd plants. Apiary unit yielded 4.8 kg honey/box with net return of Rs 410. Poultry dropping directly falling on the pond water were used as fish feed. A batch of 50 Vanraja birds gave net return of Rs 4325. Khaki Campbell duck (50 birds) gave net return of Rs 3230. Paddy straw mushroom was grown during May to September and net returns per 10 ft^2 size bed was Rs 49 in a cropping cycle of 30 days. Oyster mushroom was grown during October to February per 4 ft^2 bed was Rs 27 in a cropping cycle of 45 days.

After the second cropping cycle residual soil organic carbon and available N, P and K were analyzed under 6 different rice based cropping system. Organic carbon and available N and P_2O_5 were 0.58%, 235 kg/ha, and 29.3 kg/ha, respectively under INM and under CF treatments they were 0.55%, 229 kg/ha, and 28.3 kg/ha

Table 11 Energy input and output in rice cultivation under CF vis-à-vis INM with sesbania green manure during kharif 2012

Items			Rice grown with CF		Rice grown under Integrated nutrient with sesbania green manure and CF	
Energy input	Unit	Equivalent Energy (MJ)	Quantity/ha	Energy (MJ/ha)	Quantity/ha	Energy (MJ/ha)
Field preparation						
Human	h	1.96	10 h	19.6	10 h	19.6
Machinery	kg	62.1	1.93 kg	119.8	1.93 kg	119.8
Fuel (Diesel+Lubri)	L	56.31	32.5 L	1830.1	32.5 L	1830.1
Nursery	h	1.96	36 h	70.6	36 h	70.6
Paddy Seed	kg	14.70	40 kg	588	40 kg	588
Sesbania seed	kg	14.70	-	-	20	294.0
Sesbania seeding	h	1.96	-	-	12	23.5
Line Transplanting (Male)	h	1.96	72 h	141.1	72 h	141.1
Line Transplanting (Female)	h	1.60	288	460.8	288	460.8
Gap filling	h	1.96	12	23.5	12	23.5
Fertilizer (N)	kg	60.6	80	4848.0	41.53	2516.7
P_2O_5	kg	11.1	40	444.0	33.34	370.1
K_2O	kg	6.7	40	268.0	27.48	184.1
Weeding (2)	h	1.96	318	623.3	288	564.5
Harvesting	h	1.96	216	423.4	216	423.4
Threshing	h	1.96	144	282.2	144	282.2
Total energy input				10142		7912
Energy output						
Grain yield	kg	14.70	4570	67169	4860	71442
Straw yield	kg	12.50	5810	72625	5940	74250
Total energy output				139804		145692
Energy output : input ratio				13.8		18.4
Net Return (Rs/ha)				24400		31755

respectively. There was significant improvement in organic carbon, available N and P_2O_5 under integrated nutrient treatments with rice-horse gram sequence.

Mid-duration rice variety Surendra was grown during *Kharif* 2012 as the third season crop. Main plot was with or without *Sesbania*. The green manure crop was harvested at 48 days stage with a fresh biomass yield of 9.1 t/ha. The equivalent dry weight was 1.71 t/ha and supplied 38.47 kg N, 6.66 kg P_2O_5 and 12.52 kg K_2O/ha. In addition to green manure, chemical fertilizers @ 41.53 kg N, 33.34 kg P_2O_5 and 27.48 kg K_2O/ha were provided through Urea, DAP and MOP to make the total nutrient supply as 80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha. For plots without *Sesbania*, full dose of nutrient (80 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha) was supplied only through chemical fertilizers. The grain and straw yields under the INM involving *sesbania* were 4860 and 5940 kg/ha respectively. Grain and straw yields under the chemical fertilizer treatment were 4570 and 5810 kg/ha, respectively. Total energy input was higher (10.14 GJ/ha) when mid-season rice was grown with chemical fertilizers as compared with the rice grown using *sesbania* green manure and CF in an integrated manner (7.91 GJ/ha). However, total energy output from grain and straw was higher with the INM treatment (145.69 GJ/ha) compared to the CF treatment (139.8 GJ/ha). Higher energy output : input ratio (18.4) and energy productivity (1.37 GJ per ton yield) under the INM as compared to the CF treatment suggested higher energy efficiency under the former. The net returns were also higher (Rs 31755/ha) under the integrated nutrient treatment (Table 11).

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

Given the large spatial and temporal variability of monsoon rainfall in India, literature pertaining to the extreme rainfall analysis is limited. The study of drought indices, such as the maximum number of consecutive dry days (CDD) and the aridity intensity index (AII), is important since they directly affect the predominant monsoon dependent agriculture at its critical stages of growth. By definition, the Aridity intensity index is the average precipitation on dry days, which is the ratio between the total rain on dry days and the number of dry days. Here, a dry day is defined as rainfall < 10 mm. As the 'AII' uses below 10mm rainfall threshold to define a dry day, decreases in 'AII' indicates a moisture stress scenario from agriculture prospective. Trends in CDD and AII, indicates the seasonal and subseasonal differences between and within the two drought indices. Thus increases in CDD reflect the rise in dry spells, increases in AII suggest the rise in moisture availability. The most interesting feature to note is that the drought indices for the whole monsoon season have not captured the contradictory subseasonal patterns among the months June to September. This may be because of the obvious reason that the rainfall distribution is not uniform throughout the four months (June-September) of the monsoon season, with the average rainfall of 169 mm (standard deviation (SD) 28 mm) in June, 279 mm (SD 49 mm) in July, 249 mm (SD 30 mm) in August, 158 mm (SD 33 mm) in September, and 855 mm (SD 94 mm) in Monsoon season during the 1971-2005. In particular, while the increasing dry spell and moisture stress scenario in the active monsoon months of July and August is not reflected in the monsoon CDD, but captured to some extent in the monsoon AII index, the opposite tendency in the month of June and September is also confounded.

It is remarkable to note a distinct behavior of CDD trends on a subseasonal scale. For the monsoon onset month of June, the 'CDD' decreased comparatively in northeastern parts of central India, representing the foothill region of the Himalayas. The elevated heat pump mechanism in the pre-monsoon and early June, which brings warm and moist air from the adjacent Ocean with increased rainfall over north India, could possibly explain the observed decreases in the length of the dry spell. The most remarkable feature of the subseasonal results is the striking spatial gradient for both the CDD and AII indices in July and August (Fig. 6). The observed dipolar distribution of trends in July and August suggests that the central and northern parts of India are vulnerable to drought, as evident from the predominance of the increasing and trends in CDD decreasing AII. In contrast, the southern parts of the country, except that of the southwest coastal tract, have experienced a wetting tendency during the study period. In the monsoon withdrawal month of September, decline in the dry spells were observed in the northcentral parts and increases in eastern India. It is pointed out that the spatial distribution of the CDD and AII indices for the monsoon season did not show the distinct spatial coherence as observed in the subseasonal scale, and therefore underscores the importance of the subseasonal analysis.

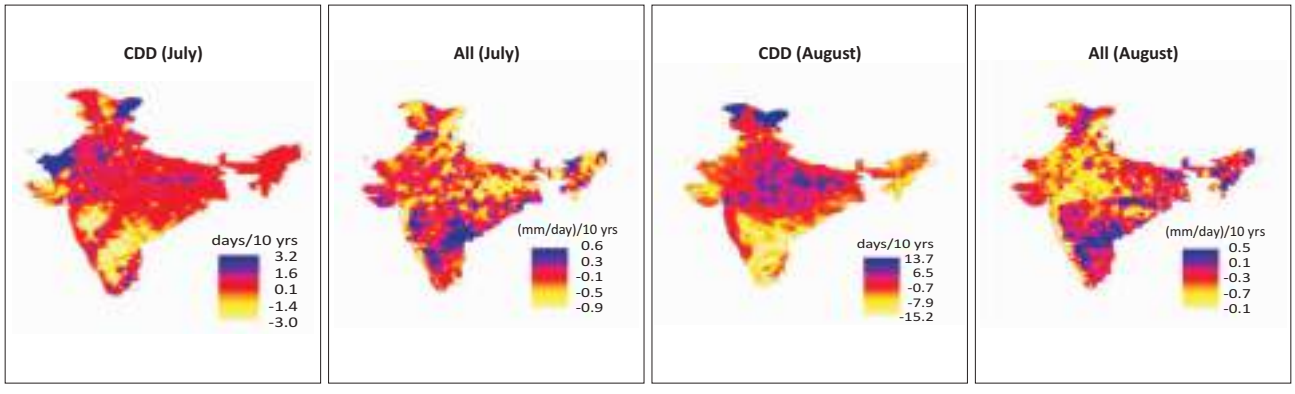


Fig. 6 The spatial distribution of CDD and AII in the active monsoon months of July and August. The central and northern parts of India are vulnerable to drought, as evident from the predominance of the increasing trends in CDD i.e. decreasing AII) during 1971-2005 period.

Canal Water Management

- National initiative for Climate resilient agriculture
- Enhancing water productivity through integrated system of rice intensification
- Development of Decision Support System (DSS) for irrigation water management in Hirakud Canal Command area
- Improving water productivity under canal irrigation command through conservation of surface and ground water using tanks and wells

Project Title : National Initiative for Climate Resilient Agriculture
Funding Agency : NICRA, ICAR, New Delhi
Project Personnel : Gouranga Kar, M. Raychaudhuri, P.S.B. Anand, D.K. Panda, S.K. Srivastava, Ashwani Kumar, C. Mayilswamy, P.K. Singh and H.D. Rank

The specific objectives of the project are studies of climatic variability and assessing their impacts on cropping system, water availability and ground water recharge and development of suitable ground water recharge structure and standardizing methodology of multiple uses for enhancing water productivity through integrated water resources management in various ecosystems. The study was carried out at Kanas and Satyabadi blocks of Puri district, Athgarh and Nishchintakoili blocks of Cuttack district, Kendrapara block of Kendrapara district and Ranpur block of Nayagarh district and Dhenkanal block of Dhenkanal district of Odisha. Development and validation of suitable ground water recharge structures were carried out in Coimbatore, Tamilnadu; Udaipur, Rajasthan and Junagarh, Gujarat. Drought analysis based on departure of one, two and three month's actual rainfall (Table 12)and Standardized Precipitation Index (SPI) (Table 13) was carried out in the study districts of Odisha viz., Cuttack (divided Cuttack and Kendrapara), Puri (divided Puri and Nayagarh), and Dhenkanal district.

Modeling impact of elevated temperature and carbon dioxide on irrigated maize

Temperature, either too low or too high exerts a major retarding effect on plants growth. The modeled results on irrigated maize at Dhenkanal showed that rise in temperature shortened the crop duration from planting to physiological maturity, retarded growth and decreased yield as compared to present at all locations. Study revealed that 0.9 °C increase in temperature that is expected in 2030 reduced crop duration from 5 to 6 % under both 370 ppm and 550 ppm CO_2 concentrations. This reduction in crop duration was higher (6 to 10%) with increase in temperature to 1.8 °C expected in 2060. There were no interactive effects of temperature and CO_2 on crop phenology.

The increase in temperature also had negative effects on leaf area index (LAI) however these effects were lesser under 550 ppm CO_2 concentrations as compared to 370 ppm. The reduction in LAI were 2 to 6 % and 6 to 15 % at 0.9 °C (in 2030) and 1.8 °C (in 2060) increase in temperature, respectively at 370 ppm CO_2 concentration. Increase in CO_2 however minimized the negative impacts of high temperature. The reduction in LAI was 0.6 to 3 % and 4 to 11 % at 0.9 °C and 1.8 °C increase in current mean temperature, respectively under 550 ppm CO_2 concentration.

Total dry matter (TDM) accumulation also reduced by increase in current mean temperature. The reduction in TDM were from 5 to 8 % and 13 to 18 % at 0.9 °C and 1.8 °C rise in temperature, respectively at 370 ppm CO_2 concentration, while the equivalent reduction in TDM at 550 ppm CO_2 concentration ranged from 2 to 4 % and 9 to 14 % at all three locations for 0.9 °C and 1.8 °C increase in current mean temperature.

Yield and yield components were negatively affected with increase in temperature under both 370 ppm and 550 ppm CO_2 scenarios. According to model simulations in 2030 with 0.9 °C increase in current temperature, the yield of maize will fall up to 11% under 360 ppm CO2 concentration. However, increase in CO_2 concentration from 370 to 550 ppm at this temperature scenario had some promotive effect on maize productivity.

Satellite based remote sensing techniques for water stress monitoring

Satellite data from MODIS TERRA satellite (Tile h25, v5, h25, v6, h26, v5, h26, v6) were acquired (2000-2011) in blue, red, middle infrared and near infrared regions and Normalized Difference Vegetation Index [(NDVI = (IR-R)/(IR+R)] were derived for drought assessment in

Table 12 Frequency of drought months between 1960-2011 based on departure of one, two and three month's actual rainfall

Districts	June		July		August		September		Jul-Aug		Aug-Sept		Jul-Sept	
	M	S	M	S	M	S	M	S	M	S	M	S	M	S
Cuttack	12	7	12	3	4	1	6	5	9	0	4	0	6	0
Puri	10	11	8	3	5	2	12	3	10	0	4	1	6	2
Dhenkanal	10	6	15	5	11	2	12	2	10	3	7	0	7	1

M= Moderately drought, S = Severe drought

Table 13 Quantification of meteorological droughts with SPI based on two and three months' rainfall departure (Data base; 1960-2011). MD= Moderately dry, SD= Severely dry ED = Extremely dry

Districts	Jul-Aug			Aug-Sept			Jul-Sept		
	MD	SD	ED	MD	SD	ED	MD	SD	ED
Dhenkanal	9	2	2	7	1	0	6	1	0
Cuttack	8	1	1	6	1	0	5	0	0
Puri	9	1	0	5	1	0	6	2	0

Odisha. Green and healthy vegetation reflects much less solar radiation in the visible compared to those in near-infrared. Based on the above relationship, Normalized Difference Vegetation Index (NDVI) was derived for a drought year (2002) and compared with a normal (2011) year (Fig. 7).

$TDM = 26.66 (NDVI) - 8.7702, R^2 = 0.78$
$LAI = 8.549(NDVI) - 2.0908, R^2 = 0.72$
$Yield = 9.45 (NDVI) - 2.9848, R^2 = 0.82$

Basic soil-water-plant-relationship study

To determine soil water retention using pedo-transfer functions and assessing their utility in simulation model, soil samples were collected at various depths (0-0.15, 0.15-0.30, 0.30-0.45, 0.45-0.60, 0.60-0.90, 0.90-1.20 m) from 3 locations *viz*. Satyabadi, Kanas, Dhenkanal of Odisha, representing land ecologies of moderate surface waterlogging (0.5-0.75 m), severe surface waterlogging (>1.0 m) and non-waterlogged upland soils, respectively. The mechanical composition of the soils revealed that soils were clay in texture at all depths at Kanas and Satyabadi whereas texture of the Dhenkanal soils ranged from sandy clay loam to clay loam. The bulk density was higher in soils of Kanas and Satyabadi while this parameter is low in Dhenkanal. The profile organic carbon stock was higher in waterlogged soils of Kanas and Satyabadi (66.6 and 78.8 $Mg.ha^{-1}$, respectively) than Dhenkanal site (59.26 $Mg.ha^{-1}$). Soil moisture retention at field capacity (0.033 MPa) ranged between 0.381 to 0.603 m^3m^{-3} at Kanas, 0.335 to 0.503 m^3m^{-3} in Satyabadi and 0.319 to 0.446 m^3m^{-3} in Dhenkanal at different depths. At permanent wilting point (1.5 MPa), the moisture content varied from 0.185 to 0.262, 0.172 to 0.246 and 0.108 to 0.139 m^3m^{-3} at Kanas, Satyabadi and Dhenkanal, respectively. Pedo-transfer functions in the form of linear equations were developed for estimating soil water retention at field capacity and wilting point using basic soil properties.

The Pedo-transfer functions in terms of multiple linear regressions were developed to predict moisture estimation (m^3m^{-3}) at field capacity (θfc) and wilting point (θwp).

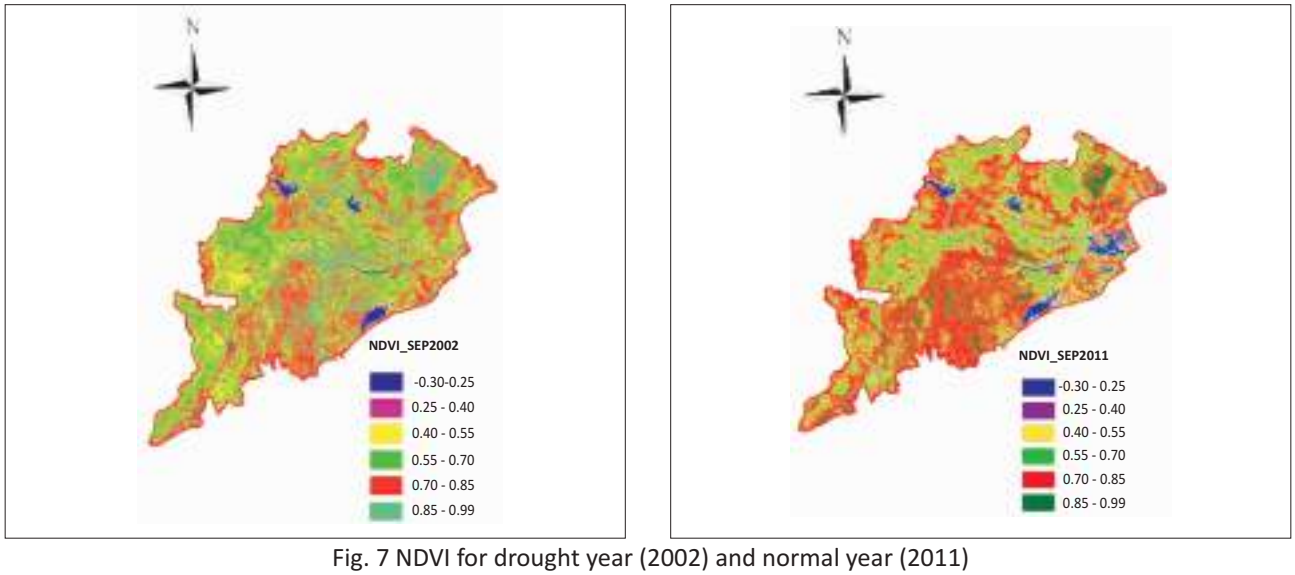


Fig. 7 NDVI for drought year (2002) and normal year (2011)

θfc = 0.418 - (0.0058*sand) + (0.0021*clay) + (0.0258*PSOC)

θwp = 0.3989 – (0.0039*sand) - (0.00384*silt)

θwp = 0.0238 + (0.0038*clay)

Cropping pattern and canal water availability in selected commands and development of water resources to bridge the mismatch between canal water demand and supply and multiple use of water

Assessed water demand and supply at distributaries/minor/sub-minor levels in different reaches in different agro-ecological situations (Pattamundai canal command, Kendrapara, Sukal minor, Puri, Odisha, Darpanarayanpur Minor Irrigattion project, Nayagarh, Odisha, Lower Bhabani Project, Tamilnadu). It was observed that water supply was not adequate during crop seasons to irrigate crops in all these study areas. The average relative water supply (ratio of water supply and water demand over a period of time) was observed to be 0.55-0.65 in winter at the head reach and 0.35- 0.50 in winter at the tail reach of watercourses. This clearly indicated the insufficiency of the available canal water supply to meet the demands. Erratic rainfall due to climatic variability and climate change aggravate the problem. Cropping system and plans have been suggested for existing supply situation and water harvesting structures were created to supplement canal water with rainwater.

It is also well recognized that sufficient water availability and flexible water delivery are key requirements that will allow farmers to adopt new technologies for improving water use efficiency. To supplements the canal water supply to irrigate crops, rainwater harvesting system was designed and implemented in the above 3 canal commands/minors and a total volume of 12842 m^3 (3 ponds), 50,323 m^3 (9 ponds) and 28,652 m^3 (6 ponds) was created at Nayagarh, Puri and Kendrapara, respectively based on the available runoff at 67% probability. Pond based farming systems (crops, on-dyke horticulture, fisheries) were developed in created water resources in 3 canal commands to enhance water productivity and to mitigate dry spells. Water productivity of the area enhanced from Rs. 1.1-1.42/m^3 through sole rice to Rs. 6.0-7.5/m^3 through pond based farming. Due to assured available water in the first year of study cropping intensity of command area of the ponds was 200-240% and gross return was varied from Rs. 47,700/- to Rs.64,300/- from the pond based farming area (Table 14). Basic soil-water-plant relationship was developed for different land ecologies of the commands/minors to study the soil water retention as influenced by texture and structure and water balance of the pond was worked out. Improved irrigations systems like furrow and drip are also being implemented to enhance water use efficiency and water productivity.

Table 14 Income of farmers after creating fourth tier of water resources in canal command of Kendrapara district

Pond area	Area of field crop cultivable land	Total farming area (area of pond + area of cultivable land)	Gross income from field crops (in Rs.)	Gross income on dyke horticulture (in Rs.)	Gross income from Fish (in Rs.)	Gross total income (in Rs.)	Total operational expenditure	Net income (in Rs.)
Pond 1 (1890 m^2)	3575 m^2	5465 m^2	K= 14526 R= 29000	10200	45000	99726	43600	56126
Pond 2 (2040 m^2)	2895 m^2	4935 m^2	K= 12000 R= 24000	11000	42000	89000	41300	47700
Pond 3 (2000m^2)	3050 m^2	5050 m^2	K= 15000 R= 24400	12000	55000	106400	42100	64300
Pond 4 (1680m^2)	3000 m^2	4680 m^2	K= 13500 R= 25465	11200	38000	87665	39200	48465
Pond 5 (1400m^2)	3472 m^2	4872 m^2	K= 19000 R= 31382	13300	46000	109682	49800	59882
Pond 6 (3500m^2)	4650 m^2	8150 m^2	R=34550	12455	52000	99005	48325	50680

K= Kharif, R = Rabi

Creation of ground water resources with improved irrigation system in alluvial zone for mitigating dry spells (Dhenkanal, Orissa) and development and evaluation of groundwater recharge structures (at Coimbatore, Udaipur, Junagarh).

To augment irrigation sources in alluvial zone of Dhenkanal and Cuttack districts, Odisha, fifteen dug wells were constructed as per the design below (Fig. 8). Pumping test was done to estimate the recharge rate for different crated dugwells which varied from 7.48 to 14.35 m^3/hr. As per the discharge rate, cropping pattern and command area (0.70-1.1 ha) of each dug well were established. After creating ground water resources with improved irrigation system, 240% cropping intensity and net income of Rs. 39,000 to Rs.44,450/ha was achieved in different dug wells.

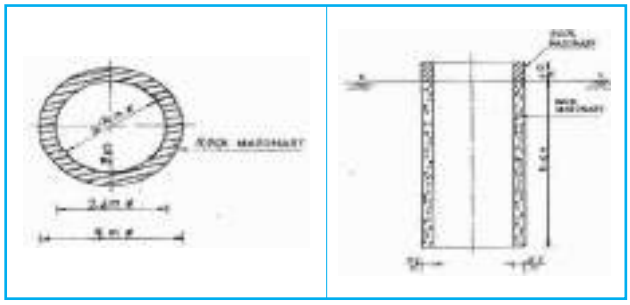
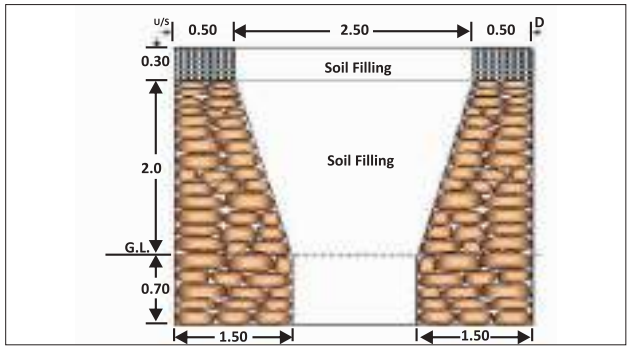


Fig. 8 Design of constructed dug wells at Dhenkanal district, Odisha.

Location specific groundwater recharge techniques like recharge shaft with percolation pond at Coimbatore, low cost dry masonry structure at Udaipur, percolation pond at Junagarh, centre were developed. These location specific technologies were tested for performance in terms of recharge rate and area of influence.

Recharge shaft developed at Coimbatore



Cross-section of dry stone masonry type rainwater harvesting and recharge structure, developed at Udaipur

Project Title	: Enhancing Water Productivity through Integrated System of Rice Intensification
Project Code	: DWM/12/156
Funding Agency	: Institute
Project Personnel	: A.K. Thakur, R.K. Mohanty, S. Raychaudhuri, O.P. Verma

A field experiment was conducted during the 2012 *kharif* season at the DWM Research Farm to evaluate the effect of rice cultivation systems on growth, physiology and grain yield. The systems of rice cultivation were SRI method and conventional transplanting method (TP) with two different nutrient managements (organic and integrated nutrient management (INM)). Experimental treatments were as follows: SRI-Organic; b. SRI-INM; c. TP- Organic; d. TP-INM

Growth, Light transmission by canopy and photosynthesis rate

During the maximum tillering stage, the SRI crop were greener than the TP crop. This was also evident from the higher SPAD value. Organically grown rice under both the cultivation systems had higher SPAD value than chemically fertilized crop (Fig. 9). The light transmission ratio (LTR) by canopy during tillering stage showed that SRI crop transmitted lesser light compared to TP crop. Hence, canopy of SRI crop intercepted more solar radiation than did the TP canopy (Fig. 10). Highest leaf photosynthetic rate was observed in SRI-organic plots, followed by SRI-INM, TP-organic and least in TP-INM (Fig. 11). These results indicate that

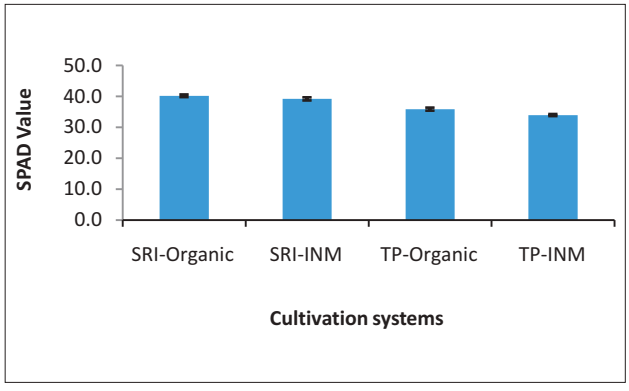


Fig. 9 Effect of rice cultivation systems on SPAD value during tillering stage. Vertical bar represents standard error of the mean (SRI: System of rice intensification; TP: Transplanted rice; INM: Integrated nutrient management)

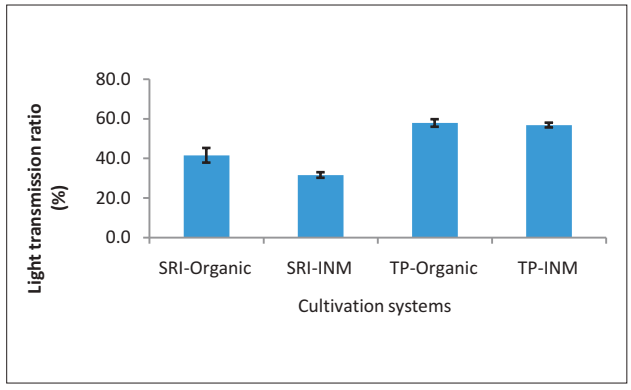


Fig. 10 Effect of rice cultivation systems on light transmission ratio (LTR) by canopy during tillering stage. Vertical bar represents standard error of the mean (SRI: System of rice intensification; TP: Transplanted rice; INM: Integrated nutrient management)

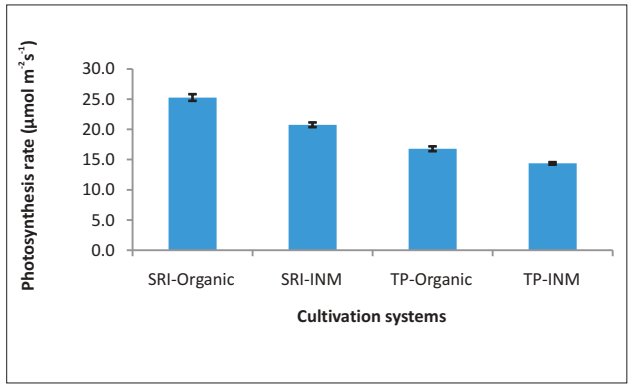


Fig. 11 Effect of rice cultivation systems on photosynthetic rate during tillering stage. Vertical bar represents standard error of the mean (SRI: System of rice intensification; TP: Transplanted rice; INM: Integrated nutrient management)

rice crop grown under SRI had significant improvement in physiology of crop than crops grown with conventional method. These improvement in plant functions significantly increased in grain production.

Root growth

Roots collected from similar soil volumes under both methods showed that with SRI practices, hills had a significantly larger amount of roots as indicated by increased root dry weight per hill at the flowering stage (Table 15), even though SRI had only one plant hill^{-1} whereas TP had three plants hill^{-1}. In spite of lower plant density in SRI, root dry weights per unit area were also higher compared to TP. INM plots had greater root dry weight than organically grown crops under both cultivation systems.

Table 15 Effect of rice cultivation systems on root dry weight after harvest of crop

Cultivation system	Root dry weight (g/hill)	Root dry weight (t/ha)
SRI-Organic	9.97	2.49
SRI-INM	11.87	2.97
TP-Organic	4.45	2.22
TP-INM	5.09	2.55
$LSD_{0.05}$	0.78	0.14

Grain yield and yield-contributing characteristics

SRI plants were taller compared to TP plants (Table 16). Organically-grown plants were shorter than the plants grown with INM in both the methods. SRI hills had nearly double the number of tillers and panicles than TP hills. The number of tillers per unit area was greater under TP method compared to SRI method mainly due to the greater number of hills per unit area under TP and also it was more with INM than organic treatments. However, the number of panicles per unit area was significantly higher in SRI plots than TP. Therefore in SRI method the effective tillers were significantly more than conventional method.

The average panicle length in SRI (21.0 cm) was significantly higher than panicles in TP (16 cm). The longer SRI panicles carried nearly 28% more number of grains compared to panicles in TP (Table 17). Highest grain yield was obtained in SRI with INM. As compared to TP-INM grain yield under SRI-INM was 48% higher, while, in SRI-Organic 24% higher. The grain yield increased under SRI was mainly due to significant improvement in number of spikelet/panicle, grain filling % and 1000-grain weight with significant increase in harvest index in SRI method compared to TP. Therefore, through SRI management grain yields could be increased significantly. Comprehensively there was significantly better root development and a more efficient physiological functioning due to changes in the plants' morphological structure due to modified crop management under SRI. Organically fertilized crops showed initially better growth in terms of SPD value observations, light interception by canopy and photosynthesis rate compared to chemically fertilized plots. However, during the later stages of crop growth there might be limitations in nutrient supply in organic SRI and TP plots leading to inferior grain production than INM plots.

Table 16 Effect of rice cultivation systems on plant height, tillering and panicle development

Cultivation system	Plant height (cm)	Tiller No. /hill	Panicle No. /hill	Tiller No. /m^2	Panicle No. /m^2	Effective tillering (%)
SRI-Organic	84.4	16.4	14.8	409.0	370.0	90.46
SRI-INM	92.1	18.9	16.4	471.6	411.2	87.20
TP-Organic	78.7	8.8	7.0	441.0	348.7	79.07
TP-INM	87.5	9.9	7.7	493.1	384.5	77.97
$LSD_{0.05}$	1.9	0.8	0.7	21.1	17.8	3.14

Table 17 Effect of rice cultivation systems on grain yield, yield contributing characters, straw weight and harvest index

Cultivation system	Ave. panicle length (cm)	Spikelet number /panicle	Filled spikelet (%)	1000-grain weight (g)	Straw dry weight (t/ha)	Grain yield (t/ha)	Harvest Index
SRI-Organic	20.1	114	81.8	24.3	4.58	4.84	0.51
SRI-INM	21.8	126	80.3	24.4	6.53	6.14	0.48
TP-Organic	16.1	96	74.8	23.1	4.99	3.88	0.44
TP-INM	15.9	91	76.5	23.3	5.68	4.14	0.42
$LSD_{0.05}$	0.6	7	2.1	0.3	0.21	0.19	0.04

Project Title	: Development of Decision Support System (DSS) for irrigation water management in Hirakud Canal Command area
Funding Agency	: ISRO, NRSA, Hyderabad
Project Personnel	: R.K. Panda, S. Mohanty and P.S. B. Anand

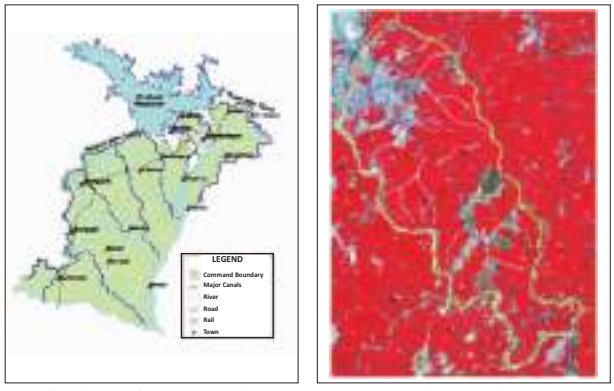
A multi layered geo-spatial data base comprising of irrigation network, command area jurisdiction and soil map, historic cropping pattern; in-season satellite data; field experimental data like depth of water application, evaporation, transpiration, percolation, conveyance efficiency, field application efficiency are being collected in Hirakud canal command area of Odisha for computation of crop / irrigation water requirements and crop / irrigation water use efficiency. These data shall be input to develop a Decision Support System (DSS) for real time adoptive irrigation water management in the canal command area

Study area

The study area is located in the canal command area of Bargarh distributary, which comes under Hirakud canal command area. It falls under the agro-climatic zone of Western Central Table Land of Odisha. The climate is hot and moist sub-humid with light to medium texture soils. Detail features of the Bargarh Distributary and its minors and sub minors are shown in Fig. 12 and Table 18. Paddy is the dominant crop cultivated both in Kharif and Rabi seasons.

Formulation of methodology for assessment of the canal performance

Optimal cropping pattern for Malipali minor of Bargarh distributary in Hirakud canal command is envisaged through assessment of its performance and identification of the gaps in demand and supply of irrigation water. Data on number of outlets, discharge at the head end and at each outlet, command area of each outlet, cropping pattern acreage for each outlet and crop water requirement in the outlets are proposed to be documented through secondary data and field observed data.



Hirakud canal command area Bargarh distributary

Fig. 12 Study area in Hirakud canal command area

Analysis of existing water resources scenario

The total water requirement and computation of supply-demand gap for Malipali minor shall be analysed based on

$$WR_{i,j} \quad K_{C(i,j)} ET_j \quad ER_j$$

$$VWR_j \quad \sum_{i=1}^{n} A_i WR_{i,j}$$

Where, WRi,j = water requirement of crop i for week j (depth unit); KC(i,j) = Crop coefficient of crop i for week j; ETj = Evapotranspiration during week j; ERj = Effective rainfall during week j; Ai = Area under crop I; VWRj = Volumetric water requirement for week j; n = Number of crops in the command area and m = Crop duration in number of weeks.

In-season crop information using multi-date AWiFS data for deriving paddy transplantation and its progress revealed increasing trend in paddy coverage area from 65 % during 1992 to 91 % during 2012 in the command area. However, non paddy area coverage remained within 6-7.8% (Fig. 13).

Field scale water balance study in paddy field revealed field evaporation, transpiration and deep percolation rates within the range of 1.3-2.3, 3.7-4.8 and 1.0-2.0 mm/day, respectively (Fig. 14).

Average loss of flow in the lined and unlined canal using pigmy type current meter was observed to be $4.16X10^{-5}$ and 2.27×10^{-4} m^3 per sec per m^2 wetted perimeter, respectively (Table 19).

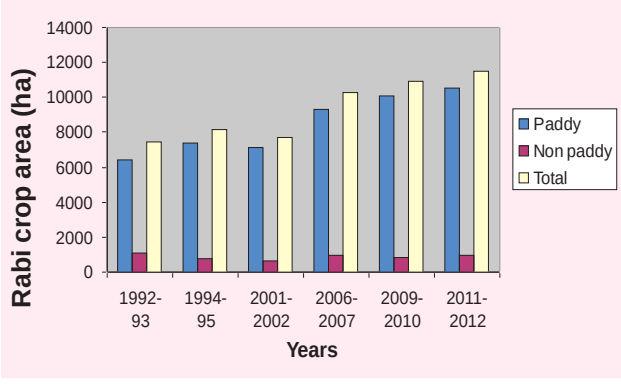


Fig. 13 Temporal crop coverage

Table 18 Detail features of the Bargarh Distributary its minors and sub minors

Particulars	Bargarh Distributary	Minors and Sub minors
CCA (ha)	12165	331.8 - 4010
Discharge (m^3/s)	9.4	0.22 – 1.67
Length (km)	29.7	0.2 – 4.4
Authorized Outlets (Nos.)	169	5 – 44
No. of minors (Nos.)	10	-
No. of sub minors (Nos.)	5	-
Outlet discharge (m^3/s)		0.001 – 0.213

Table 19 Loss of flow measurement in the canals

Types of canal section	Sectional length, m	Q_{in}, m^3/sec	Q_{out}, m^3/sec	$Q_S = Q_{in}-Q_{out}$, m^3/sec per m^2 wetted perimeter
Lined canal	87.5	5.27	5.24	$4.16X10^{-5}$
Unlined canal	102	0.85	0.76	$2.27 X 10^{-4}$

The crop growth parameters of *rabi* rice such as plant height and number of tillers / m^2 and the yield components like number of panicles/m^2, number of grains / plant and test weight and grain and straw yield of rice were found to be superior in head region followed by mid region and tail region of Bargarh distributary. The highest grain yield (6.63 t/ha) was recorded in head region which is 12 % and 23 % higher than that of mid (5.92 t/ha) and tail (5.39 t/ha) regions. The rice grain yield in head region was 5.87 t/ha, 5.48 t/ha in mid region and 5.15 t/ha in tail region.

Experimental set up in farmers' field

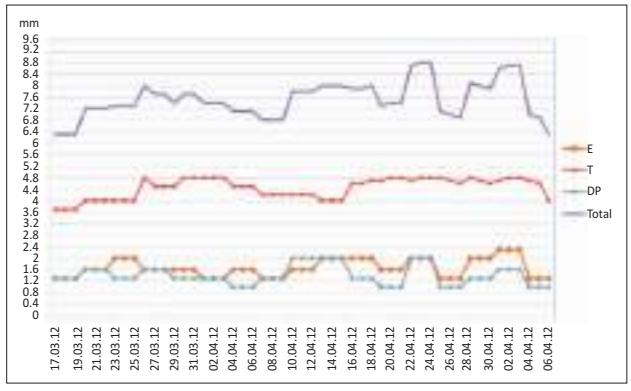


Fig. 14 Field water budget study through drum experiment

Project Title : Improving water productivity under canal irrigation command through conservation of surface and ground water using tanks and wells
Funding Agency : INCID, MOWR, New Delhi
Project Personnel: K.G. Mandal, S. Ghosh, R.K. Mohanty, M. Raychaudhuri and Ashwani Kumar

The study is being carried out in Kuanria Medium Irrigation Project (KIP) at Daspalla (20°21' N, 84°51' E elevation of 122 msl) of Nayagarh district of Odisha under Agro-Eco Sub-Region 12.2 (AESR 12.2) and Agro-Climatic Zone 7 (ACZ 7). The geographical area of Daspalla block is 571.57 km^2.

The canal systems

KIP is a medium irrigation project. Intercepting river 'Kuanria', a right tributary of river Mahanadi and a nallah named 'Khalakhala' by an earth dam form the reservoir of KIP. The catchment area of the reservoir is 124 sq km and irrigates 3780 ha of land benefiting about 37,000 people living in 67 villages under the command area. The top bank level of the dam (TBL) with 5.0 m top width is 138.0 m, flood reservoir level (FRL) of the reservoir is 135.7 m and the dead storage level is 130.3 m. The project has two number of head

regulators such as right and left distributaries (RD and LD). The RD and LD runs for a length of about 18.2 and 16.5 km having design discharges of 2.00 and 1.98 m^3s^{-1}, respectively. The gross storage capacity of the reservoir is 2200 ha m with a live storage of 1750 ha m. The gross command area (GCA) is 4800 ha and cultivable command area (CCA) is 3780 ha. The CCA of RD is 1868.13 ha and that of LD is 1911.87 ha. There are total of 32 sub-minors and 5 minors distributed over the entire command area. Among these, 16 sub-minors each are distributed in left and right distributaries, 3 minors in RD and 2 in LD. Discharge rate for all minors and sub-minors of RD and LD were measured. The water released data through RD and LD of Kuanria dam was also collected.

Studies on soil and hydraulic properties of the command

The soil properties in the head-reaches of right distributaries falls under the WUA 6. The texture 0-30 cm soil layer was sandy clay loam while in other layers it was sandy clay in the head reach of the Kuanria command area. There was little variation of bulk density among different soil layers. EC values were quite less (i.e. 0.01 to 0.06 dS m^{-1}). Soil was slightly acidic to alkaline in nature. Soil organic carbon (SOC) content gradually decreased from top to bottom soil layers. Saturated hydraulic conductivity was highest for 0-15 cm soil layer and lowest for 90-120 cm depth of soil. In the mid-reaches, texture in the 0-15 cm soil layer was sandy clay loam; 15-45 cm soil layer clay loam while in other layers it was clay. Bulk density of the soil varied between 1.48 to 1.53 Mg m^{-3} where as EC varied from 0.23 to 0.62 dS m^{-1} in all the soil layers. In general, soil was slightly alkaline in nature and soil organic carbon content varied between 0.27 and 0.67%. Saturated hydraulic conductivity varied from 0.011 to 0.026 cm hr^{-1} for all the soil layers. The soils of tail end command were analysed for determination of their physical and chemical properties. Texture for all the soil layers was clay loam for the site at WUA 5 i.e., at the tail end of the left distributaries, where water availability through canal is relatively less than the mid or head reaches. There was a definite trend that sand content was greater in every soil layer than silt and clay contents, but there was slight difference in different layers of the soil profile. It is revealed that, soil was moderately alkaline in nature. The soil organic carbon content decreased as soil depth increased. Bulk density of soil varied between 1.41 to 1.47 Mg m^{-3} and EC varied between 0.01-0.11 dS m^{-1}. Saturated hydraulic conductivity was highest in 0-15 cm soil layer and decreased towards lower depth of soil. Saturated hydraulic conductivity of tail reach soils of left distributaries were lower in comparison to that of right distributaries. As the soil properties were different at head, mid and tail reach areas of left and right distributaries under Kuanria command area, different management of irrigation is required for optimal use of canal, rainfall and ground water.

Canal water supply and its schedule

Month-wise average water supply (Table 20) showed that the amount of water released was highest in October (i.e. 354.3 and 314.2 ha.m for LD and RD, respectively). During July to October major amount of water was released from the Kuanria dam sufficient to irrigate 3780 ha of cultivable command area. Amount of released water was 1967.5 ha m during monsoon (Jul-Oct) and 703.1 ha m during dry period (Nov-Jun). The released water was much less during lean period in comparison to the same during monsoon.

Table 20 Month wise average water supply from left and right distributaries of Kuanria dam for 15 years

Month	Water supply through left distributaries (ha.m)	Water supply through right distributaries (ha.m)	Total supply (ha.m)
January	56.3	49.6	105.9
February	53.3	48.9	102.2
March	79.5	69.5	148.9
April	84.9	71.3	156.2
May	27.1	33.1	60.2
June	0.0	0.5	0.5
July	150.1	131.6	281.7
August	277.6	218.1	495.7
September	262.0	259.6	521.6
October	354.3	314.2	668.5
November	62.0	55.0	117.1
December	6.8	5.8	12.6

There are 192 and 112 number of authorized and unauthorized outlets in left and right distributaries, minors and subminors of Kuanria Irrigation project. Unauthorized outlets in left distributaries were more than right distributaries. Due to presence of large number of unauthorized outlets, tail end farmers did not get adequate and timely supply of water. There was a demand-supply gap during every month (Table 21).

Cropping pattern in the command area

The cropping system is predominantly rice-based. Rice is being grown during rainy season and green gram is mostly grown during post-monsoon season. Arhar is also grown in the upland areas. Among vegetables, brinjal is leading. Rice, brinjal and green gram occupy

Table 21 Month-wise irrigation water demand, canal water supply through distributaries, minors and subminors and demand-supply gap

Months	Demand (ha m)			Supply (ha m)			Gap (Demand-supply)		
	RD	LD	Total	RD	LD	Total	RD	LD	Total
Jul	503.5	466.7	970.2	145.0	127.3	272.4	358.4	339.4	697.8
Aug	135.2	129.8	265.0	274.1	218.5	492.6	-138.9	-88.7	-227.5
Sep	332.4	280.8	613.2	257.0	252.0	509.0	75.4	28.8	104.2
Oct	235.4	239.2	474.6	352.8	310.5	663.4	-117.4	-71.3	-188.8
Nov	56.8	71.5	128.2	60.1	53.2	113.3	-3.3	18.3	15.0
Dec	109.5	132.9	242.5	6.4	5.4	11.8	103.1	127.5	230.7
Jan	83.1	104.9	187.9	55.5	49.7	105.1	27.6	55.2	82.8
Feb	91.6	123.8	215.4	52.9	50.4	103.3	38.7	73.4	112.1
Mar	34.3	54.9	89.2	81.8	70.4	152.3	-47.5	-15.5	-63.1
Apr	11.8	18.4	30.2	82.9	69.7	152.6	-71.1	-51.3	-122.4
May	10.6	13.4	24.0	27.7	34.7	62.4	-17.1	-21.4	-38.4
Jun	2.5	3.2	5.6	0.0	0.4	0.4	2.5	2.7	5.2

about 90.4, 8.8 and 10.6% of the total command area, respectively. Sugarcane is a major cash crop in the region.

Development of rain/ runoff water storage structure & multiple use of water for fish culture, on-dyke cultivation of crops and irrigation

As runoff amount was more than 10% of the seasonal rainfall, therefore practical harvesting of runoff was possible. Rain/ runoff water storage tanks were constructed for conservation of rainfall and runoff water to ensure water availability and dependability to the farmers. In order to conserve the rainfall, seepage and excess canal water ponds are constructed within the Kuanria irrigation command area under beneficiary farmers (Table 22).

Fish cultures with 'rohu', 'catla' and 'mrigal' was made in the constructed ponds. Farmers irrigated the surrounding fields by utilising the stored water within the ponds. The harvested water in the water storage structures during monsoon season was used as multisource water for irrigation, domestic use, fish rearing and duckery, growing on-dyke papaya, banana, arhar etc and thus served as an integrated faming system for improving overall water productivity in the command.

Rain/ runoff water storage structures developed in the tail end of KIP

Table 22 The list of beneficiary farmers and the capacity of rain/ runoff water storage tanks developed in different minor/ sub-minors under the Kuanria command area

Sl. No.	Name of farmer	Distributary (Left or right)	Name of minor/ sub-minor (S/M)	Name of WUA	Pond capacity (m^3)
1.	Mrs. Jyostnamai Nanda	LD	Mangalpur S/M	2	1630
2.	Mr. Banamali Mishra	LD	Khairapankalsahi S/M	4	1630
3.	Mr. Balakrusna Pradhan	LD	Madhyakhand S/M	5	1630
4.	Mrs. Itishree Mishra	RD	Odasar S/M	6	1630
5.	Mr. Sudarsan Das	RD	Khamarasahi S/M	8	1630
6.	Mr. Banbihari Muduli	RD	Madhyakhand S/M	9	1630
7.	Mr. Hadia Nayak	RD	Lunisara S/M	10	1630
8.	Mr. Bhagirathi Nayak	RD	Soroda S/M-II	10	1630

Groundwater Management

- Groundwater recharge guidelines for agro-ecological region no. 8. with hard rock geology
- Groundwater modeling to determine the safe yield of coastal aquifer
- Impact of wastewater use on soil properties and its prospect of utilization in crop production
- Suitability of the available poor quality water resources for agricultural uses under different agro-climatic region
- Georeferenced soil information system for land use planning and monitoring soil and land quality for agriculture
- Groundwater extraction mechanisms and pump irrigation markets in Mahanadi basin
- Groundwater development and energy use dynamics for irrigation in Odisha

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

Delineation of Suitable Areas for Groundwater Recharge in Karnataka

During the reporting period, suitable areas for groundwater recharge in Karnataka were delineated. Geo-referenced maps of three different themes such as soil drainage, land capability and geology were considered in spatial analysis to delineate areas suitable for recharge in the state. During the analysis, appropriate weightage was given to each theme on the basis of its overall importance in recharge process. The infiltration process and aquifer storage capacity were given equal importance. The soil drainage and land capability themes were assigned 25 percent weightage each, thus total of 50 percent weightage while geology responsible for aquifer storage was assigned 50 percent weightage. Spatial variations were found in these three themes which were considered by dividing the themes into different categories and assigning appropriate scores. The highest score of 10 was assigned to a theme, if its properties were the most suitable for recharge and vice versa. For delineation of suitable area for recharge, the weighed sum was determined using the following formula.

WeightedSum1= [(50* GeoSc)+(25*SdSc)+(25*LcSc)]

Where:

WeightedSum1= Weighted sum indicating level of suitability of area for recharge

GeoSc = Score based on geological category
SdSc = Score based on soil drainage category
LcSc = Score based on land capability category

The maximum possible score under ideal condition can be 1000 and can vary as per spatial variations of different themes. The output of spatial analysis is given in Fig. 15. The areas having higher scores are suitable for groundwater recharge.

Prioritization of Suitable Areas for Groundwater Recharge for Karnataka

One more theme "depth to water table" was added to above mentioned three themes. All four themes were used in spatial analysis, by assigning appropriate overall weightage (50, 25, 12.50 and 12.50 percent, respectively, to depth to water table, geology, soil drainage and land capability) on the basis of their overall importance in recharge process and appropriate scores (0 to 10) on the basis of spatial variability within the themes in prioritization of recharge areas. The maximum possible score under ideal condition can be 1000 in this analysis and can vary as per spatial variations of different themes within the state. On the basis of the scores obtained, the state was divided into four categories *viz*. Areas with Recharge Priority (ARP) 1 (with highest score), ARP 2, 3 and 4 (with lowest score). The ARP 1 was considered the most suitable for recharge planning while ARP 2, 3 and 4 were not important as there was no urgency of recharge (Fig. 16).

A realistic assessment and quantification of the source water is very much essential in recharge planning. During monsoon period, runoff from rain events is important source for recharging water. Amount of

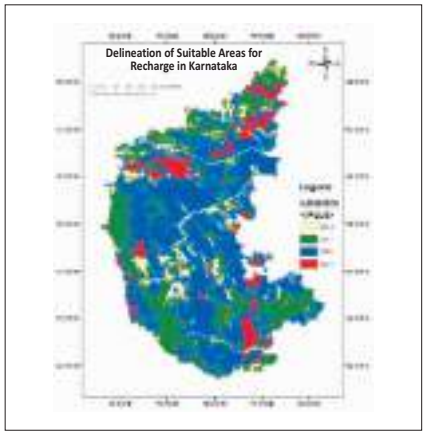


Fig. 15 Delineation of suitable areas for recharge in Karnataka

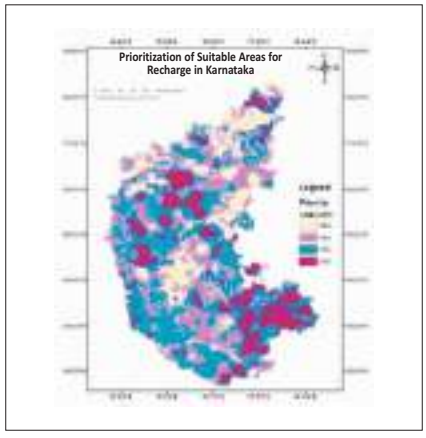


Fig. 16 Prioritization of Suitable areas for recharge in Karnataka

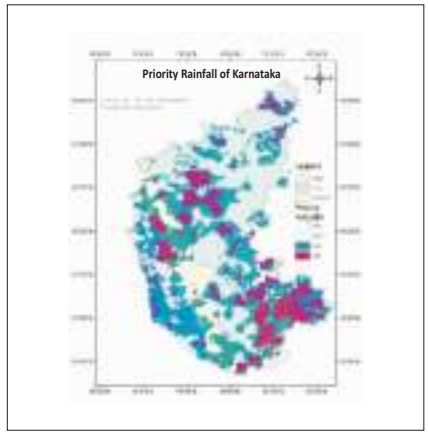


Fig. 17 An intersection of Areas with recharge priority 1 and 2 with rainfall zones for Karnataka

Table 23 Comparison of number of recharge structures in Prioritized areas in state of Tamil Nadu

Year	GW development in Karnataka (%)	Percolation tanks required in prioritized areas for 70% runoff with 3 fillings/ year	Check dams required in Prioritized areas for 30% runoff with5 fillings/ year	Remark
1998	62.55	8612 No.	18170 No.	Estimated by CGWB
2009	85.00	12021 No.	30912 No.	Estimated by DWM based on this research

runoff water varies with annual rainfall amount, soil type and land use. An appropriate value of runoff coefficient is to be based on topography and land use (i.e. land capability) and soil texture. It helps in estimation amount of runoff available from annual rainfall for recharge purpose. The state of Karnataka was divided into three zones on basis of rainfall amount. Areas with rainfall amount of 400-500 mm, 500-1000 mm and 1000-1250 mm, were considered under Low, Medium and High rainfall zones respectively. An intersection of ARP 1, 2, 3 and 4 and rainfall zones are shown in Fig. 17.

Estimation of number of structures in prioritized areas of Tamil Nadu and Karnataka

Appropriate selection of runoff coefficient based on topography, land use and rainfall amount gives reasonable estimate of amount of water available for recharging. Considering different rainfall zones and runoff coefficients, amounts of excess runoff water available for recharge in prioritized areas of Tamil Nadu and Karnataka were also estimated. In case of Tamil Nadu, 70% runoff was allotted for percolation ponds and 30% runoff was allotted for check dam. In view of bi-modal rainfall in the state of Tamil Nadu, number of fillings of each percolation pond per year was assumed as 3 while for each check dam per year fillings were taken as 5. Considering capacity of percolation tank as 0.1 mcm (100 TCM) and of check dam as 0.01 mcm (10 TCM), number of recharge structures (percolation ponds and check dam), required prioritized areas were estimated (Table 23). The results (DWM Estimated) based on 2009 groundwater development (85%) appeared to be in agreement with CGWB estimate of number of percolation pond and check dam based on 1998 groundwater development of 62.55%.

In case of Karnataka, 50% runoff was allotted for percolation ponds and 2 fillings of each percolation pond per year were assumed. In case of check dam, 25% runoff was allotted and 3 fillings of each check dam per year were assumed. The capacity of percolation tank was taken as 0.01 mcm (10 TCM) while of check dam was taken as 0.1 mcm (100 TCM). The rainfall in Karnataka is not bio-modal, hence number of fillings of structures in case of Karnataka are less compared to Tamil Nadu. Numbers of recharge structures (percolation ponds and check dam) necessary in prioritized areas were estimated for Karnataka and results are given in Table 24. The results (DWM Estimate) based on 2009 groundwater development of 70%; appear to be in agreement with CGWB estimate of number of percolation tank and check dam based on 1998 groundwater development of 33.06 percent.

Table 24 Comparison of number of recharge structures in Prioritized areas (Priority 1) in state of Karnataka

Year	GW development in Karnataka (%)	Percolation tanks required in prioritized areas for 50% runoff with 2 fillings/ year	Percolation tanks required in prioritized areas for 30% runoff with 3 fillings/ year	Remark
1998	33.06	5200 No.	17182 No.	Estimated by CGWB
2009	70.00	28466 No.	94885 No.	Estimated by DWM based on this research

Project Title	: Groundwater Modeling to Determine the Safe Yield of Coastal Aquifer
Project Code	: DWM/10/146
Funding Agency	: Institute
Project Personnel	: R. R. Sethi, M.J. Kaledhonkar and M. Das

Coastal areas are sensitive to saline water ingression in case of excessive rate of pumping. Hence groundwater pumping from shallow aquifer needs to be monitored in terms of pumping depth, pump size and pump density along the coast line. Though coastal areas of Odisha are not fully affected by salinity as a result of sea water intrusion, still there is need to identify the safe pumping limits in these zones to meet the increasing demand of water due to growing population and agricultural activities. Field studies were carried out to characterize the groundwater table depth fluctuation, change in water quality, aquifer properties for 70 coastal blocks of Odisha. Monthly water budget and groundwater scenarios for these areas have been studied and then on the basis of an analytical approach; optimal groundwater pumping guidelines for these zones were developed.

Water budget and groundwater scenarios for coastal districts

Water budget calculations for 70 coastal blocks from 7 districts i.e Balasore, Bhadrak, Kendrapara, Cuttack, Jajpur, Puri, Jagatsinghpur of Odisha were done by analyzing the monthly rainfall and Potential Evapotranspiration (PET) to know probable use of groundwater for irrigation. Among these coastal districts, Balasore receives highest rainfall of 1887 mm against estimated Potential Evapotranspiration of 1531 mm annually. But maximum rainfall of 1646 mm (87%) is received during monsoon period when evaporative demand is only 479 mm. Rest other months; the district receives 241 mm of rainfall against demand of 1051 mm. In Bhadrak, maximum rainfall of 1182 mm (87%) is received during monsoon period against evaporative demand of 498 mm where as district receives 175 mm of rainfall against demand of 1124 mm during non-monsoon season. Jagatsinghpur receives rainfall of 1538 mm (86%) during monsoon period against evaporative demand of 504 mm whereas, non monsoon rainfall is only 225 mm against demand of 1133 mm. Jajpur district receives maximum rainfall of 1431 mm (88%) against evaporative demand of 504 mm where as non monsoon rainfall is only 184 mm against demand of 1161 mm. Kendrapara district receives maximum rainfall of 1335 mm (84%) during monsoon period when evaporative demand is 499 mm only. Rest other months the district receives 240 mm of rainfall against demand of 1121 mm. Puri district receives maximum rainfall of 1356 mm (87%) during monsoon period when evaporative demand is 504 mm only. Rest other months the district receives 208 mm of rainfall against demand of 1116 mm. Cuttack district receives maximum rainfall of 1638 mm (87%) during monsoon period when evaporative demand is 511 mm only. Rest other months the district receives 236 mm of rainfall against demand of 1171 mm. In all these coastal districts groundwater is being used during non monsoon period i.e. from November to May apart from canal irrigation systems. The probable use of groundwater was further confirmed by understanding block-wise groundwater development. The status of groundwater resources showed that availability of groundwater is also highest in Balasore (75,965 ha.m) followed by Cuttack (67,458 ha.m) and Puri (67,458 ha.m). As per assessment of groundwater resources by Central Ground Water Board (CGWB) and Directorate of Groundwater Survey and Investigation, Bhubaneswar, highest groundwater development is reported in Baliapal (69.96%) followed by Bhogarai (68.39%) of Balasore district, Garadpur (67.96%) block in Kendrapara district. Out of 70 blocks, groundwater development is more than 60% in 9 coastal blocks and requires attention. On comparing the groundwater quality, in Kendrapara districts, out of 9 blocks, 4 blocks are fully affected by salinity whereas more than 50% area is under brackish/saline water. Similarly in Jagatsinghpur districts Ersama block located along the coast line is fully affected by salinity. Thematic mapping of groundwater quality i.e. pH, Electrical conductivity, Sodium, Chloride, Magnesium, Potassium has been prepared to know its spatial distribution along the coast line of Odisha. In this study, 19 blocks of Puri, Jagatsinghpur, Kendrapara, Bhadrak, Balasore districts have been considered which are located within 0-15 km away from the coast line. Groundwater development varied within 14.43 to 69.96% in these blocks of Odisha as shown in Fig. 18. There is a positive co-relation between groundwater development and salinity ingression in the coastal areas; hence groundwater use in these areas needs to be monitored and regulated.

Analytical approach to determine the safe pumping options

Ghyben-Herzberg analytical approach was used to determine the saline fresh water interface. Accordingly, seawater thickness in the aquifer depends on fresh-water thickness. The increase in saltwater thickness is generally amplified by as many as 33 times of fresh

water thickness, depending on the specific weight of the freshwater and the seawater. The distribution of freshwater head along interface is a function of saline water depth and the difference in their respective densities. The depth to the fresh and saltwater interface in a coastal aquifer under steady-state conditions is approximately 33 times the height of the freshwater head above sea level. In a coastal aquifer, freshwater recharge mainly occurs from lateral inflow and forms a lens that floats on top of a base of higher density seawater. Changes in recharge and/or pumping scenario may disturb the hydrostatic equilibrium that it results in the movement of the location of the interface and may also create a transition zone. Development of interface of seawater and freshwater, determination of hydraulic gradient and estimation flow to sea, pumping depth and pumping density have been estimated based on this methodology.

Topographical information of coastal areas of Odisha has been prepared by using Aster Global Digital Elevation Model (ASTER GDEM). DEM and slope map for the coastal tract of Odisha are shown in Fig 19 and 20 respectively. Distribution of elevation data showed that more than 42% of the areas are within 8-11 m above mean sea level. Average depth to water table during pre and post monsoon season for each coastal block has been calculated and then water table elevation map for study area has been prepared. The same was used to determine the hydraulic gradient for each area. Ghyben-Herzberg approach was used for 1 km width strip along groundwater flow direction, stretched from 0-15 km away from the coast line for all the coastal blocks of Odisha. The hydraulic conductivity value was assumed as 20-50m/day for all these blocks on the basis earlier studies of CGWB. The pumping volume and safe pumping depth for Gop, Astaranga and Kakatpur of Puri district; Kujanga, Erasama and Balikuda of Jagatsinghpur district; Ali, Pattamundai, Rajkanika, Rajnagar blocks of Kendrapara; Bhogari, Balasore, Remuna in Balasore and Basudevpur in Bhadrak districts have been estimated based on the analytical approach. Average pumping volume as safe pumping limit, optimal pumping depths from 5 strips of Pattamunadai, Balikuda and Kakatppur are given in Table 25, Table 26 and Table 27 for illustration. Pumping depth in these blocks varied within 7.9 to 11.93 m, 5.81 to 10.76 m and 2 to 6.7 m, respectively. Based on the aquifer properties, it was calculated that small pumps within 1-3 hp should be used for pumping groundwater in these areas. On an average 3-4 number of pumps per square kilometer area could be operated for maximum of 6-7 hours to check the upconing of saline water intrusion. These results are based on analytical modeling for shallow aquifer with limited field observations. However, multi layer unconfined and confined aquifer system, requires detailed data and complex numerical modeling to estimate safe pumping rate and optimal pumping depth.

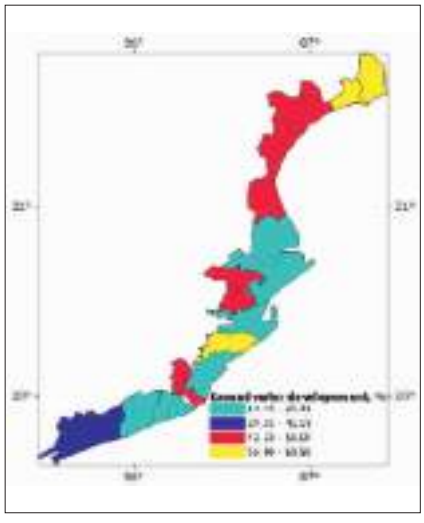


Fig. 18 Groundwater development in costal tract of Odisha

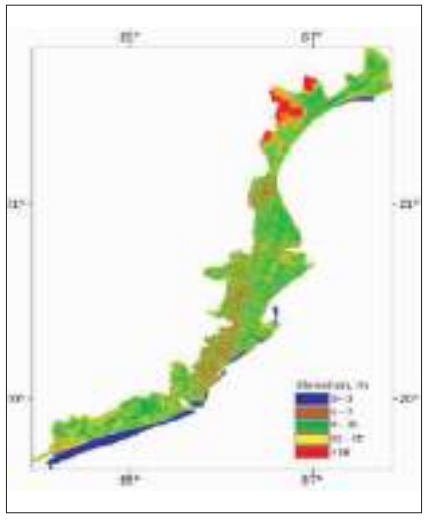


Fig. 19 Digital Elevation Model for coastal tract of Odisha

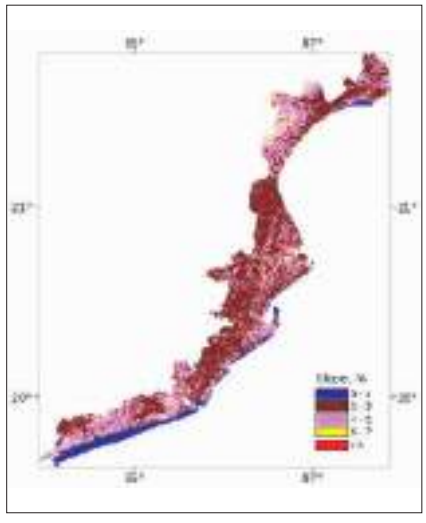


Fig. 20 Slope map of coastal tract of Odisha

Table 25 Estimation of safe pumping options for Pattamundai block of Kendrapara district

Strip No.	Depth to water table depth (m)	Water table elevation(m)	Area of the strip (m^2)	Gradient	Q_{flow} (m^3/day)	$Q_{storage}$ (m^3/day)	Q_{total} (m^3/day)	$Q_{pumping}$ (m^3/day)	Pumping depth (m)
1	1.48	6.53	66550	6.9×10^{-5}	91.84	798.60	890.44	445.22	7.90
2	1.74	7.23	73750	0.0001	210.93	354.00	564.92	282.46	8.73
3	2.33	7.60	77500	0.00023	356.50	651.00	1007.5	503.75	9.42
4	2.39	8.54	84350	0.000293	494.29	1113.4	1607.7	803.86	10.36
5	2.00	9.97	99500	0.0002	420.11	2268.6	2688.7	1344.4	11.73
Avg.	1.99	7.97	80330	0.00019	314.73	1037.1	1351.9	**675.93**	**9.63**
Max	2.39	9.97	99500	0.0003	494.29	2268.6	2688.7	1344.4	11.73
Min	1.48	6.53	66550	6.9×10^{-5}	91.84	354.00	564.92	282.46	7.90
S.D	0.39	1.33			162.44	740.78	837.17	418.58	1.48
C.V	19.49	16.68			51.61	71.43	61.93	61.93	15.41

Table 26 Estimation of safe pumping options for Balikuda block of Jagatsinghpur district

Strip No.	Depth to water table depth (m)	Water table elevation(m)	Area of the strip (m^2)	Gradient	Q_{flow} (m^3/day)	$Q_{storage}$ (m^3/day)	Q_{total} (m^3/day)	$Q_{pumping}$ (m^3/day)	Pumping depth (m)
1	3.09	6.95	62100	8×10^{-5}	74.52	10557	10631.5	5315.76	8.66
2	2.14	5.90	53100	0.00022	175.23	2548.80	2724.03	1362.02	7.07
3	3.11	4.44	41085	0.000125	77.03	6803.68	6880.71	3440.36	5.81
4	2.34	8.71	76725	9.3×10^{-5}	107.03	5616.27	5723.30	2861.65	10.76
5	5.25	6.79	59400	0.0001	99.00	27157.7	27256.7	13628.3	8.85
Avg.	3.19	6.56	58482	0.00013	106.56	10536.7	10643.2	**5321.62**	**8.23**
Max	5.25	8.71	76725	0.00022	175.23	27157.7	27256.7	13628.3	10.76
Min	2.14	4.44	41085	8×10^{-5}	74.52	2548.80	2724.03	1362.02	5.81
S.D	1.23	1.56			40.84	9723.81	9709.31	4854.66	1.88
C.V	38.74	23.81			38.32	92.29	91.23	91.23	22.86

Table 27 Estimation of safe pumping options for Kakatpur block of Puri district

Strip No.	Depth to water table depth (m)	Water table elevation(m)	Area of the strip (m^2)	Gradient	Q_{flow} (m^3/day)	$Q_{storage}$ (m^3/day)	Q_{total} (m^3/day)	$Q_{pumping}$ (m^3/day)	Pumping depth (m)
1	2.37	0.64	5950	9.9×10^{-5}	14.73	736.72	751.44	375.72	2.02
2	1.98	2.02	22500	7×10^{-5}	39.37	2913.55	2952.92	1476.46	2.97
3	1.80	3.17	35150	9.7×10^{-5}	85.24	4079.96	4165.20	2082.60	4.08
4	1.20	4.82	48850	6.1×10^{-5}	74.50	5579.56	5654.05	2827.03	5.05
5	1.11	5.90	58900	0.0001	153.79	2962.13	3115.93	1557.96	6.63
Avg.	1.69	3.31	34270	8.6×10^{-5}	73.53	3254.38	3327.91	**1663.95**	**4.15**
Max	2.37	5.90	58900	0.0001	153.79	5579.56	5654.05	2827.03	6.63
Min	1.11	0.64	5950	6.1×10^{-5}	14.73	736.72	751.44	375.72	2.02
S.D	2.37	0.64			14.73	736.72	751.44	375.72	2.02
C.V	1.98	2.02			39.37	2913.55	2952.92	1476.46	2.97

Project Title : Impact of Wastewater Use on Soil Properties and Its Prospect of Utilization in Crop Production

Project Code : DWM/11/152

Funding Agency : Institute

Project Personnel : M. Das, O. P. Verma and A. K. Nayak

Impact of United breweries (UB) wastewaters on various soil types

Data pertaining to important soil characteristics given in Table 28 reflect that the soils were acidic to neutral in reaction, low in available N, P, and organic carbon but high in Fe and Mn content.

The soils were packed at the rate of their corresponding bulk density in cylinder (25 cm length and 11.4 cm diameter) up to 17 cm length (volume 1765.77 cm^3) and leaching process was started with slightly alkaline Na and bicarbonate rich UB effluent water at constant head method for all the three soils. The process was continued till to get constant pH value of the leachate for each soil type. Leachate collected both from untreated and treated effluent of UB, from different soil types at equilibrium (Table 29) revealed that the pH was in the range of 8.04 to 8.5 with maximum Na and bicarbonate concentration was registered against alluvial soil followed by red and yellow and red and lateritic soil type. It was also found that K, Ca, Mg, P and N at different proportions varied with nature of soil and effluent type.

In terms of increasing pH, Na and bicarbonate concentration in leachate the untreated effluent water of UB was found relatively less suitable over treated effluent water for all soil types.

Post leached soils also showed a rise in pH at the range of 22 to 57% over its respective initial pH at equilibrium (Fig. 21). High pH (8.96 and 8.89) under treated and untreated UB – effluent water was obtained against alluvial among three soil types. A built – up of available N in a tune of 2.5 to 6.7 times, available P (2 to 16 times), organic carbon (1.3 to 1.7 times) and K, Ca, Mg and micronutrients at different proportions in soils were also recorded. In terms of producing impact on relevant soil parameters the impact of untreated and treated UB effluent was at par while influencing soil pH and allied parameters treated UB effluent water can be suitably used as supplementary irrigation for crops.

Influence soil type on leachate quality under Distillery effluent application at varied concentration

Leaching with distillery effluent of Sakthi Sugars Ltd, (E) at different concentrations prepared by mixing with different proportions of water (W) @ 20 E: 80W, 40 E: 60W and 60 E: 40W by following constant head method, showed a gradual increase of salinity of leachate collected over time. The increase was however not consistent with amount of effluent used and soil types. After the equilibrium reached with effluent concentration treatments the soil column was started to leach with water (W) and the leachate was collected till it reached a constant salinity (EC) value. Data pertaining

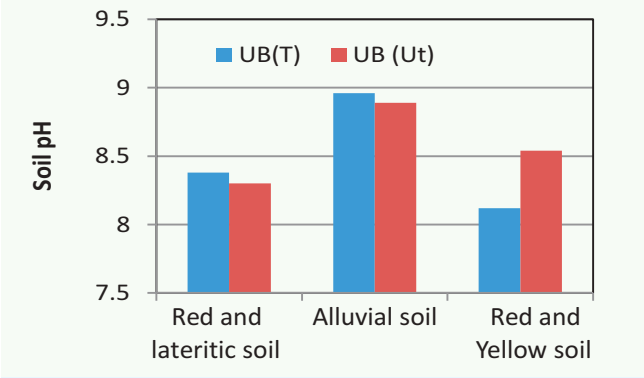
Table 28 Important physico-chemical parameters of different soil types

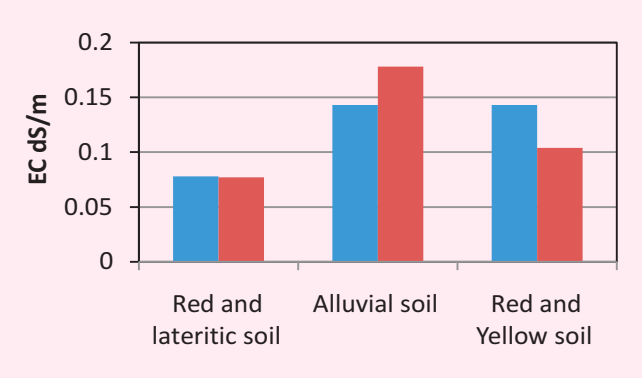
Parameter	Red and Lateritic soil	Alluvial soil	Red and yellow soil
Bulk Density (gm/cm^3)	1.6	1.5	1.15
Saturated Hydraulic Conductivity (cm/min)	0.125	0.177	0.442
pH (1:2.5)	6.45	7.3	5.42
Organic carbon (%)	0.252	0.307	0.196
Available nitrogen (%)	0.022	0.051	0.012
Available P (mg/kg)	6.45	9.65	11.43
CEC (meq/100g)	21.44	29.71	32.41
Na (meq/100gm)	4.19	5.15	13.12
K (meq/100gm)	6.5	4.18	1.7
Ca (meq/100gm)	3.02	2.41	2.241
Mg (meq/100gm)	5.43	1.81	2.068
Zn (mg/Kg)	2.244	4.794	3.494
Cu (mg/Kg)	4.35	1.25	1.56
Fe (mg/Kg)	14.004	58.504	25.584
Mn (mg/Kg)	86.298	53.848	178.156

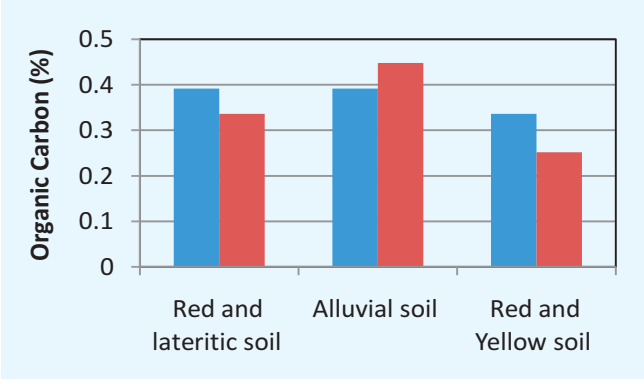
Table 29 Important properties of leachate at equilibrium with UB effluent water in different soils

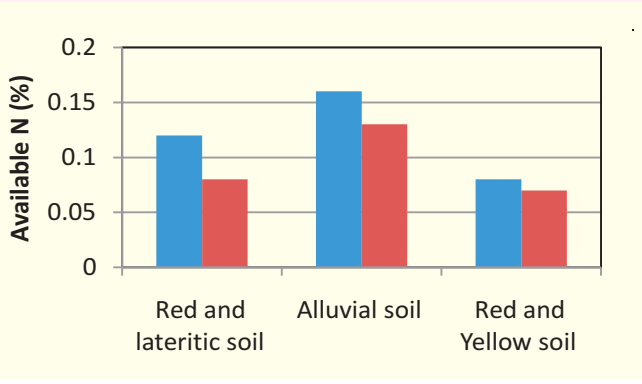
Parameters of the UB effluent water at equilibrium	Red and lateritic soil		Alluvial soil		Red and yellow soil	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
pH	8.45	8.21	8.51	8.04	8.65	8.5
EC dS/m	1.3	1.5	1.8	1.8	1.5	1.2
Na meq/L	8.55	8.39	12.71	13.04	12.2	10.37
K meq/L	0.43	0.63	0.26	0.31	0.05	0.05
Ca meq/L	0.34	0.34	0.34	0.34	0.17	0
Mg meq/L	1.38	2.75	2.41	2.78	2.06	1.72
Fe mg/L	2	2	1.6	1.6	2	2
Cl meq/L	10.23	10.26	17.6	11.73	8.8	5.86
Sulfate meq/L	0.74	0.62	0.21	0.21	0.31	0.31
Bicarbonate meq/l	10.23	10.26	17.6	11.73	8.80	5.86
Nitrate meq/L	0.03	0.062	0.06	0.03	0.062	0.062
P mg/L	0	0	0.065	0.004	0.017	0.002
Total dissolved solids gm/L	0.8	0.8	0.4	0.4	0.8	0.8
Organic Carbon gm/L	0	0	0.2	0.14	0	0
Colour× 10^3 HU	-	0.156	0.249	0.242	-	-

to salinity of input solution and leachate solutions in Table 30 reveal that the salinity of leachate at equilibrium was significantly differed with the EC of input solutions and across the soil types. Leachate collected from red and lateritic soil was relatively less saline at 40E: 60W and 60E: 40W over the leachate collected from other two soil types. Leachate collected with water from red and lateritic soil also registered a low EC value ranged from 1.0 to 2.3 dS m^{-1} compared to alluvial, and red and yellow soil types. The pattern of salinity development and reduction in leachate showed a distinct variation with soil types. Irrespective of effluent concentrations, the release of salt was relatively stagnant over red and lateritic, and red and yellow soil









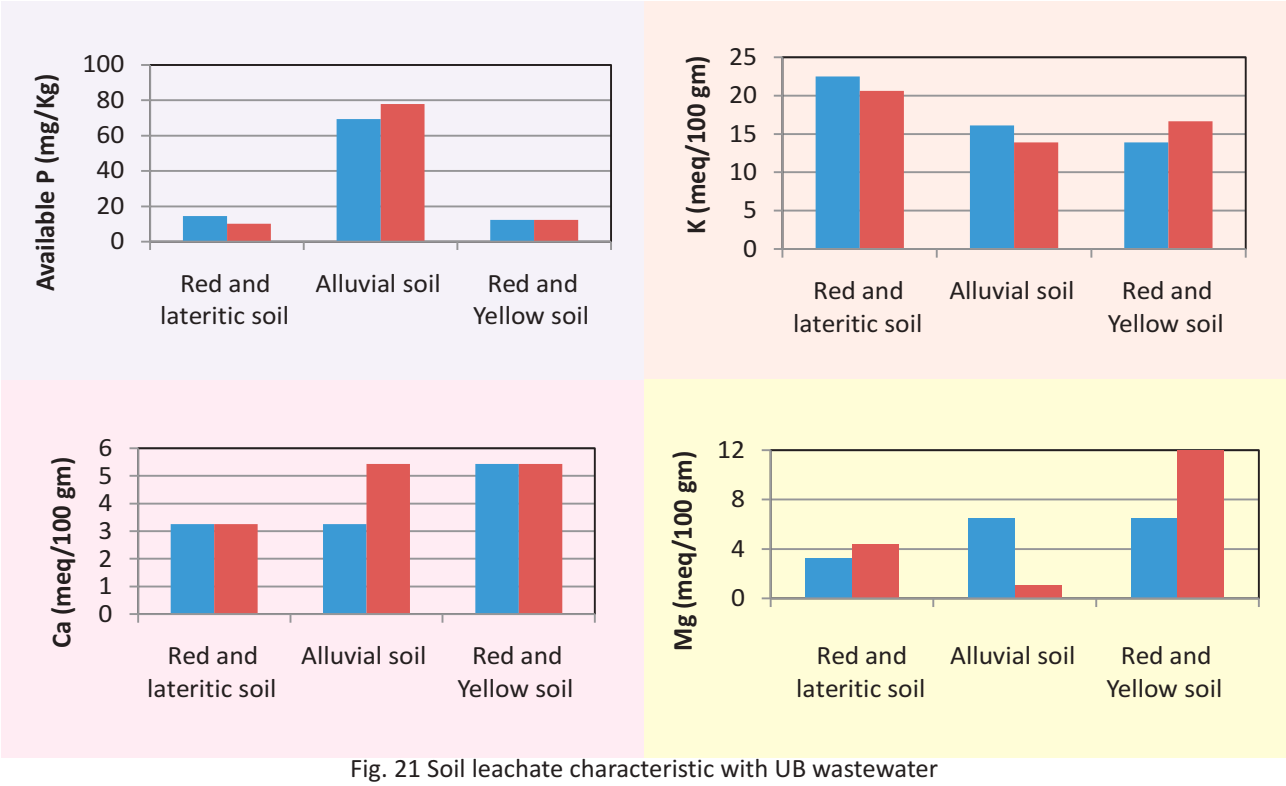


Fig. 21 Soil leachate characteristic with UB wastewater

types. No persistent salinity build up was observed even at higher concentration of distillery effluent 60E:40W application except in alluvial soil, thus the effluent up to 60 E: 40W could be suitably used for irrigating red and lateritic, and red and yellow soil types.

Table 30 Salinity (EC dS/m) of leaching solutions and at equilibrium in different soil types

Type of leaching solutions	Initial EC ± 0.2 dS/m	Red and lateritic soil At equilibrium		Alluvial soil At equilibrium		Red and yellow soil At equilibrium	
		Effluent	Water	Effluent	Water	Effluent	Water
20E : 80W	5.6	4.8	1.0	4.3	0.1	4.5	0.8
40E : 60W	9.4	6.8	2.0	7.0	1.1	6.6	1.1
60E : 40W	12.3	8.0	2.3	8.5	4.5	9.8	1..5

Project Title : Suitability of the Available Poor Quality Water Resources for Agricultural Uses under Different Agroclimatic Region

Project Code : WTCER/08/135

Funding Agency : Institute

Project Personnel : M Raychaudhuri, S. Raychaudhuri, S. K. Jena and A. Kumar

The seasonal variation in the chemical characteristics of surface water (Daya River) and groundwater along Daya River was studied.

Seasonal variation in surface and ground water quality characteristics

The seasonal variation in the chemical characteristics of surface water (Daya River) and groundwater along Daya River was studied. Various chemical characteristics viz., pH, EC, TDS, cations viz., Na^{+}, K^{+}, Ca^{++}, Mg^{++}, NH_4-N, anions viz. NO_3-N, PO_4-P, SO_4, CO_3, HCO_3, Cl, alkalinity, hardness were assessed for a period of 12 months from January to December 2012 at 20 sites of River Daya where lift points are there for irrigation. Temporal variation was observed in river and ground water from upstream to downstream. The pH of river and groundwater water showed significant variation month wise (Fig 22 and 23). The pre-monsoon and post monsoon pH varied widely in river water than in groundwater. This is mainly because of the anthropogenic effect throughout the year. The results depict that the mean minimum pH was recorded in the month of August for

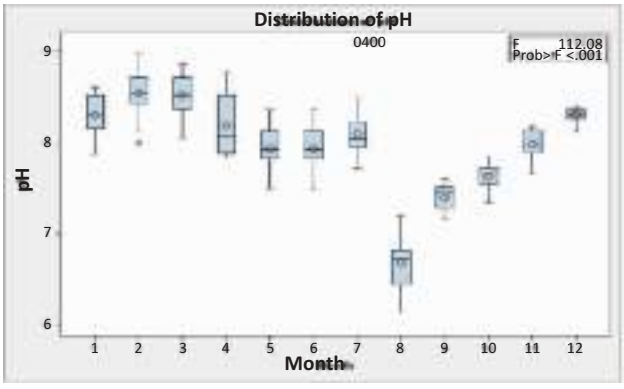


Fig. 22 Seasonal variation in pH of River water

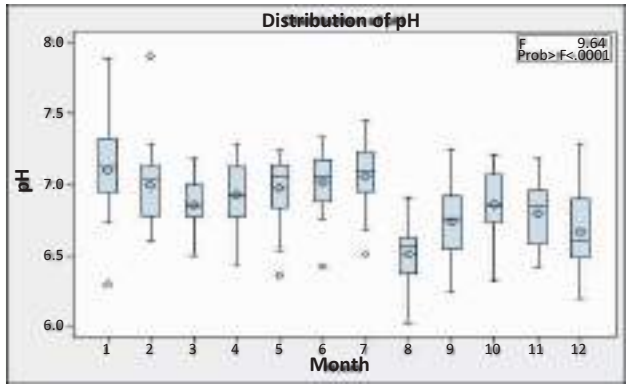


Fig. 23 Seasonal variation in pH of Groundwater

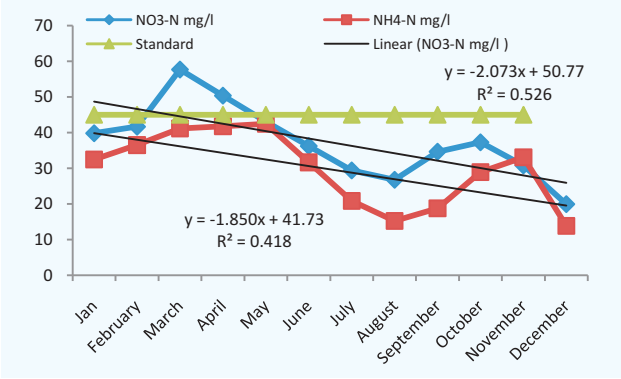


Fig. 24 Variation in NH4-N and NO3-N in River wate over the months in a year 2012

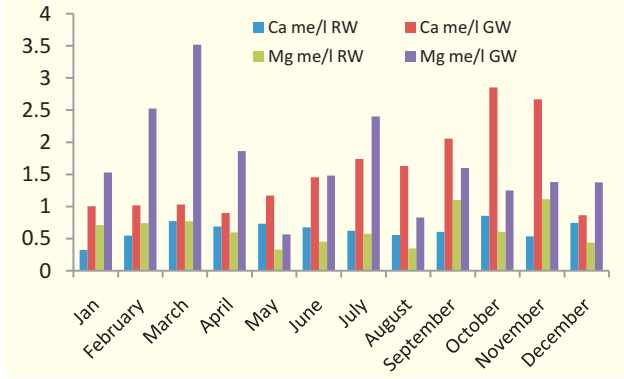


Fig. 25 Variation in Ca and Mg content in River water and ground water over the months in a year 2012

both water and the mean maximum pH was recorded in the month of February for both the water. The NH_4-N and NO_3-N content in both the water varied over the months (Fig. 24). The Ca and Mg content in both water varied widely over the months (Fig. 25). It has been observed that Mg hardness increases during the pre monsoon season in both type of water. The N content was found higher in both the water during pre-monsoon season and lower in the pre-monsoon season.

Removal of Iron using Coconut Shell Charcoal (CSC)

Ground water is an important source of agriculture in irrigated commands to adapt the climatic aberrations in kharif season and to meet the life saving irrigation in rabi and summer crops. It is also an important source of drinking water in both urban and rural India. Iron contamination is a common problem especially in rural ground water in India and is dominant in the states of Tamilnadu, Karnataka, Odisha, and Maharashtra. In Odisha iron contamination is reported in Angul, Nayagarh, Jagatsinghpur, Jajpur, Kendrapada, Puri, Khurda districts. The ground water quality assessed along 20 km stretch of Daya River contained Fe beyond the permissible limit of 0.3 ppm (BIS 1991) ranging from 0.321 to 7.01 ppm with a mean of 2.65 ppm.

Several methods to remove iron are oxidation by aeration, oxidation with chlorine and ozone, oxidation with hydrogen peroxide, biological iron removal, ion exchange (zeolite softening), stabilization or sequestering process(with poly phosphate & silicates),lime softening /lime stone bed filtration, manganese green sand process, in-situ oxidation, and membrane process. Moreover these technologies are sophisticated and only successful on commercial basis. Therefore, an attempt has been made to use coconut shell to remove iron in an economical and eco-friendly way. Coconut shell charcoal (CSC) was produced by biochar method, then ground and sieved through 60 meshes. Batch test was conducted at different concentrations of Fe in water with varying doses of CSC to determine the adsorption isotherm, adsorptive capacity and its usage based on Frendlich adsorption isotherm. Fe in the solution was estimated directly using AAS. CSC used to remove excess iron from water for potable and irrigation were found effective and dependable. The relationship between the amount of Carbon Source (CS) required to remove iron from any known Fe source to the desired level hold good which is

depicted from the high R^2 and the following equations (Table 31) were derived to determine the amount of carbon source required to remove excess iron from any known concentration of iron impurity. The amount of CSC (g/l) required to remove iron from the groundwater assessed from the villages along Daya River are presented in Table 32.

Table 31 Relationship to determine the CS amount to remove Fe from excess to desired level

Source	Within the permissible limit < 0.3 mg/l	0.3 mg/l	1.0 mg/l	5.0 mg/l
CSC	$y = 2.9x + 1.8$ ($R^2 = 0.981$)	$y = 2.84x + 1.5$ ($R^2 = 0.984$)	$y = 2.74x + 0.74$ ($R^2 = 0.981$)	$y = 1.75x + 4.5$ ($R^2 = 0.999$)

Where y stands for CS in g/l and x the concentration in mg/l of Fe in water to be treated

Table 32 Amount of CSC (g/l) required to maintain the Fe concentration (mg/l) in the desired level of 0.3mg/l (BIS potable), 1.0 mg/l (WHO potable) and 5.0 mg/l (BIS irrigation)

Village Sites	Fe (mg/l) present	Desired concentration of Fe		
		0.3 mg/l	1.0 mg/l	5.0 mg/l
	GW	GW	GW	GW
Lingipur WS	5.43	15.6	16.92	14.00
Lingipur	6.26	17.9	19.29	15.46
Sardaipur	0.321	1.62	2.41	-
Nuagaon	0.346	1.69	2.48	-
Nathpur	2.38	7.27	8.27	-
Dihapur	0.842	3.05	3.89	-
Bikipur	1.33	4.39	5.28	-
Jaypur	7.01	19.95	21.41	16.77
Jaypur Patna	2.41	7.34	8.34	-
Itipur	3.32	9.83	10.92	-
Palashpur Sashan	3.47	10.24	11.35	-
Tikarpara	5.09	14.69	15.96	13.41
Gangeshwarpur Sashan	0.824	2.99	3.84	-
Kalyanpur Sashan	0.579	2.33	3.15	-
Suabarri	1.12	3.82	4.69	-
Arjungadh	0.433	1.93	2.73	-
Poparanga	0.702	2.66	3.49	-
Raghunathpur	1.77	5.59	6.54	7.60
Vindhyagarh	1.21	4.05	4.93	-
Dakshin Nayagarh	1.22	4.07	4.95	-

Project Title : Georeferenced Soil Information System for Land Use Planning and Monitoring Soil and Land Quality for Agriculture

Funding Agency : NAIP, ICAR, New Delhi

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

Under the project the physical and hydraulic properties were assessed for the georeferenced sampling sites of both Indo-Gangetic Plain (IGP) and Black Soil Region (BSR) Region and it constituted a total of 345 soil samples from 67 soil profiles.

IGP: The Field capacity (FC) and permanent wilting point (PWP) of IGP soils (162 nos) showed significant negative correlation with sand and positive correlation with slit and clay content. Saturated hydraulic conductivity showed significant positive correlation with sand and significant negative correlation with silt and clay content. It also showed significant negative correlation with FC, PWP and AWC. The soil moisture characteristics revealed that Ks maintained significant negative correlation with available moisture content at different pressure heads. Pedotransfer functions (PTFs)

were developed to estimate Ks from particle size distribution and moisture characteristics of the IGP soils through multiple regression models. The particle size distribution viz., clay, silt, organic carbon and BD significantly contribute towards Ks and the expression holds good for estimation of Ks. Pedotransfer function of IGP soils is given below:

Ks = 8.205 - 0.066 Silt (%) - 0.038 Clay (%) + 1.11 OC (%) - 2.995 BD (g/cc)

To refine the multiple regression model, IGP soils were classified as arid, semiarid, sub humid and humid areas according to their bio-climates and the following PTFs were developed:

Arid: Ks = -1.96 + 0.069 Silt (%) + 0.021 Sand (%)+ 2.27 OC (%)

Semi Arid: Ks = - 0.195 + 0.193 OC (%) + 0.007 FC (%) - 0.00631 PWP (%)

Humid: Ks = 2.363 - 0.01991 Silt (%) - 0.0123 Clay (%) - 0.02 FC (%)

SubHumid: Ks = 7.83 - 0.174 Silt (%) + 1.26 OC (%) - 0.084 FC (%)

BSR: The FC and PWP of BSR soils (236 nos) showed significant negative correlation with sand and significant positive correlation with clay and silt content. AWC also showed a significant positive correlation with silt and clay and negative correlation with sand content. Ks showed significant positive correlation with sand content and negative correlation with silt and clay content, FC, PWP and variable moisture content characteristics at different pressure heads. It also showed negative correlation with bulk density of the soil. Pedotransfer relations were developed for Ks with particle size distribution and moisture characteristics of the BSR soils through multiple regression models. It has been observed that unlike IGP soils the contribution of FC, PWP and AWC towards Ks is significant in these soils along with clay, silt, organic carbon and BD. Pedotransfer relations of BSR soil horizons are given below:

Ks = 2.981 - 0.025 Silt (%)- 0.028 Clay(%) -0.022 BD (g/cc)

PTFs for BSR Soils under different Bioclomates are as follows:

Arid: Ks = 4.090 - 0.048 Silt (%) - 0.047 Clay (%)

Semi Arid: Ks= 1.623 - 0.015 Silt (%) - 0.04 clay (%) + 0.113 OC (%) - 0.253 BD (g/cc) + 0.017 FC(%) - 0.021 PWP(%)

SubHumid: Ks = 1.798 - 0.024 Silt (%) - 0.023 Clay (%) + 0.058 OC(%) + 0.186BD (gm/cc)

SubHumid Moist: Ks = 0.706 + 0.006 Silt (%) - 0.002 Clay (%) + 0.1001 OC (%) - 0.178 BD (gm/cc) -0.003FC (%)- 0.006PWP (%)

It was observed that under arid, semiarid, and subhumid condition silt, and clay contribute significantly to Ks but under humid moist condition FC and PWP also contribute significantly.

Project Title	: Groundwater Extraction Mechanisms and Pump Irrigation Markets in Mahanadi Basin
Project Code	: WTCER/07/129
Funding Agency	: Institute
Project Personnel	: M.K. Sinha, K.G. Mandal, and S. Mohanty

Sample based study was conducted to assess the, economics and impacts of irrigation markets on farm economy. Multi-stage purposive sampling method was used to select the sample village and the ultimate farmers. A cluster of three villages from Salepur and Sadar Block of Cuttack district were identified as sample village. Primary data were collected by personal interview methods by interacting sample household. A sum total of 116 samples were analyzed for the study, where 55 were the bore well owners and 61 farmers were not the owner. Further, samples were classified based on size of holding as marginal, small, semi medium and medium farmer. There were no large farmers found among the sample villages. Different water user groups as self users, self user + seller, self users +buyers and buyers were also identified across the villages.

The sample household reveals that small and marginal farmers were found to dominate the agrarian structure in this region. The structure of market was found to be informal, based on informal contract enforcement. Average operated farm size was 1.45 ha and 88 percent was under irrigation in sample villages. Buyers were the dominant participant (53%) in the water market and 93.47% of marginal farmers and 31.11% of small farmers were found to be water buyers. The availability of groundwater market provided these resource-poor farmers an easy access to irrigation water. Most of the semi-medium and medium farmers (69.56%) belong to self-users + sellers category followed by small farmers (48.89%). It explicitly illustrates that the number of water buyers decreased as the size of farm increased, while the number of sellers increased with the size of the farm. Thus, sizes of farm holding were important determinants to classify them as buyers and sellers.

Table 33 Cost of water extraction and return from water selling (Rs./hr)

Component	System A (2HP)	System B (3.5 HP)	System C (5 HP)	Overall Average
Cost of water extraction				
A.Fixed cost*	12.69	13.44	13.11	13.08
B.Operating cost**	30.00	50.00	70.00	50.00
C.Total cost	42.69	63.44	83.11	63.08
Average selling Price	50.00	75.00	100.00	75.00
Net Income				
A. Over operating cost	20.00	25.00	30.00	25.00
B. Over total cost	7.31	11.56	16.89	11.92

Figures within the parentheses are the percentage of the total cost; *included depreciation and interest on fixed investment of pump sets, installation and conveyance; **maintenance and fuel cost included

Buyers were the resource poor farmers in majority. In the sample villages, only 31.83% of the groundwater extracted goes to buyer's field. And among beneficiary, 34% are the marginal farmer, 37% are the small farmer and 25% are the semi-medium farmer.

The cost of irrigation water was estimated after considering the fixed costs of tube well installation as well as variable costs in running the tube well. As the majority of sample farmer availed subsidy on the pump set, therefore, cost was imputed on subsidized pump set. On an average, per hour cost of irrigation water was estimated to be Rs 63.08, with Rs 13.08 as fixed expenses and Rs 50.00 as variable expenses (Table 33). The per hour irrigation costs varying from Rs. 42.69 to Rs.83.11 based upon the engine capacity of different farm-size holders. It was further observed that the per hour fixed irrigation cost were within the range of Rs. 12.69 to Rs. 13.11. On an average, per hour variable irrigation cost worked out to be Rs 30-70 mainly as the fuel charges.

The amortized average total cost of water extraction was worked out to be Rs 63.08 per hour in the region. The per hour average selling price was found to be Rs 75.00, which were substantially higher than the corresponding operational cost as well as the total cost of water extraction. This implied that groundwater markets were exploitative in nature for the buyers of water. Most of the buyers were farmers with small landholdings and they had limited livelihood options. Therefore, they had to participate in water trading on the existing terms and conditions for their assured employment opportunities and food security. Sellers of water earned a net profit of Rs 11.92 per hour over the total cost and Rs 25.00 per hour over the total operational cost of water extraction, making selling of water was a remunerative business economically for the sellers of water. Further, the unit cost of pumped groundwater decreases with the number of hour of running. The average cost of pumped groundwater decreases from Rs. 2.75/m^3 at 200 hrs running to Rs. 2.06/m^3 for 600 hrs running. This is due to the fact that with increasing hour of running, the fixed cost per unit of pumped water reduces. The cost of pumped groundwater in different systems with number of hour of running has been shown in graphical form in Fig. 26 .

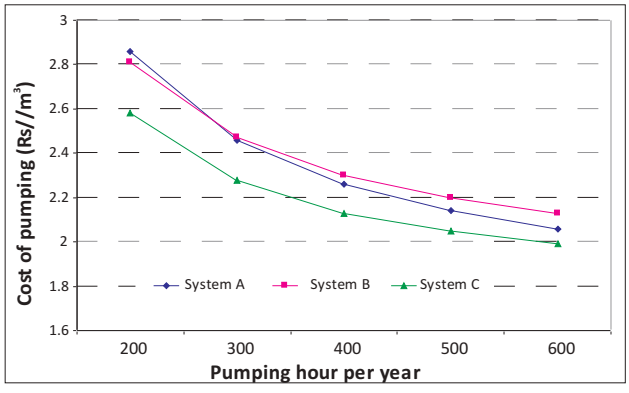


Fig. 26 Variation of cost of pumped groundwater with pumping hour per year

Cropping intensities across different categories of farmers reveals that cropping intensity among the smaller farmers is better than the large groups of farmers. Marginal farmer recorded better cropping intensity (169%) compared to small and medium farmers. Though this can be attributed to small size holding (average 0.57 ha), where they use all managerial skill for their livelihood. Even small acreage improves, it will reflect in form of intensities. The cropping intensity across different water user groups, the buyers groups performed better with 176 % compared to 133% and 143% of self user and sellers.

The study also reveals that seller gets a significant amount as rent of the pump irrigation apart from the fuel cost. The margin of renting amount of pump varies from Rs. 20.00 to Rs. 25.00 for 2 hp pump, Rs. 25.00 to

Rs. 30.00 for 3.5 hp pump, and Rs. 30.00 to Rs. 35.00 for 5 hp pump. A minimum hour of running or renting of the pump per year is required to get back the annual fixed cost of the system. The survey of the farmers indicates that the average working hours of the pump per year varies from 211 to 349 hrs., which is more than the minimum running hours of the pump. Therefore, groundwater marketing is profitable in the existing field scenario of the study area.

Project Title	: Groundwater Development and Energy Use Dynamics for Irrigation in Odisha
Project Code	: DWM/11/149
Funding Agency	: Institute
Project Personnel	: S.K. Srivastava, R.R. Sethi, A. Kumar and A.K. Nayak

Spatial variations and trend in groundwater table depth

To study the spatial variations in groundwater table depth, administrative districts of Odisha were classified into three distinct clusters using k-means cluster analysis on the basis of groundwater development, discharge, draw-down, water table fluctuation and electrified villages (Fig. 27).

The average water table depth in Odisha during pre-monsoon season is 6 meter below ground level (bgl) and varies from -1.11 meter to 28.14 meter in 2009 (Table 34). However, the average groundwater table depth in post-monsoon season increases upto 3.39 meter and varies from -0.73 to 23.87 meter. Among the clusters, water table depth in cluster2 (coastal/alluvial belt) is comparatively higher than cluster1 and cluster3 in both the seasons. Further, results of the time series regression analysis, to capture the trend in groundwater table depth, showed that average water table in cluster1 witnessed a declining trend in pre as well as post monsoon seasons during 1997 to 2009. The estimated coefficients indicated that average water table in the cluster1 declined at the rate of 8 cm and 5 cm per annum in pre and post monsoon season, respectively during the period under consideration. Contrary to it, average water table in cluster2 (coastal/alluvial areas) witnessed an increasing trend at the rate of 9 cm and 6 cm per annum during the same period. In cluster3, trend in water table was not found to be statistically significant. It is to be noted that average water table depth at cluster level give macro level scenario. Therefore, trend in water table was further examined at disaggregated (block level) in both pre-monsoon period. The results showed that in 140 blocks (45% of the total blocks), there was no significant change in water level in pre-monsoon season during 1997 to 2009 (Fig. 28). In 92 (30% of the total blocks), water table was found to be increased. This indicated the scope for accelerating groundwater utilization in the blocks with no change/increase (232 blocks) in water table during the period under consideration. On the other hand, in 77 blocks (25% of total blocks), water table witnessed declining trend in pre-monsoon season during 1997-2009. This necessitates implementation of groundwater recharge activities in these 77 blocks to ensure sustainable development of groundwater in the state.

Fig. 27 Classification of districts using k-mean cluster analysis

Cluster-wise diagnosis of IPC revealed the creation of irrigation potential is largely affected by the type of groundwater structures. With only 13 % of the total geographical area, 19 % of agricultural land, 24 % of groundwater resources and 16 % of groundwater structures of the state, cluster2 constituted about 52 % (2.88 thousand ha) of the total IPC of Odisha in 2006-07. This is primarily because of dominance of shallow and deep tubewells in this region which has larger irrigation

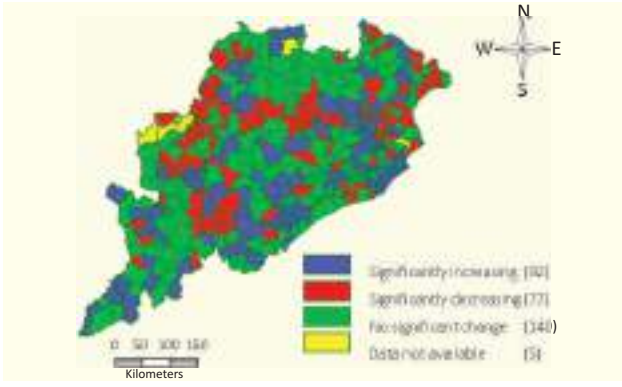


Fig. 28 Block-wise trend in water table in pre-monsoon season during 1997-2009 Inter-cluster variations in groundwater irrigation potential created (IPC) and its utilization (IPU)

Table 34 Cluster-wise trend in water table and aquifer properties in Odisha

Particulars	Cluster1	Cluster2	Cluster3	Odisha
	Water level (meter) in 2009#			
Pre-monsoon	6.13(-1.11 to 28.14)	5.03(-0.50 to 15.25)	6.39(-0.95 to 18.92)	6.02(-1.11 to 28.14)
Post-monsoon	3.63(0.02 to 23.87)	2.73(-0.45 to 11.15)	3.57(-0.73 to 15.55)	3.39(-0.73 to 23.87)
	Trend (decline/increase/no) during 1997-2009$			
Pre-monsoon	-0.089**	0.095***	0.007	0.009
	(0.034)	(0.020)	(0.020)	(0.018)
Post monsoon	-0.057*	0.068***	0.009	0.009
	(0.033)	(0.019)	(0.026)	(0.023)

#Figures within parentheses are minimum and maximum value of water table
$ figures within parentheses are standard error of the estimated regression parameter (time)
*** significant at 1% level of significance, ** significant at 5% level of significance, * significant at 10% level of significance

command area as compared to dugwells. Cluster1 and cluster3 constituted about 4 % and 44 % of the total IPC of Odisha in 2006-07, respectively. In these clusters, dugwells were the predominating structures which constituted about 75 % of the total IPC in the respective cluster. Although cluster2 constituted highest share in total IPC of the state, it exhibited least (30.44%) utilization of already created potential as compared to other clusters in 2006-07. In cluster1 and cluster3, utilization of IPC was 45 % and 41 % in 2006-07, respectively with the declining trend over the years. The poor utilization of the already created irrigation potential leads to loss of financial resources in one hand and loss of opportunity to improve agricultural productivity and income through advantages of assured irrigation on the other. Non-functioning of the wells was the predominant reason for poor utilization of created potential. These non-functional wells can be targeted and repaired to improve irrigation infrastructure in the state which would involve much less investment than creating new infrastructure.

Inter-cluster variation in energy use for irrigation

The total energy consumption for groundwater irrigation (Mjoule/annum) was estimated as 7.37×10^8 M Joule/annum in Odisha, 55 % (4.08×10^8 M Joule/annum) of which was consumed in cluster2. The largest share of cluster2 in total energy consumption was due to dominance of energy intensive shallow wells (64 % of the total groundwater structures) constituting about 90 % of the total energy consumption in the region. Cluster1 and cluster3 consumed 4 % and 41 % of the total energy consumed, respectively with dugwells (man/animal) predominating contributor among the groundwater structures. The inter-cluster variation in composition of groundwater structures also influenced sources of energy used for groundwater extraction. In cluster1 and cluster3, 'man/animal' power was major source of energy (constituting 69% and 49%, respectively) as 88 % and 77 % of the total groundwater structures used this energy, respectively. On the other hand, in cluster2, 'diesel' was the major energy source (constituted 56% of the total energy consumed in the region) as 48 % of total functional groundwater structures and particularly 59 % of the predominant shallow wells were operated using 'diesel' energy. The 'diesel' energy was followed by the 'electricity' (constituted 42% of total energy consumed in the region) in-spite of technological superiority and cheap operational and maintenance of electric pumps over diesel pumps. The farmers are forced to use diesel operated pumps due to poor power infrastructure and unreliable electricity supply for irrigation purpose.

In Odisha, only 1.3% of the total electricity consumption was consumed for irrigation /agriculture purpose compared to national average of 20.97 % in 2008-09. Moreover, electricity consumption in agriculture sector showed a declining trend both in terms of absolute units (from 305 million units to 155 million units) as well as its share in total electricity consumption (5.6 % to 1.3%) between 1992-93 and 2008-09. Further, estimated electricity consumption for groundwater pumping constituted 57 % (74 million units or kilowatt hours) of the total power consumption in agricultural and allied sectors (130 million units or kilowatt hours) in the state for the base year 2006-07.

Economics of groundwater irrigation in Odisha

The estimated cost of groundwater extraction (Rs/m^3) was significantly higher in cluster1 and cluster3 (hard rock areas) as compared to cluster2 (alluvial/coastal belt) due to comparatively higher digging cost, higher head and less discharge in these areas. Further, the groundwater extraction cost (Rs/m^3) was significantly higher in diesel operated pumps as compared to electric operated pumps. Significantly higher cost of groundwater extraction in diesel operated pumps (than electric pump) was due to higher share of diesel in total irrigation cost than electricity. Therefore, the impact of a unit increase in energy cost, a common phenomenon now days, on total irrigation cost will be much less in electric operated wells than diesel pumps. Presently, for irrigation/agriculture sector, being a special category both from political and social ground, the Government is providing diesel (Rs. 10.97 subsidy on February, 2012) as well as electricity (298.87 paise per unit subsidy in 2011-12) at subsidized rate. The increase in electricity tariff will not only reduce the subsidy burden on Government exchequer but also bring about efficiency in use of groundwater resources due to positive marginal cost of the pumping. The estimated groundwater extraction cost the estimated cost of groundwater extraction with the increased electricity tariff rate (327 paise per unit for assessment year 2011-12) was lesser (30% to 135% in cluster1, 117% to 207% in cluster2 and 30% to 149% in cluster3 depending upon type of wells) than subsidized diesel operated wells. Hence, the farmers with the diesel pump will naturally be shifting to electric pumps provided assured and quality electricity supply is guaranteed. Additionally, if conducive product disposal infrastructure (marketing, processing, cold storage, etc) is provided, the assured irrigation will also motivate the farmers to diversify towards high value crops such as vegetables, floriculture, etc which will accelerate the overall agricultural growth in the state. It is worth noting that above mentioned benefits of electricity based irrigation rest on the provision of assured and quality power supply and development of favourable marketing infrastructure in the state. The part of the investment in developing power and marketing infrastructure can be made through the increase in power tariff and the removal of estimated annual subsidy per well. Therefore, in the Odisha state, which is pioneer in electricity reforms in the country, there is ample opportunity to harness the potential of groundwater resources through suitable energy regulations for accelerated agricultural growth.

Waterlogged Area Management

- Assessment of waterlogging and land use system in different coastal districts of Odisha using remote sensing and GIS.
- Crop management interventions and contingency crop planning for post flood management in Odisha
- Assessment and development of water resources for diversified agriculture in waterlogged high rainfall area
- Growth and production physiology of cat tail (Typha) under waterlogged condition
- Characterization and Utilization of Sewage Water of Urban/Peri-Urban areas for Agricultural purposes

Project Title : Assessment of Waterlogging and Land Use System in Different Coastal Districts of Odisha using Remote Sensing and GIS

Project Code : DWM/10/148

Funding Agency : Institute

Project Personnel : A.K. Nayak and G. Kar

The study was conducted to assess the waterlogged area and crop loss in costal blocks of Odisha using GIS and remote sensing. The IRS LISS-III Satellite data and Land use map, geomorphology map (IRS 1C/1D, 2002-03) were collected from Orissa Remote Sensing Application Centre, Bhubaneswar to use in the study. The waterlogged areas obtained by different methods (PCA and R31) for different coastal Blocks of Jagatsinghpur. The waterlogged areas were divided into i) severely waterlogged area and ii) slightly waterlogged

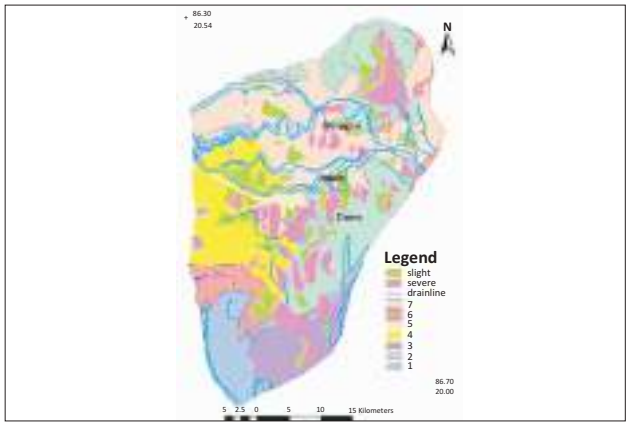


Fig. 29 Map showing severe and slight waterlogged areas, drainages and different soil series (1-7) of the study area

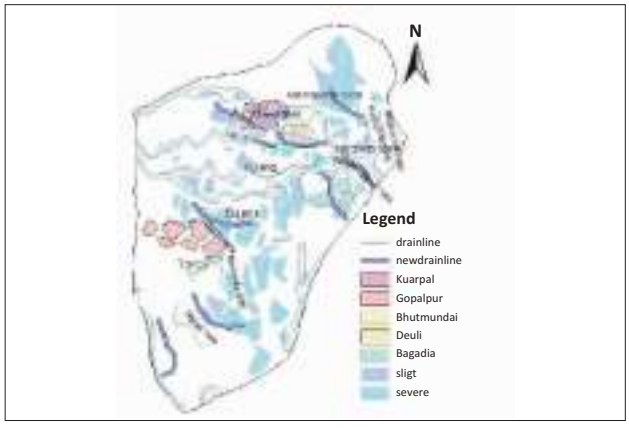


Fig. 30 Map showing new drainage system and suggested pond area in the villages of the study area

area on the basis of density slicing of blue tones of the rectified image. The waterlogged areas with slight and sever conditions were indicated in the figure. When the classified image was superimposed with hydro-geomorphological maps and groundwater table map, it was observed that the areas of deltaic plain and flood plains were mostly supporting waterlogged condition. The principal cultivated crop in the study area is rice. Using MXL classification and NDVI map, the crop areas were calculated. The MXL classification method assumed that statistics for each land use was normally distributed and thus groups pixels into a specific class that had maximum probability. There was an increase of 741 ha in rice crop area in Marsaghai and approximately 1400 ha and 2000 ha decrease in rice crop area found in Ersama and Kujang blocks in 2010 as compared to 2002 data. The soil series and drainage maps were generated using the rectified image and ground truthing. Thematic map was prepared for the new drainage system and suggested pond areas in the villages of the study area depending on the waterlogged condition which are shown in the Fig. 29 and 30.

Project Title : Crop Management Interventions and Contingency Crop Planning for Post- flood Management in Odisha

Project Code : DWM/09/142

Funding Agency : Institute

Project Personnel : P.S.Brahmanand, S.Roy Chowdhury, and S. Ghosh

A study was undertaken to identify the soil and crop related problems of flood prone areas, develop contingent crop planning and crop management interventions for post flood management in Odisha. Some of the soil related problems of the flood affected regions of Odisha include excess sand deposition in the fields resulting in unfavorable soil physical condition, flat coastal belts with poor drainage, high degree of siltation of the rivers, soil erosion, breaching of the embankments and spilling of floodwaters over them which in turn cause severe floods in the river basin and delta. Moreover, unsuitable soil reaction in coastal areas due to inundation of sea water, the retention of water in the fields for longer period in some patches makes it difficult for the farmers to implement the alternate crop plans. Most Seriously Affected areas (MSA) in terms of flood frequency and incidence were also identified. Mahakalapada, Garadpur, Ali, Kendrapada, Pattamundai, Rajkanika and Rajnagar blocks were categorized as seriously affected areas due to flood incidence in Kendrapara district. In Mahakalapada

block, Buinpur, Atal and Kalaspur were identified as most seriously affected areas due to flood incidence. Similarly, in Garadpur block, Garadpur, Patakura, Madhusashan and Talakusima come under most seriously flood affected areas. Flash flood tolerant rice varieties such as Swarna Sub-1 during Kharif season and cultivation of drought tolerant crops like sweet potato and sunflower under zero tillage in rabi season have been identified as most effective crop management interventions for post flood management in Kendrapara district. After implementation of contingency crop plan for two years, the socio-economic status of the farmers was found to be improved significantly compared to pre project scenario. The results of the on-farm field trial conducted in Raisar village, Garadpur block of Kendrapara district to assess the relative performance of SML-668 variety of green gram and local variety under post flood situation revealed that the number of pods per plant was found to be 13.8 in SML-668 variety compared to 10.5 in local variety. Block wise contingency plans were prepared for 11 blocks of Puri (Table 35), 16 blocks of Cuttack (Table 36), 8 blocks of Jagatsinghpur (Table 37), 11 blocks of Balasore (Table 38) and 5 blocks of Bhadrak (Table 39) districts of Odisha.

Table 35 Contingency crop planning for 11 blocks of Puri district during post flood period

Sl.No.	Name of the block	Contingent measures
1	Puri sadar	Salt and waterlogging tolerant rice varieties like Lunishree.
2	Pipli	Growing short duration rice varieties
3	Delanga	Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation
4	Kanas	Zero tillage with sweet potato, sunflower.
5	Nimapada	Deep waterlogging tolerant rice varieties like Hanseswari and Varshadhan.
6	Kakatpur	Flash flood tolerant rice variety Swarna sub1. Salt and waterlogging tolerant rice varieties like Lunishree. Zero tillage with maize in case of complete crop loss.
7	Astaranga	Salt and waterlogging tolerant rice varieties like Lunishree. Over aged rice seedlings of 60 days age.
8	Brahmagiri	Overaged rice seedlings of 60 days age. Salt and waterlogging tolerant rice varieties like Lunishree.
9	Krushnaprasad	Flash flood tolerant rice variety Swarna sub1.
10.	Satyabadi	Deep waterlogging tolerant rice varieties like Hanseswari and Varshadhan.
11.	Gop	Flash flood tolerant rice variety Swarna sub1. Zero tillage with maize in case of complete crop loss.

Table 36 Contingency crop planning for 16 blocks of Cuttack district during post flood period

Sl.No.	Name of the block	Contingent measures
1	Salepur	Flash flood tolerant rice variety Swarna sub1. Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation
2	Banki sadar	Zero tillage with sweet potato, sunflower. Growing short duration rice varieties
3	Athagarh sadar	Flash flood tolerant rice variety Swarna sub1. Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation
4	Tigiria	Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation Zero tillage with sweet potato, sunflower.
5	Narasinghpur	Growing short duration rice varieties

6	Gobindpur	Flash flood tolerant rice variety Swarna sub1. Zero tillage with maize in case of complete crop loss.
7	Baramba	Over aged rice seedlings of 60 days age. Flash flood tolerant rice variety Swarna sub1.
8	Kantapada	Overaged rice seedlings of 60 days age. Salt and waterlogging tolerant rice varieties like Lunishree.
9	Niali	Flash flood tolerant rice variety Swarna sub1. Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation
10.	Mahanga	Deep waterlogging tolerant rice varieties like Hanseswari and Varshadhan. Flash flood tolerant rice variety Swarna sub1.
11.	Cuttack sadar	Flash flood tolerant rice variety Swarna sub1. Zero tillage with maize in case of complete crop loss.
12.	Tangi	Growing short duration rice varieties Flash flood tolerant rice variety Swarna sub1.
13.	Dampada	Salt and waterlogging tolerant rice varieties like Lunishree.
14.	Krisnanagar	Growing short duration rice varieties
15.	Baranga	Flash flood tolerant rice variety Swarna sub1.
16.	Choudwar	Medium waterlogging tolerant rice varieties like Durga. Sunflower,bittergourd and sweet potato with zero tillage in post flood situation

Table 37 Contingency crop planning for 8 blocks of Jagatsinghpur district during post flood period

Sl.No.	Name of the block	Contingent measures
1	Biridi	Overaged rice seedlings of 60 days age. Flash flood tolerant rice variety Swarna sub1. Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation
2	Raghunathpur	Zero tillage with sweet potato, sunflower. Growing short duration rice varieties
3	Kujang	Flash flood tolerant rice variety Swarna sub1. Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation
4	Tirtol	Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation Overaged rice seedlings of 60 days age. Salt and waterlogging tolerant rice varieties like Lunishree. Zero tillage with sweet potato, sunflower.
5	Ersama	Growing alternate crops like water chestnut and integrate with aquaculture. Growing short duration rice varieties. Salt and waterlogging tolerant rice varieties like Lunishree.
6	Balikuda	Flash flood tolerant rice variety Swarna sub1. Zero tillage with maize in case of complete crop loss.
7	Nuagoan	Over aged rice seedlings of 60 days age. Flash flood tolerant rice variety Swarna sub1. Zero tillage with sweet potato, sunflower.

8	Jagatsinghpur	Overaged rice seedlings of 60 days age. Growing alternate crops like water chestnut and integrate with aquaculture. Salt and waterlogging tolerant rice varieties like Lunishree.

Table 38 Contingency crop planning for 11 blocks of Balasore district during post flood period

Sl.No.	Name of the block	Contingent measures
1	Bhogarai	Flash flood tolerant rice variety Swarna sub1. Growing short duration rice varieties
2	Simulia	Zero tillage with sweet potato, sunflower. Overaged rice seedlings of 60 days age.
3	Balasore sadar	Flash flood tolerant rice variety Swarna sub1. Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation
4	Khaira	Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation Zero tillage with sweet potato, sunflower.
5	Soro	Growing alternate crops like water chestnut and integrate with aquaculture. Over aged rice seedlings of 60 days age. Deep waterlogging tolerant rice varieties like Hanseswari and Varshadhan.
6	Bahanaga	Flash flood tolerant rice variety Swarna sub1. Zero tillage with maize in case of complete crop loss.
7	Remuna	Over aged rice seedlings of 60 days age. Flash flood tolerant rice variety Swarna sub1.
8	Baliapal	Overaged rice seedlings of 60 days age. Salt and waterlogging tolerant rice varieties like Lunishree.
9	Jaleswar	Growing alternate crops like water chestnut and integrate with aquaculture Flash flood tolerant rice variety Swarna sub1.
10.	Nilgiri	Zero tillage with maize in case of complete crop loss. Deep waterlogging tolerant rice varieties like Hanseswari and Varshadhan. Flash flood tolerant rice variety Swarna sub1.
11.	Nilgiri sadar	Flash flood tolerant rice variety Swarna sub1. Deep waterlogging tolerant rice varieties like Hanseswari and Varshadhan.

Table 39 Contingency crop planning for 5 blocks of Bhadrak district during post flood period

Sl.No.	Name of the block	Contingent measures
1	Bhadrak sadar	Over aged rice seedlings of 60 days age. Flash flood tolerant rice variety Swarna sub1.
2	Basudevpur	Medium waterlogging tolerant rice varieties like Durga. Sunflower, bittergourd and sweet potato with zero tillage in post flood situation Zero tillage with sweet potato, sunflower. Growing short duration rice varieties
3	Chandabali	Salt and waterlogging tolerant rice varieties like Lunishree. Flash flood tolerant rice variety Swarna sub1. Over aged rice seedlings of 60 days age.
4	Tihidi	Deep waterlogging tolerant rice varieties like Hanseswari and Varshadhan. Zero tillage with sweet potato, sunflower.
5	Bhandaripokhari	Flash flood tolerant rice variety Swarna sub1. Growing short duration rice varieties

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

During the year under report, the impacts of link drains and renovated ponds in terms of the hydrology and crop diversification were studied in the waterlogged area of Pattamundai (Kendrapara), Odisha. The observed flow rate in the link drain and minor were computed with the range of 0.2-0.45 and 0.9-1.63 m3/sec, respectively during the monsoon period (29th – 46th weeks) (Fig. 31).

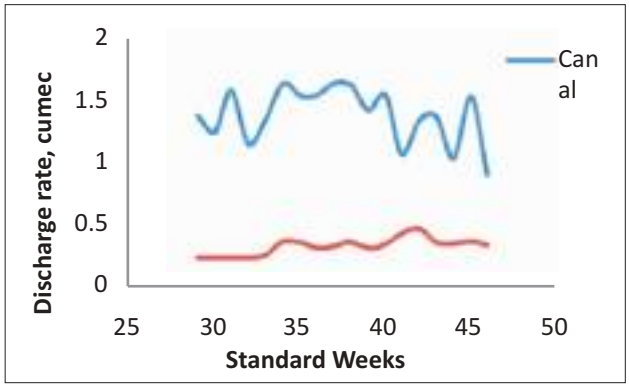


Fig. 31 Observed flow rate (cumec) during 29th - 46th weeks

Determination of drainage coefficient for design of link drains

Daily runoff events were estimated using USDA SCS CN procedure for the period 1990 -2012. The results revealed that there are more than 19 nos. of peak runoff events having more than 100 mm depth occurring in a day in the study area, which require to be either removed through the link drainage system or storing in the harvesting structures for crop diversification (Fig. 32).

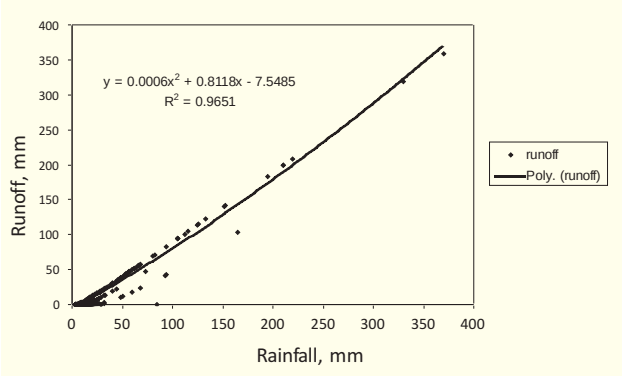


Fig. 32 Rainfall versus computed surface runoff

Based on Gringorten's plotting position approach, the depth-duration-frequency relationship was developed and the drainage coefficient was computed. The drainage coefficient for the study area was computed as 162 mm/day for 5-years return period (Fig. 33). However, the results documented in the compendium "Mahanadi Delta Development Plan", in which a design discharge of 1.4 cumecs/km (= 121.00 mm/day) was recommended for Mahanadi Delta area of Odisha.

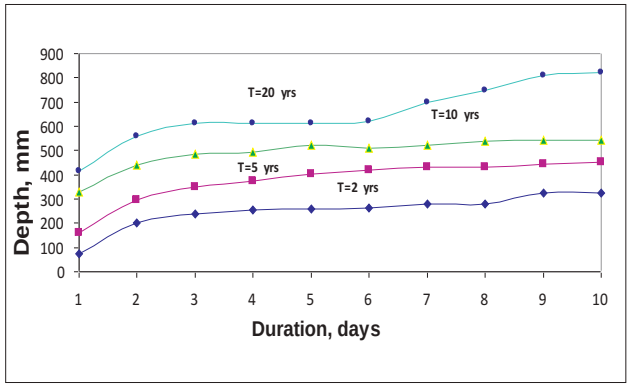


Fig. 33 Derived Depth-duration-frequency relationship

Assessment of area under renovated ponds and impact on the crop diversification

After determining the optimal cropping pattern, the areas under the renovated ponds were assessed through a questionnaire survey. The village-wise area and number of renovated ponds constructed including self and Govt. financed is presented in Table 40. It is observed that total 39 nos. of ponds having size ranging between 1200-6000 m^2 (30 m x 40 m - 80 m x 75 m) covering 6.2 % area of the command area of 300 ha were either renovated or newly constructed along side of the link drain through self finance or MGNREGA scheme Govt. of Odisha in surrounding 6 villages.

Table 40 Area under renovated ponds

Sl. No.	Name of the village	Area under renovated ponds (ha)
1	Baipada	3.84 (10)
2	Osangara	2.16 (5)
3	Jigaran	4.14 (7)
4	Amber	3.24 (9)
5	Kakharuni	2.52 (3)
6	Naladhalia	2.7 (5)
	Total	18.6 (39)

The values shown in the parentheses are the total no. of renovated ponds

Week-wise temporal water availability in one of the representative renovated pond was measured during the year 2012. The results revealed that the depth of water fluctuated between 0.5 m (in 23rd week) to 3.2 m (in the 31st week) (Fig. 34) indicating adequate water availability for growing various crops during Rabi season. An attempt was made through questionnaire survey to study the impact of availability of water and its influence on newly taken up crops in the command area. Total 39 respondents from 6 villages reported with promising crop yields during Rabi season.

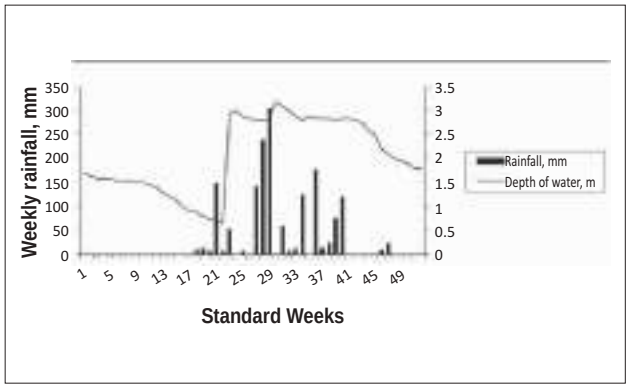


Fig. 34 Rainfall versus pond water level

Diversified crops during Rabi season

Project Title	: Growth and Production Physiology of Cat Tail (*Typha*) under Waterlogged Condition
Project Code	: DWM/09/139
Funding Agency	: Institute
Project Personnel	: S. Roy Chowdhury, P.S.Brahmanand and Ashwani Kumar

The objective of the study was to identify doses of N-fertilizers and proper time of application for better productivity of cat tail under waterlogged condition. The soil in the experimental field has been inceptisol derived from alluvial deposit of Rupnarayan river in Kolaghat in East Medinipur district. The crop was planted in split-plot design with four levels of N i.e. 0, 30, 60 and 90 kg N ha^{-1} in main plot and fertilizer application at three different stages of crop i.e. basal, 3 Month after planting (MAP) and 6MAP as subplot. The pH of the soil in the experimental field was also acidic between 4.2 - 4.6 and the soil organic carbon ranged between 1.8 to 2.9%. The pH of the water ranged between 6.1 to 6.8 and the electrical conductivity of water was between 0.01 to 0.02 $dS.m^{-1}$.

The measurement of tallest leaf was taken as plant height. The plant height increased through N fertiliser application and the increase was significant when N fertiliser was applied as basal dosage and effect was significant at 60 and 90kg/ha level of N application.

With increased water level, under partial submergence the leaf chlorophyll content showed a decline. However the reduction in chlorophyll content was minimum at higher N level i.e. at 90kg/ha N level where the plants maintained better chlorophyll level compared to other treatments. Similarly even though nitrate reductase activity decreased under partial submergence, at higher N level, i.e. 90kg/ha cat tail maintained higher NR activity suggesting effective N uptake and metabolism even during excess water situation. The NR activity was consistently higher at 90 kg/ha N level compared to other N level in post submergence period in November when other treatments showed a decline during said period. The nitrogen use efficiency enhanced from 73.7 kg dry leaf yield per kg N applied at 30 kg N/ha to 95.2 and 163.3 kg dry leaf yield per kg N applied at 60 kg and 90 kg N/ha respectively. The net photosynthesis rate (Pn) at basally applied N level was significantly higher than treatments without N. Both the fertiliser level and stage of application had significant effect on net photosynthesis rate. However the interaction between

stage and N level was not significant. The increased N fertiliser level consistently showed more number of leaves per unit area both at pre- and post-monsoon period. The leaf number at final harvest stage (18 MAP) was highest (126.67 leaves /m^2) in N 90 kg/ha treatment (Fig. 35). Eventhough specific leaf weight (SLW, mg/cm^{-2}) improved at higher N level, other leaf quality parameters like tenacity and extension did not change significantly with increased N application.

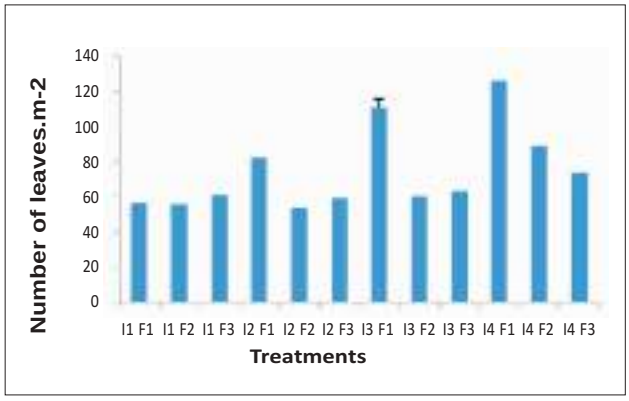


Fig. 35 Number of leaves per m^2 at harvest.

I1,I2,I3 and I4 are applied N level @ 0, 30, 60 and 90kg/ha respectively. The F1, F2 and F3 are stages of application i.e. F1= basal, F2 = 3 months after planting and F3 = 6 months after planting (MAP). The symbols are as in figure. Vertical bar is lsd for N at p = 0.05%.

Crop-weed interaction

The population of grassy weeds like *Echinocloa colona* and *Panicum repenshas* and broadleaf weeds like *Marselia quadrifolia* and *Monochoria vaginalis* witnessed a significant decline with the advancement of the time period due to higher weed suppressing ability of Typha sp. from second year onwards. This has resulted in lower dry weed biomass in *Typha* field during second year. However, the reduction in population of sledges like *Cyperus difformis* was fund to be relatively less.

The dry weed biomass was found to be significantly higher under fertilizer treatments compared to that of control treatment as in the first year. It was recorded highest when N was supplied @ 90 kg/ha (13.4 g/m^2) followed by N @ 60 kg/ha (12.7 g/m^2) and 30 kg N/ha (11.7 g/m^2). The highest weed biomass was observed when N was applied at 60DAP compared to 30 DAP and basal doses. This further confirms the weed smothering nature of *Typha* sp. under basal treatment compared to N application at 30 DAP and 60 DAP and was mainly due to better growth of main crop.

Project Title : Characterization and Utilization of Sewage Water of Urban/Peri-Urban Areas for Agricultural Purposes

Project Code : DWM/09/137

Funding Agency : Institute

Project Personnel : S. Raychaudhuri, M. Raychaudhuri and S.K. Rautaray

Increasing urbanization is leading to more and more demand for domestic and industrial water usage and it may increase to 29.2 BCM by 2025. Therefore, the allocation of fresh water is likely to be diverted more towards urban areas and higher value products. The fresh water availability for irrigation in India is expected to reduce by 162.3 BCM by 2025. Higher water supply would surely add to the level of wastewater generated at present level of 38.3 billion litres per day (bld) against the installed sewage treatment capacity of just 11.8 bld resulting in discharge of untreated wastewater to the environment. It is projected that by 2050, about 48.2 BCM (132 billion litres per day) of wastewaters (with a potential to meet 4.5% of the total irrigation water demand) would be generated. Huge cost of centralized treatment for all the wastewater generated in India is an infeasible proposition and unlikely to happen in near future while it is a valuable resource having fertilizer values. It has associated risks also. Reuse options for urban wastewater needs to be explored while irrigation is the end use. That is why the project was envisaged to with the objectives, characterization of sewage water with it's spatio-temporal variation and effect of sewage water on soil properties, plants yield and quality with sewage water of Bhubaneswar city

Analyses of sewage samples for physico-chemical, microbiological properties

The collected samples were analysed for physical parameters viz. turbidity, total dissolved solids (TDS), suspended solids (SS), total solids (TS), chemical parameters viz. pH, EC, alkalinity, ionic concentrations (nitrate, ammonium, phosphates, Cl, Na, K, Ca, Mg etc including trace/heavy metals) and biological parameters related to it's quality from the point irrigation purposes mainly and other possible uses. The mean EC, suspended solids, dissolved solids and total solids were found lower in rainy than that in summer and winter seasons. However, in general, the pH (acceptable range 6.5 – 8.4), EC (0.25 – 0.75 in Class II), dissolved solids (<1000 mg/l) and alkalinity (<250

mg/l) of all the water samples are within acceptable limit for irrigation. The nitrate level was below the accepted limit (45 ppm, BIS 1991) having mean of 18 ppm in summer, while chloride concentration in some summer samples calls for restriction in use. The mean concentrations of cations of all the drains are below critical limits, contributing to the fertilizer value of wastewater. Trace element concentrations in all the samples are in safe limits where Cd concentrations in some samples are higher than safe range even for short term use in irrigation. Organic pollutant load (BOD^5) was found maximum in Niladri vihar followed by Nicco Park and Science Park while Sanik School had lowest BOD^5 in summer. Among all the drains Nicco Park and Lingaraj drains seem to be the most polluted while at Sainik School and Kedargouri, pollute was least.

Spatio-temporal variations in sewage water characteristics

The quantity and characteristics of domestic discharges is dependent on various domestic activities and other routine courses. Samples were collected from the major drains in Bhubaneswar city at same location at different point of time in a day in summer viz. Morning, Day and Afternoon. The trend in changes of drain waters characteristics viz. pH, EC, TDS, BOD and Mn at different time of a day are shown in Fig. 36. The BOD_5 was maximum in day times in all the drains and dropped in the afternoon (after 2 PM). In a particular day, the quality of the drain water changed from morning to afternoon. The quality deteriorated significantly from morning to day and in the afternoon the quality tends to improve.

Significant changes in the parameters between rainy and non rainy seasons were observed for most of the parameters. The quality parameter values in rainy seasons were lower than non rainy seasons, probably due to dilution during the rainy period. However, sodium and chloride varied significantly among all the seasons. No significant changes in concentration of Iron and Cd between rainy and nonrainy seasons were observed. Significant changes in water quality parameters were observed in the same drain with distance. The trend in BOD_5 of the same drain in summer changed with distance. Discharges of organic pollutant were comparatively much higher between Joydev Vihar and Science Park than that before Joydev Vihar Chhowk and between Science Park and Vani Vihar in the morning. Whereas, the BOD values increased considerably at the day time (after 10 AM) from Joydev Vihar to Vani Vihar indicating on-going discharges along the drain at that period of time and that continued till the afternoon (after 2 PM) as suggested by the BOD values. The spatio-temporal changes in the drain water quality parameters suggest the scope of differential on site treatment of urban wastewater instead of treatment of all the generated wastewater. As the quality of wastewater place to place, there is need for segregation of differential water quality to reduce treatment costs. As the quality of the drain water changes at different times in a day and seasons as well, the operational cost of treatment processes can be reduced.

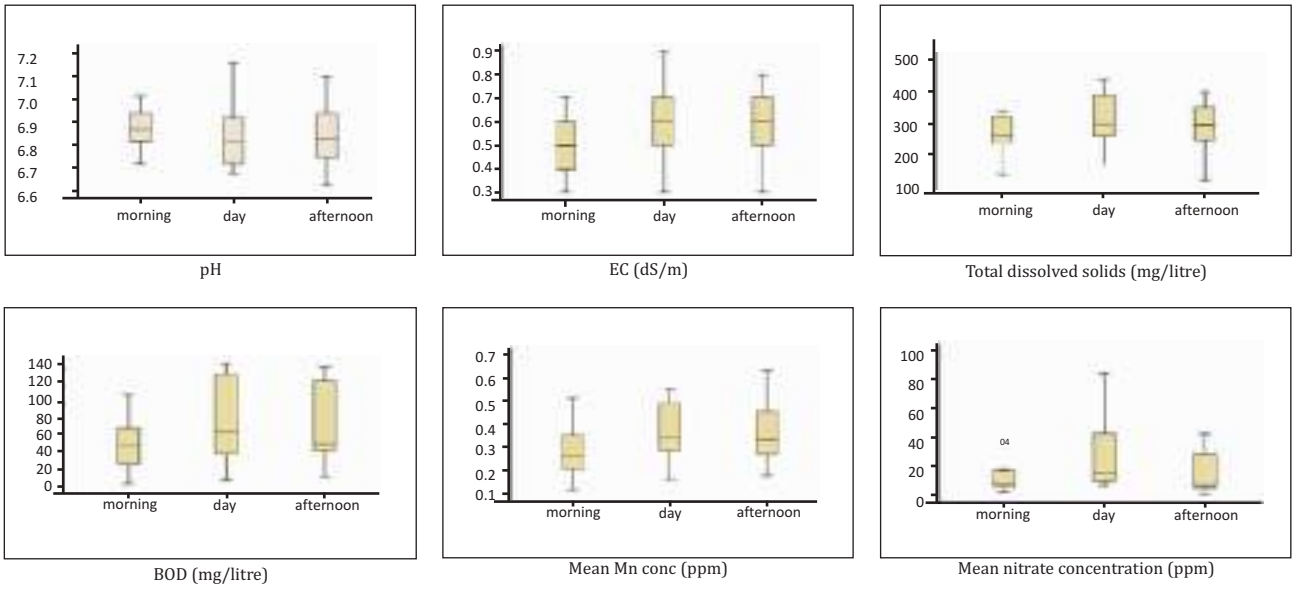


Fig. 36 Variations in mean drain water quality parameters in different point of times in a day

Studies on effect of sewage water on soil's properties in vertical soil column

Soil Column Study

In soil column study, the conductivity of leachates progressively increased with depths. The increase in exchangeable K and decrease in Na in leachates indicate retention of K and leaching of Na. Increase in conductivity in leachates with higher depths is evinced due to dissolution of salts. The concentration of NO_3 in leachates decreased while the NH_4 increased. The general trend was that the cations were leached more than the anions *viz.* nitrate and phosphates are retained in soil columns except chloride because chloride is not adsorbed or held back by soil. Addition of wastewater increased the organic carbon levels at all the depths. The soils also showed higher respirometric C in soils at all depths. Higher respirations are indicative of higher microbial activity. The soil microbial biomass carbon (soil MBC), a good indicator of microbial population was also found maximum at surface layer probably addition of more microbe from wastewater or availability of nutrients rendered multiplication of microbes thus higher population and higher MBC. Therefore, higher respirometric activity could be due to higher microbial biomass at surface layers rather than only organic matters. The drop in MBC values at lower depths could be the result of retention of microbes in the upper layers when soil column acted as filter. The Fe concentration increased at all depths having maximum value at surface soil and then progressively decreased while Cu was found maximum at 15 – 30 cm layer, but higher than initial value at all depths. Mn, Cr, Pb also similar trend as found in Fe. But Cd concentration was much higher than the original Cd level in soil and maximum at surface. Fe, Mn, Cr and Pb concentration increased by 13, 94, 72 and 21percent respectively in surface soils. Significant correlation between Organic carbon (OC) and Cd could be an indication of Cd containing organic pollutants in wastewater, however, OC bears no other significant correlation with other metals. The respirometric carbon had significant correlations with most of the metals except Cu and Cd. Significant relations with Fe, Zn, Mn and Cr with respirometric C may have reason as these metals are required in living cells. Thus, quantity of added metals might have contribution in higher respiration.

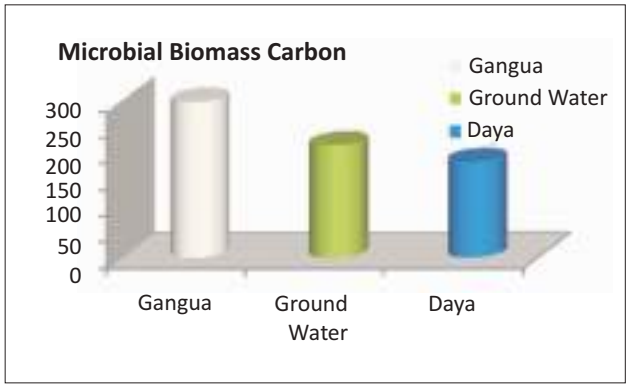
Field studies on effect of sewage water on soil properties

Physical properties of soil

Texturally the Gangua irrigated (GI) soils (clayee to sandy clay) were heavier than those with other irrigation (OS) sources (sandy clay loam). The mean values of moisture holding capacity and volume expansibility were 10 and 33 percent higher in Gangua irrigated soils. In spite of higher silt and clay in Gangua irrigated fields, the lower density could be attributed to the higher pore space. Possibly, higher clay provides greater surface area for reactivity and opportunities for formation of clay organic complexes, retaining more organic particles. That provides better opportunities for microbial interaction, thus, higher soil respiration. Higher respiration leads to more carbon dioxide generation or gaseous exchanges, making the soils porous. No indication of deterioration in soil physical properties with long term wastewater irrigation.

Chemical properties of soil

The Gangua water irrigated soils had lower mean soil pH, Bray's extractable P and higher electrical conductivity, organic carbon, available nitrogen, exchangeable potassium indicative of improved fertility



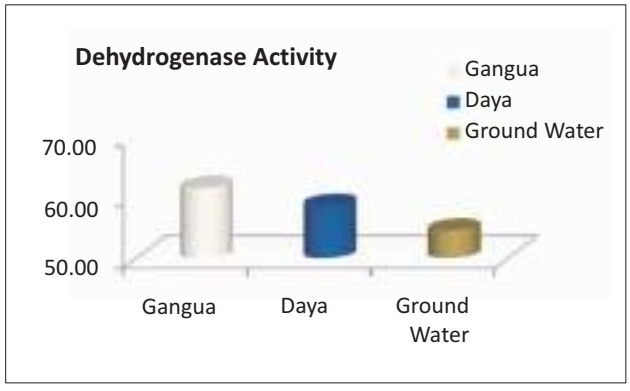


Fig. 37 Effect of different irrigation sources on soil microbial properties

status of Gangua irrigated soils. The higher OC, N, K could be attributed to the addition of organic and inorganic waste discharged into the drains in Bhubaneswar city from domestic and industrial activities. The exchangeable calcium and magnesium were higher in Gangua irrigated soils and so also sodium. However, the sodium concentration was not so alarming, because, higher calcium and magnesium concentrations counteract the sodium toxicity. However, higher magnesium concentration in comparison to that of calcium may aggravate sodium toxicity. While higher Ca/Mg ratio (>1) suppress the sodium toxicity. Even though the exchangeable sodium concentration in soils was higher in Gangua irrigated soils due to sodium rich wastewaters than other soils, their level was not high enough to invite any special attention. Probably, the sodium ions were not retained by soils or easily washed down the surface soils through rain water. Column study as discussed in previous section that, even though the higher concentration of Na in wastewaters, while inundated, it was not retained by soil.

The microbial properties

The GI soils had higher mean MBC (235 μg g^{-1} dried soil), respirometric CO_2 – C (196 μg g^{-1} soil). The GI soil had values of respirometric CO_2 – C ranging from100 to 345 but in the OS irrigated soil, it varied between 100 and 328. The water soluble organic carbon (WSC) and potassium sulphate extractable carbon (PSC) were also higher in the GI soil. The OC had significant correlations with other microbial parameters except water soluble C (GI) in both the OS and GI soils. As organic matter is the food source of microorganisms, higher organic matter is congenial for microbial growth and their activities. However, higher significant coefficients for GI soils between OC and other parameters could be an indication of organic pollutants in Gangua water from domestic or industrial discharges did not have negative impact on soils microbial activity. The respirometric C had a significant correlation with OC in GI soil where no such correlation was obtained in OS irrigated soil.

Effect of different irrigation sources on soil properties

Experiment was conducted on impact of long term irrigation sources viz. river water (DI), ground water and wastewater (Gangua water) on soil. The soil microbial biomass carbon increased significantly in Gangua irrigated soils (GI) over Daya river irrigated (DI) soils and insignificantly over ground water irrigated (GRWI) soils. GRWI soils also had higher SMBC (soil microbial biomass carbon) over DI soils (Fig. 37). The mean dehydrogenase activity was found highest in GI soils among the three irrigation. However, no significant change was observed in dehydrogenase activity with different sources of irrigation

Heavy metal enrichment

Enrichment factor has been calculated to determine the degree of soil pollution rather heavy metal accumulation in soil contaminated (wastewater irrigated viz. Gangua) with respect to soil to soil at the uncontaminated sites i.e OS irrigated. EF = Concentration of metals in GI soils/ Concentration of metals in OS irrigated soils. All the metal concentrations in Gangua irrigated soils were higher in compared to OS irrigated soils. The enrichment factors were in the order, Fe > Zn > Mn = Cd > Cr > Cu. The higher enrichment value indicates higher retention of metals in soils from irrigating water thereby higher rate of accumulation

Studies on effect of sewage water on plant yield and quality

The mean grain yield (7%), straw yields (9.3%) and number of panicles per square meter in wastewater irrigated plots were significantly higher than river water irrigated plots significant differences among varieties were also observed with grain and straw yield, number of panicle under both the type of irrigations. *Lalat* showed maximum significant grain and straw yields under both the irrigation sources followed by *Naveen, Parijat* and *Khandagiri*. Among the varieties, Naveen showed 12 % and 15% increase in grain and straw yield over river water irrigated plots, followed by Khandagiri (10 and 15% respectively for grain and straw) while *Lalat* showed minimum. The wastewater irrigated soils had significantly lower mean grain-straw ratio (0.93), indicative of comparatively higher vegetative growth in wastewater irrigated soils. Probably higher level of major nutrients in wastewater irrigated soils encouraged vegetative growth in comparison to river water irrigated soil. Among the varieties the grain straw ratio varied significantly. Therefore irrigation with wastewater has a positive impact on the productivity of paddy.

The vegetables (edible part) analysed for heavy metals include *viz*. malabar climbing (poi), amaranthus red (lal saga), amaranthus green (sabuja saga) and three types of vegetables which are eaten cooked *viz* ladies finger, ridge gourd and bitter gourd and two types of vegetables/fruits often eaten raw *viz* tomato and watermelon. All the Gangua irrigated vegetables had

higher concentrations of heavy/trace metals in their edible parts in comparison to the samples grown with other irrigation sources. The mean transfer factors of all vegetables on other source irrigated soils were higher than that in Gangua (wastewater) irrigated soils.

In general Fe concentrations were highest in tomato among all the metals in the vegetable samples followed by watermelon and amaranthus green. The Cd concentrations exceeded the permissible standards (0.2 mg/kg) of FAO for most of the vegetables in both the type of irrigation. Cr and Cu concentrations were within permissible limits in all vegetable samples while Zn exceeded in most of the samples. Among vegetables, ridge gourd had the lowest mean transfer factor in both the OS and GI soils followed by ladies finger and bitter gourd. The mean transfer factor of all vegetables in OS irrigated soils was higher (11.1) than that in GI soils. Transfer Factors has been identified as an effective screening tool for segregation of safe and unsafe crops which can be grown with urban wastewater as supplementary source of irrigation. Accumulation of heavy metals were lower in fruit parts than leaf and stems in general.

Conjunctive use of fresh water and wastewater

Four vegetables viz., okra, bitter gourd, ridge gourd and cucumber were grown with three irrigation water treatments viz., Daya water irrigated (T1), Gangua water irrigated (T2), and Daya and Gangua (T3) water alternately irrigated during the dry seasons of 2010-12 in 7 farmers' field. There was an increasing trend for the yield and yield attributes of test crops irrigated with Gangua water as compared with those irrigated with Daya water. The yield advantage ranged from 9% (13.1 t/ha) for bitter gourd to 15% (9.2 t/ha) with cucumber. When the crops were irrigated with Daya and Gangua water (1:1), yield advantage was also noted which ranged from 3% with okra to 11% with ridge gourd. The total heavy metal concentrations in soils viz. Fe, Cu, Zn, Mn, Cr, Cd were in the order T2 > T3 > T1 but within permissible in all the treatments. Conjunctive use of wastewater with river water other source may save up to 50% of fresh water. The heavy metal concentrations remained within permissible limits in edible parts of vegetables grown with conjunctive irrigation.

On-farm Research and Technology Dissemination

- Sustainability of Water User Associations (WUAs) and Effect of Participatory Irrigation Management (PIM) on Agriculture and System Performance
- Tracking Change in Rural Poverty in household and Village Economies in South Asia
- Strengthening Statistical Computing for National Agricultural Research System
- Farmers Participatory Action Research Programme (FPARP Phase-II)

Project Title : Sustainability of Water User Associations (WUAs) and Effect of Participatory Irrigation Management (PIM) on Agriculture and System Performance
Project Code : DWM/10/145
Funding Agency : Institute
Project Personnel: S. Ghosh, P.S. Brahmanand, P. Nanda and D.U. Patil

Transfer of irrigation management responsibilities from government agencies to farmers/ water user associations (WUA) is now an important policy being implemented through Participatory Irrigation Management (PIM) programmes with a view to provide equitable, timely and assured irrigation. It has resulted variable impact over space and time across different irrigation systems. In this context, PIM under minor (lift) irrigation system was assessed during the year under report. Minor (lift) irrigation systems at 42 Mouza area of Cuttack district in Odisha (20°23'N and 85°27'E) was selected for study. A total of 15 minor irrigation systems were characterized. It revealed most of the systems are having 10HP electric pumping unit with average seven outlets and mean command area of 14 ha. Average number of members in the water user association was 10 without any women member in most of the cases and usually held meeting twice in a year. On an average Rs.25000/- was collected as water tax to meet the operation and maintenance expenditure of the irrigation system and account balance was about Rs. 5500/-. Paddy was predominant crop in *kharif* and vegetables, pulses and oilseeds were grown in during rabi season. In some of the system's command sugarcane and maize were also grown. Farmers-members having land in command areas under jurisdiction of different Pani Panchayats/ WUAs were selected following stratified random sampling method. Questionnaire survey was carried out covering 150 sampled member-farmers representing 15 WUAs for their perceptions on participation in WUA's activities, irrigation services and WUA's performance.

Extent of farmers' participation

Framers' participation in different activities undertaken by Pani Panchayats (leadership seeking participation, members awareness on WUA activities, attending meetings, voluntary physical / labour and

Table 41 Farmers-members' participation in different activities undertaken by *Pani Panchayats* under minor (lift) irrigation systems at 42 Mouza in Cuttack district.

	Extent of farmers' participation						
Name of *Pani Panchayats* (PP)	Leadership seeking participation	Members awareness on WUA activities	Attending meetings	Voluntary physical / labour contributions	Voluntary financial contributions	Social auditing	Overall participation
Digabarini PP	4.70(0.48)	3.90(0.32)	3.60(0.97)	3.20(0.79)	3.60(1.26)	3.60(1.43)	3.77(0.53)
Balunkeswar PP	4.30(0.67)	4.20(0.63)	3.70(1.06)	3.50(0.85)	3.50(1.08)	4.10(1.20)	3.88(0.79)
Jagannath PP	4.80 (0.42)	4.80 (0.42)	4.60 (0.52)	3.90 (0.57)	3.90(0.57)	4.40 (0.84)	4.40(0.29)
Maa Tarini PP	4.90(0.32)	4.20(0.42)	4.30(0.95)	3.90(0.74)	4.10(0.88)	3.90(0.57)	4.22(0.11)
Maa Durga PP	4.40(0.52)	4.20(0.63)	3.90(0.74)	3.30(0.48)	3.40(0.52)	4.20(0.92)	3.90(0.39)
Kadameswar PP	4.20(0.63)	4.10(0.74)	4.20(0.42)	3.90(0.74)	3.60(0.70)	3.70(1.06)	3.95(0.26)
Gopinath PP	4.60(0.70)	4.30(0.67)	3.70(0.82)	3.70(0.48)	3.90(0.99)	3.20(1.03)	3.90(0.43)
Gopaljee PP	4.50(0.53)	4.10(0.57)	3.90(0.74)	3.89(0.93)	3.90(0.74)	3.90(0.99)	4.03(0.54)
Maa Jaguli PP	4.56(0.73)	4.11(0.78)	4.22(0.83)	3.67(0.71)	3.56(1.24)	3.22(1.09)	3.89(0.77)
Sapneswar PP	4.50(0.53)	4.20(0.42)	3.90(0.74)	3.67(0.87)	4.00(0.94)	4.40(0.84)	4.12(0.51)
Jhadakhandi PP	4.30(0.82)	3.80(0.63)	3.80(0.79)	3.60(0.97)	3.20(1.32)	3.90(1.45)	3.77(0.70)
Maa Gayatri PP	4.70(0.48)	4.20(0.42)	4.40(0.70)	3.90(0.74)	4.00(0.67)	4.50(0.85)	4.28(0.42)
Maa Basudev PP	4.09(0.83)	4.09(0.70)	4.09(0.70)	3.91(0.83)	4.36(0.81)	3.82(0.75)	4.06(0.21)
Mahalaxmi PP	4.60(0.52)	4.10(0.57)	4.00(0.47)	3.70(0.82)	4.00(1.05)	3.60(0.70)	4.00(0.45)
Lakshmi Narayan PP	4.60(0.52)	4.50(0.71)	4.20(0.42)	3.60(0.52)	3.50(0.71)	3.80(0.92)	4.03(0.49)
Average	4.52(0.22)	4.19 (0.23)	4.03(0.29)	3.69 (0.23)	3.77 (0.31)	3.88 (0.39)	4.01(0.18)

Minimum and maximum mean perception score is 1 and 5, respectively; figures in parenthesis indicate standard deviation values

financial contributions, social auditing) was studied with the help of a Farmers' participation index (FPI):

FPI = (Mean participation score / Maximum participation score) X 100

where, mean participation score = S Pi/N and Pi =S PPj,

PPj = Total score of farmers' participation, i = 1,2, ……., N and j = 1,2, ……., K, N and K = total number of respondents and total number of activities, respectively.

Extent of farmers' participation in different activities revealed that overall participation of the member was quite good with mean score >4. However, voluntary physical and financial contributions were relatively low (Table 41). FPI values ranged from 75 to 88% indicating the effectiveness of PIM in selected minor (lift) irrigation systems. The overall participation of the members was quite high in case of all Pani Panchayats which may be due to smaller size of group and major responsibilities in different activities were often taken by all the member-farmers.

Irrigation performance

The irrigation performance was assessed from farmers' perspectives on the parameters viz. tractability, convenience, predictability and equity. Tractability was measured on the basis of farmers' perceptions on quantity of water supply, point of water delivery and stream size. Convenience was determined through timeliness of irrigation, duration of water supply, and frequency of getting water. Predictability was assessed on the basis of farmer's degree of confidence with respect to water supply service, or how much information is available to farmers about the water delivery schedule. Equity was studied with respect to the equal benefits derived by the member-farmers from irrigation service. The above-mentioned variables were studied through farmers' responses on each on a 5-point continuum scale (1- very poor to 5 - excellent) and mean perception score was derived. Perception of farmers on overall irrigation service was also studied on similar scale.

All the four factors *viz*. tractability, convenience, predictability and equity were relatively higher in *kharif* season than in *rabi* season (Table 42). Out of these four factors, tractability and convenience were perceived higher in majority of the Pani Panchayats during both kharif and rabi season as compared to predictability or equity. Equity was perceived comparatively low (3.30) during rabi seasons in most of the Pani Panchayats. The overall irrigation performance was quite good during both the seasons.

Table 42 Farmers' perceptions on lift irrigation systems' performance under minor (lift) irrigation systems at 42 Mouza in Cuttack district

Name of *Pani Panchayats* (PP)	Parameters of irrigation performance							
	Tractability		Convenience		Equity		Predictability	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
Digabarini PP	4.53 (0.22)	3.58 (0.29)	4.50 (0.26)	3.73 (0.32)	4.30 (0.67)	3.50 (0.53)	3.80 (0.32)	3.43 (0.50)
Balunkeswar PP	4.35 (0.87)	3.33 (0.54)	4.35 (0.78)	3.55 (0.45)	4.00 (1.15)	3.11 (0.93)	4.13 (0.71)	3.40 (0.56)
Jagannath PP	4.68 (0.33)	3.70 (0.37)	4.70 (0.20)	3.70 (0.28)	4.50 (0.71)	3.20 (0.42)	4.20 (0.48)	3.53 (0.42)
Maa Tarini PP	4.53 (0.25)	3.78 (0.43)	4.63 (0.18)	3.90 (0.32)	4.30 (0.67)	3.50 (0.53)	4.13 (0.39)	3.77 (0.27)
Maa Durga PP	4.75 (0.31)	3.53 (0.25)	4.68 (0.21)	3.53 (0.22)	4.70 (0.48)	3.30 (0.48)	4.50 (0.28)	3.23 (0.27)
Kadameswar PP	4.23 (0.28)	3.98 (0.34)	4.28 (0.34)	3.83 (0.29)	3.80 (0.63)	3.40 (0.52)	3.70 (0.25)	3.53 (0.32)
Gopinath PP	4.08 (0.44)	3.83 (0.51)	4.18 (0.44)	3.73 (0.38)	4.30 (0.82)	3.60 (0.52)	3.73 (0.41)	3.60 (0.34)
Gopaljee PP	4.35 (0.32)	3.68 (0.37)	4.30 (0.42)	3.73 (0.25)	4.10 (0.57)	3.20 (0.42)	4.23 (0.59)	3.50 (0.48)
Maa Jaguli PP	4.28 (0.71)	3.36 (0.47)	4.14 (1.00)	3.28 (0.40)	4.00 (1.32)	3.00 (0.50)	4.07 (0.89)	3.33 (0.47)
Sapneswar PP	4.55 (0.45)	3.53 (0.43)	4.68 (0.31)	3.55 (0.47)	4.60 (0.52)	3.30 (0.67)	4.10 (0.85)	3.47 (0.61)
Jhadakhandi PP	3.98 (0.51)	3.88 (0.38)	4.23 (0.51)	3.75 (0.24)	3.90 (0.74)	3.70 (0.95)	4.00 (0.31)	3.60 (0.41)
Maa Gayatri PP	4.45 (0.44)	3.63 (0.27)	4.67 (0.31)	3.69 (0.27)	4.70 (0.48)	3.10 (0.32)	4.37 (0.29)	3.23 (0.32)
Maa Basudev PP	4.27 (0.44)	3.91 (0.41)	4.39 (0.39)	3.59 (0.36)	4.27 (0.79)	3.36 (0.81)	4.18 (0.50)	3.52 (0.40)
Mahalaxmi PP	4.28 (0.34)	3.40 (0.29)	4.45 (0.51)	3.58 (0.35)	4.90 (0.32)	3.10 (0.32)	4.10 (0.22)	3.27 (0.38)
Lakhmi Narayan PP	4.78 (0.22)	3.48 (0.40)	4.55 (0.35)	3.35 (0.49)	4.10 (0.99)	3.10 (0.88)	4.04 (0.42)	3.08 (0.46)
Average	4.41 (0.23)	3.64 (0.21)	4.45 (0.20)	3.63 (0.17)	4.30 (0.33)	3.30 (0.21)	4.09 (0.22)	3.43 (0.18)

Minimum and maximum mean perception score is 1 and 5, respectively; figures in parenthesis indicate standard deviation values

Agricultural performance

Paddy was the major crop in the command area under jurisdiction of all the selected 15 Pani Panchayats covering about 164 ha out of 197 cultivated area during kharif season. Sugarcane was grown in about 20 ha area. Agricultural performance in rabi season was also better as farmers could cultivate in about 171 ha growing paddy (47 ha), sugarcane (45 ha), pulses (38 ha) and vegetables (36 ha). Oilseeds were not preferred except groundnut which was grown only in about 1 ha area under the jurisdiction of Jagannath PP. The cultivation during rabi season was possible due to availability of timely and reliable irrigation (Fig. 38). More area can be brought under cultivation by reducing paddy area and growing more remunerative oilseed crops like groundnut, sunflower, etc during rabi season.

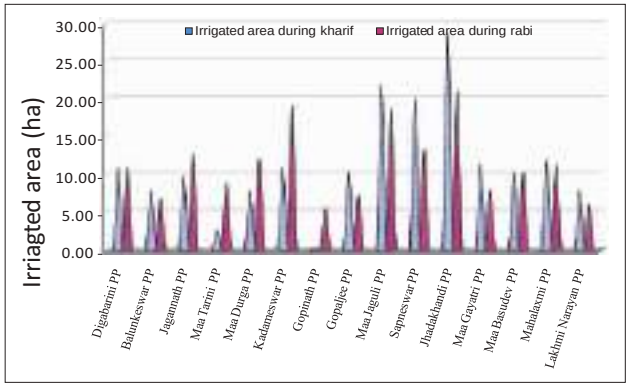


Fig. 38 Irrigated area under minor (lift) irrigation systems at 42 Mouza in Cuttack district

Performance of Pani Panchayats

Performance of Pani Panchayats was assessed from the farmers' perspectives taking farmers' responses on a total of 20 parameters related to issues like participation, operation and management, water management, financial management and organizational linkage. Pani Panchayats' performance was perceived favourably with mean performance score >4.0 (Fig. 39). More than 60% of farmers are irrigating even during night time. Out of the five issues considered water management was perceived to be best performed by the Pani Panchayats, which showed effectiveness of PIM in the selected minor (lift) irrigation systems. However, financial sustainability needs to be strengthened as WUAs' mean account balance was quite low (about Rs. 5500/-)

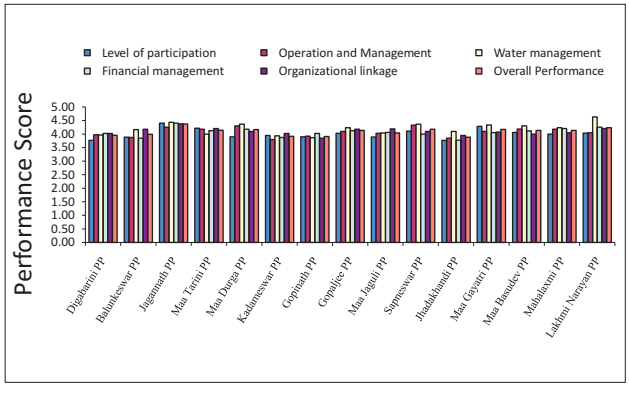


Fig. 39 Performance of Pani Panchayats as perceived by member-farmers under minor (lift) irrigation systems at 42 Mouza in Cuttack district

Project Title : Tracking Change in Rural Poverty in household and Village Economies in South Asia

Funding Agency : Billand Mehinda Gates Foundation

Project Personnel : M.K. Sinha, P. Nanda, A. Kumar

The study aims to understand the dynamic process for reducing poverty by tracking the household and village economies from Odisha villages. Regular high frequecy data were collected on monthly basis to enhance availability of reliable household, individual, field specific, plot level data on agriculture, labour, expenditure, incomes and consumption several times throughout the year. This was to address the dynamics of economic, social and institutional development. Meso level data on the agriculture and poverty related variables were also collected. Data base is also being prepared in a user-friendly format of CSPro. This software package can be accessed in user friendly format by individuals, researcher and planners.

Data from Sogar village of Dhenkanal showed that the maximum numbers of were in age group of 31 to 60

years followed by the age group 17 to 30 years(Fig. 40). By combining these two groups, a large percent of population are in the earning age group. Out of this, a sizable population has little land or no land. The wide spread disparity in land distribution in the village

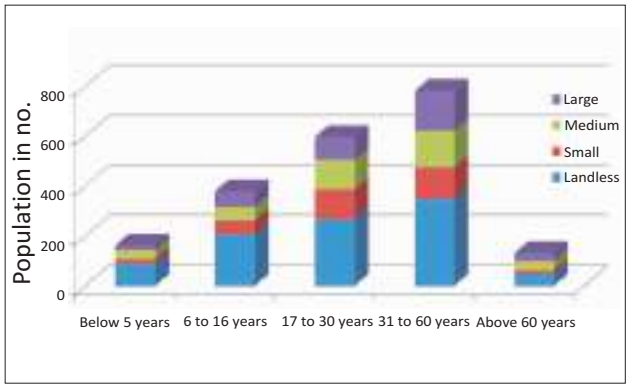


Fig. 40 Age wise demographic distribution in the village

contributes to their poor economic status and non availability of agricultural livelihood options for them.

Further, due to limited irrigation facility, agriculture is unable to serve the need of the farm households. About 48% of total working population arranged their livelihood from different type of non-farm activities (Fig. 41). A total of 64.19 % of landless and 41.86 % of small farmers earn their livelihood by performing non-farm works as they have too small holding land to cultivate. The same is also true for large farmers as their lands have poor irrigation facility. In case of medium farmers, the livelihoods depend on agriculture and non-farm works which is 34.09%. Agriculture comes second while providing livelihoods which is about 27.85 %, out of which 20.96 % are cultivators and 6.89 % are agricultural workers.

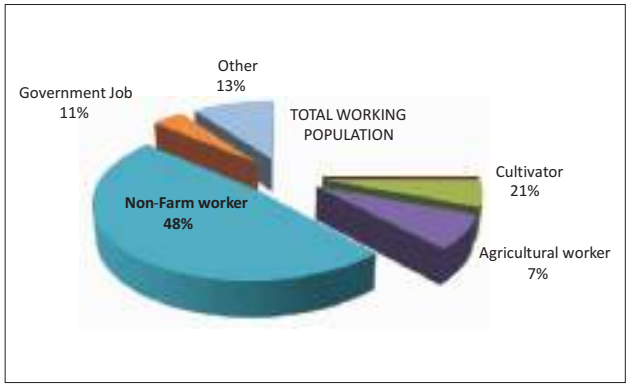


Fig. 41 Occupational Diversification

Project Title : Strengthening Statistical Computing for National Agricultural Research System

Funding Agency : NAIP, ICAR, New Delhi

Project Personnel : D.K. Panda and G. Kar

The DWM Statistical Computational Hub was assigned to conduct one Software Installation Workshop, two 6-days training programs and two 3-days sensitization programs for the scientists of 28 ICAR institutes and SAUs of eastern India. On 22 June 2012, the Software Installation-cum-training program was organized at DWM and the installation of the SAS software version 9.3 was imparted to 20 nodal officers under the DWM Statistical Computing Hub. During 27-29 June, 2012, the first 3-days sensitization program was conducted at ICAR Research Complex for Easter Region(ICAR RCER), Patna with the participation of 25 researchers. The next sensitization program was organized at Indira Gandhi Krishi Vishwa Vidyalaya (IGKVV), Raipur during 19-21 October with the participation of 22 persons. The first 6-days training on "Data Analysis for Water Management Research using SAS" was organized at DWM, Bhubaneswar during 18-23rd February 2013. Scientists of AICRP (Water Management) and DWM participated this specialized training. The second 6-days training on "Data Analysis using SAS" was organized during 25th February to 2nd March 2013 at National Institute of Research on Jute and Allied Fibre Technology (NIRJAFT), Kolkata. A total of 18 scientists and 9 research scholars were trained.

A dedicated website http://www.dwm.res.in/naip-nars/ was developed absolutely devoted for providing information on advanced statistical tools and techniques using the software SAS for scientists of NARS organizations of Eastern India. All the activities under the NAIP Project "Strengthening Statistical Computing for National Agricultural Research System" have been uploaded. The training manual on "DATA ANALYSIS USING SAS", with 122 pages has also been uploaded.

Project Title : Farmers Participatory Action Research Programme (FPARP Phase-II)

Funding Agency : MOWR, New Delhi

Project Personnel : G. Kar, R. K. Panda, S. Raychaudhuri, O. P. Verma and A. Kumar

During the period under report, efficient water harvesting through control of seepage and conveyance losses, on-farm efficient irrigation water application for increasing water use efficiency were carried out. Two ponds of size (Diamension: 50 m x 26 m and 25 m x 22 m) were lined at Balasore project sites by the help of LDPE sheet having 250 µ size for efficient water harvesting and control of seepage losses. The stored water from ponds is used for supplemental irrigation to crops. In order to provide proper conveyance of irrigation water in the crop fields, PVC pipes were laid out in eleven beneficiary farmers' fields at Balasore and Mayurbhanj project sites. The performance of the developed system have been evaluated by growing mustard (Toria) crop in village Routrapur, Balasore during rabi, 2012.

The mustard (Toria) variety M-27 crop was sown in 3 acre area with scientific agronomic management practices. The field experiment was conducted to assess the effect of different planting dates on yield and water use efficiency of Toria crop. The treatments were three planting dates *viz*., 22 November, 8 December, 22 December and farmers' practices (22 December), with 30x10 cm spacing. The recommended dose of fertilizers were used as 60-30-30 kg/ ha N, P_2 O_5 ans K_2O, respectively. The crop was irrigated in ridge & furrow method of irrigation by 20 m X 3 m size basins. The harvested water stored in the LDPE sheet lined pond was conveyed through underlined PVC pipe line network. Total three irrigations were applied using RBC flume with scheduling of each irrigation at 8.5 cm depth of water with irrigation water depth of 12 cm in case of the farmers' practices. The crop was sprayed with pendimethalin @ 5ml in 1 litre of water for the control of weeds. The confider insecticide application was done for the control of insect and pests.

The toria yield response to sowing date was in favour of early sowing (22 November) rather than late sowing (22 December). The maximum seed yield of 7.21 q/ha was achieved with water use efficiency of 2.83 kg/ha-mm. Late sowing by 30 days resulted in reduction in seed yield and water use efficiency by 44.5 % and 61 %, respectively (Table 43).

Table 43 Effect of planting dates on yield & water use efficiency of Toria

Sowing dates	Seed yield (q/ha)	Water use (mm)	WUE (kg/ha-mm)
S_1 (22 November 2012)	7.21	255	2.83
S_2 (8 December 2012)	6.40	255	2.51
S_3 (22 December 2012)	4.25	255	1.67
Farmers' practices (22 December 2012)	4.0	360	1.11

Events / Trainings Organized for Women Empowerment

Four one-day farmers training programs on 'Rainwater management for sustainable agriculture and rural livelihoods' were conducted at Mahadia, Dhenkanal on 16.2.2013, at Pasa Singh, Dhenkanal on 17.2.2013, at Kotapala, Dhenkanal on 2.3.2013 and at Khamara, Dhenkanal on 3.3.2013 in which a total of 51 women farmers out of 127 total farmers were trained.

An exposure-cum-discussion visit was organized for two female students from Global Engineering of Purdue University, USA to discuss and know about various problems of water quality for crop irrigation at the Institute from 16 – 21 May 2012 in the Institute.

Organized summer training programme of one month duration from 1-30 June 2012, for ten no. of B Tech students including two girl students.

Women students were guided for partial fulfillment of the degree of Master of Technology Sambalpur University and Utkal University.

Twenty one post graduate standards students including girl students from Dept. of Forestry, OUAT, were exposed to salient outputs and achievements of our Institute as a part of their study tour on Feb. 27, 2013 in the Institute.

All India Coordinated Research Projects

AICRP on Water Management

- Twenty five centres were operating under the All India Coordinated Research Project on Water Management. Salient theme wise research achievements of the AICRP centres during 2012-13 are given below.
- At Bhavanisagar, drip irrigation at 80 liters/tree/day along with 100 percent recommended nitrogen and potassium through fertigation at monthly intervals + 100 per cent phosphorus and 100 per cent of micro nutrient once in 3 months gave significantly higher coconuts of 134 nuts/ tree. In sugarcane subsurface drip irrigation at 100 per cent PE and fertigation of 75 per cent recommended dose with liquid bio-fertilizers recorded significantly higher cane yield.
- At Navasari, adoption of drip irrigation and fertigation of (N and K in 8 equal splits at weekly interval) + mulching with black plastic or black/silver mulch) could enhance fruit yield of water melon (summer) by 47% and save water up to 34%.Planting of sugarcane by pit method (soil with hard pan by keeping spacing of 1.75 m x 1.75 m between two pits) under drip irrigation recorded significantly higher cane yield (151 t/ha) as compared to paired row planted control (128 t/ha). Scheduling of irrigation at 0.8 PEF and mulching with black plastic in pigeon pea (*rabi*) increased seed yield (1730 kg/ha) by 62 % and saved 15 % of irrigation water as compared to control. In drip irrigated banana, adoption of fertigation twice in a week @ 80% of recommended dose increased fruit yield by 43 % over surface irrigation control.
- At Parbhani, use of online drip with application of paclobutrazole (hormone) at 2 ml/m plant spread improved yields in mango varieties of Malika, Neelam, Totapuri and Fasali. Inline ring drip layout system with 75% recommended dose of fertilizers (600:300:300 g/plant NPK) in 12 to 16 splits for sweet orange; inline drip scheduled at 40% of pan evaporation and 75% recommended dose (75: 38:38 kg/ha NPK) for okra; subsurface inline drip irrigation with water of 60% pan evaporation and 50% RDF (60:30:30 kg/ha NPK) through fertigation was found beneficial are recommended. Inline drip irrigation with laterals spaced at 120 cm and water at 0.75 ETc for paired row planting (45x15) +75 cm for sorghum whereas raised bed placed at 150 cm apart with planting on bed at 45x15 cm for rabi sorghum is recommended. Similarly the inline drip irrigation system for Bt. cotton can be economically used for next crop rotation of pigeon pea at spacing of pigeon pea + soybean (2:3) at 90 x 60-180 cm.
- At Palampur, cauliflower-capsicum cropping sequence fertigated with recommended NPK fertilizers (*on soil test basis*) and irrigated at 3 day interval with water depth of 1.2 times CPE was beneficial. Broccoli crop gave better yield with 50 % of recommended NPK (*on soil test basis*) in 8 splits and irrigated at 3 day interval through gravity fed drip system with water depth of 1.0 times CPE. In pea Micro-sprinkler irrigated dosage with 0.8 CPE was best. However, irrigation with 0.6 CPE and fertigation with 50 per cent of recommended NK saved irrigation water and fertilizers.Green pea sown after 10 Mg ha^{-1} FYM incorporation should be mulched after emergence with rice straw @ 10 Mg ha^{-1} and irrigated at IW/CPE ratio of 0.6.The Okra-broccoli cropping sequence should be fertilized with recommended NPK complemented with vermicompost @ 2.5 Mg ha^{-1} and irrigated with 3 cm water depth at 0.3 bar suction
- At Dapoli of Konkan region, the water harvesting structure named as "Konkan Vijay Bandhara" were constructed through peoples participation in all the villages. The total volume of water stored in all Bandharas was 3762.50 m3 at the end of monsoon season. The retention period of water in the Bandhara ranged from 45 to 60 days depending upon the storage, volume and percolation. The peoples were promoted to take second crop on stored water, in all about 35 acres of land in rabi season was irrigated to grow short period leafy and fruity vegetables in Sadave village. The pooled analysis of sapota fruit yield for consecutive 6 years indicated that application of water at 100%PE through applicator was consistently superior for 6 years and significantly highest (27.76 q/ha) as compared to other imposed treatments. The second highest yield was fetched in the control (I5) treatment (24.90 q/ha), which was significant over other irrigation levels of application through applicator. It is recommended that, in lateritic soil of Konkan region, the sweet corn crop Variety- Sugar 75 should be grown under inline drip irrigation system and irrigation should be scheduled on alternate day at 7.4 to 19.0 lit/plant from January to April (total water 46.3 ha-cm) with 80% of recommended dose RDF (160:48:48 kg/ha, N:P:K) through WSF to get maximum production and benefit.

- At Jammu, Zero tilled wheat crop produced 2.13 q/ha more yield than conventionally grown wheat with 15.48 kg/ ha-mm WUE. Under light textured soils, the technique of zero-tillage for wheat establishment with IW/CPE ratio of 1.0 having (3) number of irrigations each of 40 mm depth resulted in highest yield of 4.85 t/ha .Scheduling irrigations at 3 days after disappearance of ponded water, for areas having light textured soils of canal command areas, increased yield of basmati rice (cv. Basmati-370) up to 3.12 t/ha. Integrated fertilization of (50% N + 50% green manure) would be the best option for further promoting the rice yield by up to 3.19 t /ha, besides maintenance of soil health. Laser leveled plots in both rice and wheat crops proved to be more water productive as compared to traditionally leveled plots. Water use efficiency in wheat was 8.07 kg/ha-mm with laser leveled plots showing 23.39% increase over traditionally leveled plot whereas in rice, laser leveled plots recorded 1.85 kg/ha-mm of WUE registering 25.85 % increase over traditionally levelled plot. Direct seeded wet sowing produced higher yield of 44.14 q/ha being at par with direct seeded dry sowing and conventionally sown rice 39.65 q/ha and 37.70 q/ha) but superior to SRI method of cultivation (37.70 q/ha) with WUE 2.05 kg/ha-mm. Application of water on every 4th day i.e. 3DADPW produced highest yield of 43.3 q/ha being superior to 5 and 7 DADPW with WUE of 1.75 kg/ha-mm.

- At Madurai, demonstration of water saving technologies viz., Drum seeding and SRI resulted in enhanced water saving and water productivity of 17.1%and 85.6 Rs. ha-1 mm-1 and 21.3 % and 95.1 Rs. ha-1 mm-1 respectively. Similarly the machine transplanting and irrigation to 5 cm one day after disappearance of ponded water accounted water saving of 19.6 %. Application of 100 per cent RDF (P&K-50% as basal + balance as WSF + LBF + Humic acid+ N through system) (T5) at six days interval is an ideal practice to achieve higher yield in the maize based cropping system as compared to traditional method of applying fertilizers with surface irrigation. Drip fertigation of 125 % of recommended P and K - 50 % P and K as basal and balance nutrients through WSF + soil application of sulphur @ 30 kg/ha to third ratoon sugarcane under sub surface drip irrigation system recorded the highest individual cane weight (1.69 kg), cane yield (178 t/ha) and net income (Rs.3,00,726 /ha).Subsurface drip fertigation system in maize-cotton-maize cropping system brought out the fact that 120 cm lateral spacing was found to be ideal for maize-cotton-maize cropping system as it recorded the higher water use efficiency and water productivity with the maximum net return in terms of cotton equivalent (8085 kg/ha), net return (Rs.2,31,492) and B:C ratio (4.06). Among different irrigation methods tested in groundnut, Micro-sprinkler methods of irrigation registered the highest pod yield of groundnut (3200 kg / ha) followed by sub-surface drip irrigation method. Method of fertilizer application to groundnut revealed that 50 per cent P and K as basal by straight fertilizer and the balance P,K and full N as water soluble fertilizer was statistically superior to the rest of the methods of fertilizer application in registering the pod yield and water use efficiency. Subsurface drip fertigation with 100 per cent RDF as WSF (WSF – Urea, 13: 40: 13, KNO3) + LBF had positive impact on the growth and yield attributes of ratoon banana and resulted in higher bunch yield (37.29 t/ha), water use efficiency (22.35 kg/ha/mm) and water productivity (268.16 kg/ha).

- At Pusa, under OFWM activities in Barkagaon sub-distributary of Gandak Command, it was found that improved water management practices for rice under SRI consisting of 3 days drying after disappearance of 3 cm of ponded water in rice performed better mean yield being 59.95 q/ha as compared to control in which mean yield was 42.79 q/ha. The WUE was also higher in the SRI (199.83 kg/ha-cm) as compared to 101.88 kg/ha-cm in the control. In case of wheat, grown after harvest of rice in Barkagaon sub-distributary of Gandak Command, higher yield (39.58 q/ha) and WUE (219.89 kg/ha-cm) were recorded with improved water management practices. With farmer's practice the yield and WUE were found to be 34.69 q/ha and 144.54 kg/ha-cm respectively. Brown manuring along with 100 % RDF and at 3 days after disappearance of ponded water proved as the best treatment combination for rice crop while application of vermi compost @ 3 t/ha or Brown manuring along with recommended dose of inorganic fertilizer and irrigation at 1.0 IW/CPE ratio was found to most suitable for wheat crop. Rice-Maize+Potato-Dhaincha or Rice-Maize+Pea cropping sequence should be adopted with irrigation level of 1.0 IW/CPE in dry season crops for sandy loam soil. Three irrigations at 20, 30 and 80 days after sowing either in zero tillage or conventional tillage method of wheat sowing was found most suitable.

- At Chiplima, under Hirakud command, transplanting of rice (cv: Khandagiri) on 15th January with application of irrigation at 1 day after disappearance of ponded water produced highest

grain yield with lowest water use efficiency. Under rice-rice cropping system in Hirakud command the field should be prepared with tractor operated mould board plough followed by rotavator with cage wheel. After puddling, urea should be applied @10 kg ha-1 with standing water of 10 cm for easy and efficient decomposition of stubble. Rice (cv: APO) with nitrogen @ 80 kg ha-1 along with application of irrigation water at 5 days interval produced highest grain yield. Whereas water use efficiency, was highest when irrigation was applied at 9 days interval.

- At faizabad, application of 7cm water through check basin (10x10m) at 1-3 days after disappearance of ponded water gave higher paddy yield with 35-46% water saving over farmers practice. Under limited water availability at the tail end of the distributary maximum pigeonpea equivalent yield of 17.29 q/ha was recorded with maximum net return of Rs. 37870/- when it was grown on raised bed in paired row inter cropping with rice on farmers field. Integrated farming system including pisi culture and duckery under multiple use of water was found most remunerative with highest net return of Rs. 83038/- per hectare per year and benefit cost ratio of 2.56 against conventional rice-wheat cropping system. Application of 6cm water through check basin (50m2) at critical stages produced 35.14% higher wheat yield with 50.29% WEE over farmers practice. Drip irrigation system with 80% wetted surface and 100% N recorded the highest Aonla yield of 45.8 kg/plant with 33% water saving in comparison to surface irrigation in which it was 25.8 kg/plant.
- At Shilling under North east Hilly region, residue management and conservation tillage in Rice-based system revealed significantly higher grain yield of rice under Zero Tillage for all crops with residue retention (5800 kg/ha) followed by the treatment where reduced tillage (5000 kg/ha) was practice along with residue incorporation. Under terrace land situation, zero tillage was equally good with conventional tillage in respect of yield of maize and succeeding toria. Further, maize along with groundnut intercropping system with or without residue incorporation was found suitable with significantly higher Maize equivalent yield. At Shillong, in Maize-Mustard cropping system, zero tillage was equally good with conventional tillage. The grain yield of maize and seed yield of mustard was significantly higher under the treatment that received Maize stalk cover + Poultry Manure + *Ambrossia* @ 5t/ha. Maize intercropped with Ash gourd was found as the best system for the terrace condition of mid altitude of Meghalaya in regards to soil moisture conservation and yield of Maize.

AICRP on Groundwater Utilization

Nine centres were operating under the All India coordinated Research Project on Groundwater Utilization for conducting research and extension activities in the field of regional groundwater assessment and modeling; conjunctive use of surface and groundwater in canal command areas; artificial groundwater recharge; groundwater pollution and transfer of technologies. Salient theme wise research achievements of the AICRP centres during 2012-13 are given below.

Regional groundwater assessment and modeling

Regional Climate Model data on weather conditions for Ludhiana were evaluated for biases and corrected through different functions. Climatic projections for 21st century showed that there would be increase in mean annual temperature and rainfall. The same data were used for groundwater modeling.

Different thematic maps and satellite image of IRS P6, LISSIII for Narsinghpur district of Upper Narmada Basin were used in GIS based spatial analysis to demarcate groundwater potential zone in the district.

In Coimbatore district of Tamil Nadu, which is located in PAP basin, out of 9 blocks, 6 blocks are over-exploited, 2 blocks are critical and one block is semi-critical.

In Wakal river basin in Rajasthan, about 48.83 per cent of the basin falls under poor groundwater potential zone and requires immediate attention to ensure sustainable groundwater management in the basin. The southern part of the basin, with 9.2 per cent (i.e. 174.39 km^2) of the total basin area, is suitable for artificial recharge.

Assessment of ground water resources of the southern districts viz. Patna, Gaya, Nalanda, Nawada, Bhojpur, Buxar and Aurangabad of the Bihar State was carried out. On basis of stage of groundwater development, the districts are under safe category.

Aquifer mapping of Uben river basin, Gujarat was done by vertical electrical sounding resistivity technique. Lime stone was found in unconfined aquifer near Girnar hilll whereas sand stone was found away from Girnar. In both the places, sand stone formations were covered by basaltic rock in confined aquifers.

Conjunctive use of surface and groundwater

Analysis of groundwater quality parameters in the command area of Mahadev distributary of Uttarakhand showed that groundwater of 27.17, 51.60, 11.22 and 5.67 percent of command area was found under excellent, good, doubtful and unsuitable category for irrigation purpose, respectively.

Total profit in the Dhimri canal command in Uttarakhand could be increased to Rs.270.79 lakhs compared to Rs.100.6916 lakhs under the existing cropping pattern by adopting optimal crop plan including Wheat, Rice, Sugarcane and Oil Seed crops and using fifty percent ground water recharge and surface water.

Under Conjunctive use planning of surface and groundwater in Mula Irrigation Project, Rahuri centre collected primary data related to reservoir storage and operation, climate, canal network and operation, command details, cropping pattern and amounts of canal and groundwater use necessary for optimal conjunctive use model.

Water user associations in command areas of three basins namely; Narmada, Betwa and Tones were surveyed to understand adoption of agricultural technologies and status of water productivity. It was found that water scarcity was responsible for better water management and higher water productivity values were observed in Betwa and Tones basin compared to Narmada Basin.

Performance of Pollachi main canal irrigation system (Zone-A and Zone B of 4(L) distributary of the main canal) in Tamil Nadu was evaluated in terms of Adequacy Index (PI_A), Dependability Index (PI_D), Equity Index (PI_E) and overall efficiency (PI_{EF}). The efficiency of the system over the years irrespective of their turn/ zone was rated as 'poor' (0.21-0.62), as the canal system was unable to meet water requirements of crops in command.

The agricultural productivity indicator i.e. water use efficiency was worked out for crops grown in command area of Zone-A and Zone B of 4(L) distributary of Pollachi main canal from year 2000 to 2010. Further linear programming technique was used to formulate the conjunctive use optimization model to arrive at the optimal allocation of surface and groundwater and to maximize the benefits within the framework of given constraints and designed cropping pattern.

Strategy for conjunctive water use of harvested water in check dam and groundwater was developed by Junagadh centre for growing wheat crop. It is recommended that state Govt. may allow use of harvested for irrigation instead of storing it for recharge only.

Artificial groundwater recharge

An artificial neural network (ANN) model was developed and validated with recorded ground water level in an observation well in command of Pimpalgaon Ujjaini Percolation Tank-I. The model gave satisfactory results.

On basis of survey of Haveli system in three villages of Jabalpur region; Sahsan Dhaneta and Ghunsor of Shahpura block, it was found that initial investments in Haveli fields were lower and economic returns from produce were higher.

Natural recharge in study area of 7400 sq. km, located in Walyar sub basin in Tamil Nadu, was estimated by empirical approaches as 11 to 15 percent with an average of 14 percent. This estimate was within range of 10 to 15 percent, given by Groundwater Estimation Committee (GEC) for hard rock areas. Water balance study of rainwater harvesting structures was carried out to estimate contribution of structures to recharge process.

The average recharge rate as result of low cost rainwater harvesting structure was estimated in micro-watershed in Rajasthan as 10.34, 7.63 and 7.55 cm/day for year 2010, 2011 and 2012, respectively, whereas corresponding net recharge volume was 7873.20, 6131.06 and 3918.44 m^3.

Groundwater pollution

On the basis of groundwater sampling in vicinity of Budha Nala waste water drain near Ludhiana city, it was observed that average concentrations of arsenic, magnesium, manganese, lead, boron and calcium in the samples were higher than maximum permissible limit of 0.01, 30.0, 0.1, 0.01, 0.5 and 75.0 mg l^{-1}, respectively, during the post-monsoon season.

Groundwater in districts of Bhatinda, Faridkot and Muktsar of south west Punjab was assessed for suitability of irrigation on basis of different quality parameters. Majority of the groundwater samples (37 percent) in the Bhatinda district were under marginal saline to highly saline (category 2) and could be used after mixing with canal water. The 24 percent of the samples were suitable (category 1) and 39 percent were unsuitable for irrigation (category 4) during pre-monsoon season. Similar types of categories were also observed in Faridkot and Muktsar districts.

The study to investigate effects on physico-chemical characteristics of ground water and surface water as result of disposal of effluent into streams in vicinity of Bajpur industrial area of Uttarakhand revealed deterioration in quality parameters of surface and groundwater resources.

Groundwater wells in vicinity of lagoons of untreated effluents from sugar factory and distillery and paper mill in Rahuri area were grouped as low, medium and high polluted depending on distance from lagoon. Effects of such polluted ground waters on yields of wheat crop and soil properties are being studied.

In Parambikulam Aliyar Basin of Tamil Nadu, magnesium dominated among cations followed by sodium, calcium and potassium. All the samples were with SAR < 10 and came under low sodium category. Also RSC < 5, all samples were under safe category. Maps showing spatial distribution of EC and Cl^- concentrations in basin were prepared

Groundwater of Rajsamand district in Rajasthan was found as Na-Mg-Ca and Cl-HCO_3-SO_4 type. The majority of groundwater samples were in high to very high salinity class.

Characterization of wastewater in districts of Haroti region covering districts of Bundi, Kota, Baran and Jhalawar of Rajasthan was initiated through survey, primary data collection and analysis.

In case of okra crop experiment by Pusa centre, yield attributing characters viz. plant height, flowering time, fruit yield, dry matter yield were found maximum with alternate irrigation with fresh and sewage water in comparison to other irrigation treatments. Also uptake of micronutrients (Zn, Fe and Mn) was highest. Porosity of the soil was improved while hydraulic conductivity and bulk density values of soil decreased.

The quality parameters of groundwater in vicinity of sea coast were assessed by Junagadh centre. Mostly samples belonged to very high (C5) to medium (C2) classes. None of samples were of safe category (C1). Effect of monsoon was not observed on ground water quality due to scanty rainfall.

A suitability of groundwater for drip irrigation in Amareli and Bhavnagar district of Saurashtra region was assessed. It was found that total permanent hardness of groundwater samples varied from 8.4 to 123.5 ppm at Amareli and from 9.2 to 129.2 ppm at Bhavanagar. It was less than 150 ppm *i.e.* safe limit for drip irrigation. The average of SAR and SSP were within critical limits of 10 and 60%, respectively. Very meager amounts of Fe, Mn and Cu were observed in ground water.

Transfer of technology

Scientists of different centres organized farmers' training, trainers' trainings, delivered TV and Radio talks, participated in *Krishi-Mahostav* and conducted demonstrations on groundwater recharge, water management and agricultural pumps. Six meetings for 319 farmers in districts of Uttarakhand and 2 trainings for 52 Trainers' were organized by Pantnagar centre. A State Level workshop was organized by Jabalpur centre for members of WUA and state officials on 29-30th August, 2012 on topic "*Kamand Kshetron Mein Jal Utpadakta S ansthaon Ki Bhoomika*". Around 216 participants attended the workshop. Training on "Water management" to the tribal farmers from 8 to 10th Jan. 2013 was held at Kokkal village of Nilgiri district by Coimbatore centre. Scientists also participated in seminars, conferences, symposia and workshops. The centres published extension articles, technical bulletins and research papers. A QRT meeting for centres of AICRP on Water Management and AICRP on Groundwater Utilization in Eastern Region was organized on 10th August 2012 at DWM, Bhubaneswar, for Southern centres was organized during 3-5th Sept. 2012 at AICRP on Groundwater Utilization, WTC, TNAU, Coimbatore and for northern centres at PAU, Ludhiana centre from 23 – 25th September 2012. Er. Chetan Singla received a fellowship of under prestigious The Netherlands Fellowship Programme (NFP) for attending a short course on Groundwater Resources and Treatment at Delft.

List of Publications

A. RESEARCH PAPERS IN REFERRED JOURNALS

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B. RESEARCH BULLETIN/ INFORMATION BROCHURE /LEAFLET

Ghosh, S. ,Kumar, A., Panda, D.K., Nanda, P., Nayak, A.K. and Verma, H.C. 2012. Links between irrigation, agriculture and living scenario in eastern Indian states. Research Bulletin No. 54. Directorate of Water Management (ICAR), Bhubaneswar, Orissa, India. 43p.

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C. BOOKS/ TRAINING MANUAL

Dubey, S. K., Dubey, R. K., Singh, A. K., Panda, P. K., Kala, S. and Sharda, V. N. (2012). Conservation of natural resources for food and environmental security (edited book), Satish Serial Publishing House, New Delhi.

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Awards / Honours / Recognitions

- Dr. P.S. Brahmanand, Senior Scientist, Dr. S. Ghosh, Senior Scientist, Dr. A. Kumar, Director and Mr. B.S. Parswal, T-6 were awarded with Indira Gandhi Rajbhasha Puraskar (First Prize) for the Year 2010-11 by Honorable President of India Shri Pranabh Mukherjee on 14th September 2012 for their contribution of best Original Book in Hindi ''वैशीकरण और भारतीय खाद्य सुरक्षा''".

- Recognition Award of 'National Academy of Agricultural Sciences (NAAS) in the field of soil, water and environmental science for the biennium 2011-12 was awarded to Dr. Gouranga Kar, Principal Scientist of this institute for his outstanding contribution on soil and water management. He developed agro-climatic and land specific technologies to mitigate drought / dry spells and to produce stable and higher yields and income from rainfed lands. He implemented sustainable cropping system, land use and water resources plan on large rainfed areas in farmer's field using remote sensing and GIS. The award was given by his Excellency, Governor of Odisha, Shri M.C.Bhandari on the occasion of XIth Agricultural Science Congress, held at OUAT, Bhubaneswar during 7th to 9th February, 2013.

- Dr. S. Ghosh, Senior Scientist and Dr. D.K. Panda, Senior Scientist received Lal Bahadur Shastri Outstanding Young Scientist Award 2011 of Indian Council of Agricultural Research (ICAR) in the category of Social Science and Natural Resource Management, respectively conferred by Hon'ble Union Minister of Agriculture and Food Processing

Industries Sh. Sharad Pawar and Hon'ble Minister of State for Agriculture and Food Processing Industries Sh. Harish Rawat at National Agricultural Science Complex, ICAR, New Delhi on 16th July 2012 in presence of Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR.

- Dr. Atmaram Mishra, Principal Scientist was awarded with Fellow of the Indian Society of Agricultural Engineers, New Delhi. The award was formally conferred during the 47th ISAE Annual Convention

during 28-30 January, 2013 at Acharya N.G.Ranga Agricultural University, Hyderabad.

- Dr. Atmaram Mishra, Principal Scientist was awarded with Fellow of the Indian Association of Soil and Water Conservationists, Dehradun. The Award was formally conferred during the regional conference of IASWC on Farmers first for conserving soil and water resources in southern region during 14-16th March 2013 at Karnataka Veterinary Council, Bangalore.

- Dr. Gouranga Kar, Principal Scientist has received the prestigious Fellowship of Indian Association of Soil and Water Conservationists, Dehradun. He chalked out contingency crop planning for drought mitigation and implemented for different southwest monsoon situations through alternative crop and water management and farmers were benefited by adopting this technology. Software's were developed for determining climate risks, reference evaporation and crop water balance study in watershed. The award

was given at the Annual conference on "Livelihood and environmental security through resource conservation in eastern region of India (5-7th April, 2012), held at OUAT, Bhubaneswar.

- Dr. Gouranga Kar, Principal Scientist has received the prestigious Fellowship of Association of Agro-meteorologists of India for his outstanding contribution in the field of Agro-metrological science. The award was given by Dr. L.S. Rathore, Hon'ble Director General, Indian Meteorological Department, New Delhi at the National Symposium on "Climate Change and Indian Agriculture : Slicing down the uncertainties (22-23 January, 2013) at CRIDA, Hyderabad.
- Dr. A. K. Thakur, Senior Scientist has been awarded Fellow of Indian Society for Plant Physiology (FISPP)-2012
- DWM Proficiency Award for the year 2010 was given by Director, Dr. Ashwani Kumar to different categories of staff (Scientific, Administrative, Technical and Supporting) on the foundation day of the Institute (12th May) for their good work. The recipients of the award in different categories were as follows:

Scientific Category	
1.	Dr. K.G. Mandal
2.	Dr. S. Mohanty
3.	Dr. D.K.Panda
4.	Dr. A.K.Thakur
Technical Category	
1.	Mr. S.K.Dash
Supporting Category	
1.	Mr. SanatanDas

- Dr. Madhumita Das, Dr. O.P.Verma, Dr. D.P. Sinhababu and Er. Ranu Rani Sethi received second best poster award on our paper entitled as 'Improving livelihood security through paddy cum brackish water shrimp farming in coastal Odisha' presented under Theme II on Sustainable production through resource management and conservation agriculture in Golden Jubilee International Symposium on "Sustainable Rice production and Livelihood Security: Challenges and Opportunities", at Cuttack (Odisha), India, during March 2- 4, 2013.

- Dr. A. K. Thakur, Senior Scientist has been awarded Best Poster Presentation Award-2012 for the presentation of research paper entitled 'Enhancing productivity and climate resilient crops through system of rice intensification (SRI)' at National Seminar of Plant Physiology by ANGRAU, Hyderabad during 12-14 December, 2012 held at ANGRAU, Hyderabad.
- Dr. S. Mohanty, Dr.M.K. Jha and Dr. A. Kumar received 'Banabihari Mohanty Memorial Award' from 'The Institution of Engineers, Orissa Chapter' for the research paper 'Simulation-Optimisation Modelling for Optimal Management of Groundwater in a Well Command of Eastern India.'
- Dr. S. Roy Chowdhury, Principal Scientist served as referee for international Journal "Photosynthetica", Academy of Sciences of the Czech Republic during 2012-13.
- Dr. S. Roy Chowdhury, Principal Scientist has been nominated as Editor for Indian Journal of Plant Physiology, of Indian Society for Plant Physiology, New Delhi for three year from 2012-2014.
- Dr. Madhumita Das, Principal Scientist was appointed as external examiner for evaluation of a Ph D thesis on "Land and water productivity of sundarbans as influenced by micro climate' of Bidhan Chandra Krishi Viswavidylaya.
- Dr. M.J. Kaledhonkar, Principal Scientist acted as co-chairman of the technical session-3 on Theme IV on Water and Environment during International Groundwater Conference (18-21 Dec. 2012)
- Dr. M.J. Kaledhonkar, Principal Scientist has been nominated as member of Editorial Board of Journal of Soil Salinity & Water Quality of Indian Society of Soil Salinity & Water Quality, CSSRI, Karnal.
- Dr. M.J. Kaledhonkar, Principal Scientist is selected as Executive Committee Member (National) of Association of Global Groundwater Scientists and Member of Editorial Committee Journal of Groundwater Research
- Dr. Gouranga Kar, Principal Scientist has been elected as Secretary, Indian Meteorological Society (Bhubaneswar chapter) in the Executive Council of the Chapter (H.Q.: New Delhi) for the biennium 2012-14.
- Dr. Gouranga Kar, Principal Scientist has been elected as Vice President, Association of Agro-meteorologists of India in the Executive Council of the Association (H.Q.: Anand, Gujarat) for the biennium 2013-14.
- Dr. Gouranga Kar, Principal Scientist, acted as a chairman of a session "Management of natural resources for sustainable agricultural production" in IInd J and K Agricultural Science Congress held at Jammu from (Jammu & Kashmir) 15-17 December, 2012.
- Dr. K.G. Mandal, Senior Scientist has become Elected Member of the Sectional Committee of the Section of Agriculture and Forestry Sciences for the year 2013-14 (101th Session of the Indian Science Congress) of the ISCA, Kolkata.
- Dr. K.G. Mandal, Senior Scientist has been selected as Editorial Board Member of the International Journal of Agronomy, Hindawi Publishing Corporation, USA.
- Dr. K.G. Mandal, Senior Scientist has been selected as Editorial Board Member of the Journal of Water Resources and Ocean Science, Science Publishing Group, USA.
- Dr. Gouranga Kar, Principal Scientist acted as a co-chairman of a session "Modern tools and techniques, Simulation modelling" in the Natural symposium on "climate change and Indian Agriculture : Slicing down the uncertainties, 22-23rd January, 2013 at CRIDA, Hyderabad.

Visit Abroad on Deputation

- Dr. A. Kumar, Director, DWM, Bhubaneswar, Dr. S.K. Jena, Principal Scientist, Visited Bulgaria under Indo-Bulgarian inter government programme of cooperation in science and technology project entitled" Decision support system for assessing impact of low quality water used in irrigated agriculture on food production" during 11th to 28th June, 2012.
- Dr Ashwani Kumar and Er. Ranu Rani Sethi attended a 3 week Capacity building program on "Improving the capacity of Indian State level water authorities on systemic and adaptive governance to climate change" at University of Melbourne, Victoria, Australia under Aus-Aid Asian Public Sector Linkages Program during 15th October to 3rd November 2012.

- Dr. A. Kumar, Director, DWM, Bhubaneswar, Dr. S.K. Rautaray, Principal Scientist, Dr. M. Raychaudhuri, Senior Scientist and Dr. S. Raychaudhuri, Senior Scientist visited CEBAC-CSIC, Murcia, Spain and Wageningen University, The Netherlands during 27th February to 7th March, 2013 under the New Indigo project, "Reuse options for marginal quality water in urban and peri-urban agriculture and allied services in the gambit of WHO guidelines (REOPTIMA)" sponsored by DST, Government of India.

QRT/ RAC/ IRC/ IMC Meetings

QUINQUINNIAL REVIEW TEAM (QRT) MEETING

The first meeting of 4th QRT meeting of Directorate of Water Management (DWM), Bhubaneswar was held during 3rd - 4th July, 2012 at Krishi Anusandhan Bhawan-II, Pusa, New Delhi under the Chairmanship of Dr G.B. Singh, former Deputy Director General (NRM), ICAR. The meeting was attended by Dr. G.B. Singh, Chairman, QRT, Prof. Jaswant Singh, Member, Prof. S. Raman, Member, Dr. K. Palanisami, Member, QRT, Dr. A. K. Singh, DDG (NRM), ICAR, Dr. J.C. Dagar, ADG (soil & water), ICAR, Dr Ashwani Kumar, Director, DWM, Dr. Gouranga Kar, Member Secretary, QRT. In his remark Dr. G.B Singh, Chairman highlighted the some of the water management issues of the country like problems in equity, distribution and efficiency of canal irrigated system, declined performance of tank irrigation system and ground water development prospects and potentials in different parts of the country. The second meeting of 4th QRT meeting of Directorate of Water Management (DWM), Bhubaneswar was held during 7th -11th September, 2012 at the head quarter of Directorate of Water Management, Bhubaneswar. The meeting was started with the field visit to Rubber dam site of the DWM on 7th September, 2012. The third meeting of the QRT was held during 3-5 September 2012 at Water Technology Centre, Coimbatore where progress of last five years (April 2007-March 2012) of 4 centres of AICRP on WM (Belvatgi, Bhavanisagar, Chalakudi, Madurai) and one centre under AICRP on Ground water utilization (Coimbatore) was reviewed. The fourth meeting of was held during 20-21 September, 2012 at CSK HPKV, Palampur. Fifth QRT meeting was held from 23rd – 25th September, 2012 in the Department of Soil and Water Engineering. Punjab Agricultural University, Ludhiana. In the meeting progress of work of 6 AICRP on Water Management centres and 4 AICRP centres on Groundwater Utilization from Northern India was reviewed. Sixth meeting of the QRT was held at Navsari Agricultural University, Gujarat during 10-12 October 2012. Finally last meeting of the 4th QRT was held at DWM head quarter, Bhubaneswar where draft report was prepared and the team also interacted with IMC for appraisal of major recommendations. Dr. Gouranga Kar, Principal Scientist and Member Secretary organized all the meetings and stakeholders' discussion at different institutes.

RESEARCH ADVISORY COMMITTEE (RAC) MEETING

The first meeting of sixth Research Advisory Committee of Directorate of Water Management was organized on 11 and 12th February 2013 at DWM Bhubaneswar under chairmanship of Dr. S.R. Singh, former Vice

Chancellor, RAU, PUSA and Project Director, DWMR, Patna, at Directorate of Water Management, Bhubaneswar. The meeting was attended by Chairman, RAC Dr. S.R. Singh, Former VC, RAU PUSA and PD, DWMR, Patna, and other members, Dr. B. Mohan Kumar, ADG (AG&AF), ICAR, New Delhi, Dr.S.D. Sharma, Ex-Dean (Agric. Engg.) OUAT, Bhubaneswar, Er. A.S. Goel, Superintendent Engineer Hydrological Observation Circle, CWC, Bhubaneswar, and Dr. Ashwani Kumar, Director, DWM, Bhubaneswar along with the scientists of Directorate of Water Management, Bhubaneswar. The Chairman and other RAC members in their opening remark outlined guiding principles of water management which was emphasized even in ancient Indian literatures. At the beginning of the meeting, Director presented the progress and achievements of the institute during 2011-12 followed by presentation of work under different programmes and AICRPs by programme leaders and Principal Scientists of AICRPs. The Chairman and other members appreciated the scientists for the achievements of DWM and AICRP on WM as well as AICRP on GWU projects during the period under report.

INSTITUTE RESEARCH COUNCIL (IRC) MEETINGS

During the year 2012-13, Institute Research Council (IRC) meetings were organized on 27th - 28th December 2012 and 23rd March 2013, respectively. The results of the on-going research projects were presented in the meeting and new research project proposals were discussed. The meeting was organized and coordinated by Dr. Atmaram Mishra, Principal Scientist and Member Secretary, IRC and chaired by Dr. Ashwani Kumar, Director, DWM, Bhubaneswar. All the scientists of the Institute participated in the meeting. During 2012-13, 9 projects were completed. Besides 11 ongoing projects, another 5 new projects were approved.

INSTITUTE MANAGEMENT COMMITTEE MEETING

During the year 2012-13, Institute Management Committee (IMC) meeting was held on 14th December 2012 at DWM Bhubaneswar under the chairmanship of Dr. Ashwani Kumar, Director, DWM, Bhubaneswar. Dr. P.K. Mishra, Director, Central Soil and Water Conservation Research and Training Institute, Dehradun, Dr. K.N. Tiwari, Professor, Department of Agricultural Engineering, Indian Institute of Technology, Kharagpur, Dr. R.C. Srivastava, Pr. Scientist, DWM, Bhubaneswar, Dr. A. Mishra, Pr. Scientist, DWM, Bhubaneswar, Sh. S.R. Khuntia, Chief Finance and Accounts Officer, CRRI, Cuttack and Sh. S.K. Mathur, Administrative Officer and Member Secretary, DWM, Bhubaneswar were present in the IMC meeting. The proceeding of last IMC was reviewed. Presentations were made on research activities and financial position followed by discussion. IMC was apprised of details of DPC/selection committees and equipments purchased. Purchase of new equipments was also discussed. The construction works done during 2010-11 and 2011-12 was also discussed in the meeting. Consultancy services provided by DWM were also appraised to the IMC members.

List of Completed / Ongoing / New In-House Projects

A. LIST OF IN-HOUSE RESEARCH PROJECTS COMPLETED DURING 2012-13

Sl. No.	Project Code	Project Title	PI Name
1.	WTCER/07/129	Economic perspectives of ground water extraction mechanism (GSMs) and irrigation markets in Mahanadi basin	Dr. M.K. Sinha
2.	WTCER/08/131	Improving the land use in rainfed medium and upland using CAM plants	Dr. O.P. Verma
3.	WTCER/08/132	Enhancing water productivity through integrated system of rice intensification	Dr. A. K. Thakur
4.	WTCER/08/135	Suitability of the available poor quality water resources for agricultural use under different agro climatic region	Dr. M. Raychaudhuri
5.	DWM/09/137	Characterization and Utilization of Sewage Water of Urban/ Peri-Urban areas for Agricultural Purposes	Dr. S. Raychaudhuri
6.	DWM/09/139	Growth and production physiology of cat tail *(Typha sp.)* under waterlogged condition	Dr. S. Roy Chowdhury
7.	DWM/09/141	Enhancing water use efficiency in selected vegetable crops by improving soils through vermin-compost and mulches application	Dr. Rajbir Singh
8.	DWM/09/142	Crop management interventions and contingency crop planning for post flood management in Orissa	Dr. P.S.B. Anand
9.	DWM/11/149	Ground water development and energy use dynamics for irrigation in Orissa	Dr. S. K. Srivastava

B. LIST OF IN-HOUSE ONGOING RESEARCH PROJECTS DURING 2012-13

Sl. No.	Project Code	Project Title	PI Name
1.	DWM/09/138	Micro-catchment water harvesting in the rainfed ecosystem of humid region	Dr. A. Mishra
2.	DWM/09/140	Assessment and development of water resources for diversified agriculture in waterlogged high rainfall area	Dr. R.K. Panda
3.	DWM/09/143	Development of water and energy efficient integrated farming system model for the rainfed farmers	Dr. S.K. Rautaray
4.	DWM/10/145	Sustainability of water Users associations (WAUs) and effect of participatory irrigation management (PIM) on agriculture and system performance	Dr. S .Ghosh
5.	DWM/10/146	Ground water modeling to determine the safe yield of coastal aquifer	Mrs. R.R. Sethi

Sl. No.	Project Code	Project Title	PI Name
6.	DWM/10/147	Conservation agriculture practices in maize based cropping system with special emphasis on nutrient and water availability for the rainfed sub-humid agro-ecosystem	Dr. H. Chakraborty/ Dr. P.K. Panda
7.	DWM/10/148	Assessment of water logging and land use system in different coastal district of Orissa using remote sensing and GIS	Dr. Ashok K. Nayak
8.	DWM/11/150	Ground water recharge guidelines for agro-ecological Region No. 8 with hard rock geology	Dr. M. J. Kaledhonkar
9.	DWM/11/151	Performance evaluation of drip irrigated mango (*Mangifera indica* L.) under deficit irrigation	Dr. Deepa Samant
10.	DWM/11/152	Impact of wastewater effluents on soil productivity constituents and its prospect of utilization in farming	Dr. M. Das
11.	DWM/12/153	Effect of dry spell occurrence on reduction in paddy yield and optimum design of rain water harvesting structure for its mitigation	Dr. S. Mohanty
12.	DWM/12/154	Extreme climatic effects on major cropping systems of Orissa	Dr. D.K. Panda
13.	DWM/12/155	Water budgeting in high-value shrimp monoculture and carp poly culture under varying intensification levels	Dr. R.K. Mohanty
14.	DWM/12/156	Enhancing water productivity through integrated system of rice intensification	Dr. A.K. Thakur

C. LIST OF IN-HOUSE NEW RESEARCH PROJECTS UNDERTAKEN DURING 2012-13

Sl. No.	Project Code	PI Name
1.	Development of run-off recycling model for production and profit enhancement through alternate land and crop management practices	Dr. P. K. Panda
2.	Evaluating deficit irrigation under drip system for rice based cropping sequence in canal command area	Dr. P. Panigrahi
3.	Identification of suitable crops for waste water irrigation	Dr. S. Raychaudhuri
4.	Development of agricultural water management portal	Dr. Ashok K. Nayak
5.	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

Human Resource Development

Participants	Name of the Seminar / Conference / Workshop	Organized by	Date of events
Dr. D.K. Panda	International conference on "Cryosphere and Climate Change" organized by the Snow and Avalanches Study Establishment (SASE).	Snow and Avalanche Study Establishment, Manali	2-4 April, 2012
Dr. A. Mishra Dr. S.K.Rautaray Dr. G. Kar Dr. S.Mohanty Dr.P.K.Panda Er Ranu Rani Sethi Dr. S.K. Srivastava	Conference on Livelihood and Environment Security through resource conservation in Eastern region of India (LESRC 2012)	Indian Association of Soil and Water Conservation, Dehradun & OUAT, Bhubaneswar	5-7 April, 2012
Dr. A. Mishra	Management Development Programme of Leadership Development – a pre RMP programme	National Academy of Agricultural Research Management, Hyderabad	9-20 April, 2012
Dr. K.G. Mandal	Annual International Event, "India Water Week 2012- Water, Energy and Food Security: Call for Solutions" at New Delhi.	Ministry of Water Resources, Govt. of India	10-14 April, 2012
Dr S. Raychaudhuri	17th Annual convention and Symposium 'Applications of Clay Science : Agriculture, Environment and Industry'	Clay Mineral Society of India, New Delhi and NBSS & LUP, Kolkata	27 – 28 April, 2012
All Scientists of DWM	'Agri-Business Camp for Zonal Technology Management- Business Planning and Development' at DWM, Bhubaneswar	ZTM-BPD Unit, NIRJAFT, Kolkata & Agri-Business Incubation (ABI) Programme, ICRISAT, Hyderabad	2 May, 2012
All Scientists of DWM	Brain Storming Session on "Water Policy- Issues and Strategies for Future" on 25th Foundation Day Celebration (Silver Jubilee), DWM, Bhubaneswar	DWM, Bhubaneswar	12 May, 2012
All Scientists of DWM	Lecture through Video Conferencing on XII Plan Programmes, delivered by Dr. S. Ayyappan, Secretary, DARE & DG, ICAR	DWM, Bhubaneswar	19 May, 2012
Dr. A. Mishra Dr. S. Roy Chowdhury Dr. R. K. Panda Dr. S.K. Rautaray Dr. K.G. Mandal Dr. S. Mohanty Dr. S. Ghosh Dr. S.K Srivastava	Global Conference on "Horticulture for Food, Nutrition and Livelihood Options" at OUAT, Bhubaneswar, Odisha	ASM Foundation, New Delhi and OUAT, Bhubaneswar	28-31 May, 2012
Dr. A. Mishra	Review meeting of Vigilance Officers with Chief Vigilance Officer of ICAR &Director DARE at ICAR-RCER, Patna	ICAR Vigilance Cell	4 June, 2012
Dr. S.K. Rautaray Dr. A.K. Thakur	Consultative Meeting on Research Issues in SRI	Livolink Foundation at Hotel Suryansh, Bhubaneswar	16-17 June, 2012
Dr. D.K. Panda	Workshop on "NAIP Project Evaluation"	IASRI, New Delhi	25 June, 2012

Dr. P.S. Brahmanand	NAIP Cost Committee Meeting	NAIP, ICAR, New Delhi	12 June 2012
All Scientists of DWM	Policy Dialogue on "Priorities and possibilities of investment for accelerating agricultural growth and reducing poverty in Odisha" at Hotel Suryansh, Bhubaneswar	DWM, Bhubaneswar & NCAP, New Delhi	6 July, 2012
Dr. M.K. Sinha	Training on 'Field Survey, Electronic Compilation and Analysis of Data	National Centre for Agricultural Economics and policy Research, New Delhi	21-28 July, 2012
All Scientists of DWM	International Inception Workshop under New Indigo on "Reuse options for marginal quality water in urban and peri-urban agriculture and allied services in the gambit of WHO guidelines" at DWM, Bhubaneswar	DST , Govt. of India & DWM, Bhubaneswar	29 August to 1 September, 2012
Dr. K.G. Mandal Dr. S. Ghosh	Golden Jubilee National Seminar on 'Advances in agricultural research towards food security and environmental sustenance'	Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal	01-03 September, 2012
Dr. Ashwani Kumar Dr. R.C. Srivastava Dr. A. Mishra Dr. M Das Dr. S. Roy Chowdhury Dr. R. K. Panda Dr. S.K. Rautaray Dr. R.K. Mohanty Dr. S. Mohanty Dr. S. Ghosh Dr. A.K. Nayak Dr. P. Panigrahi Dr. S.K Srivastava	Meeting on Water Platform	DWM, Bhubaneswar	9-10 September, 2012
Dr. A. Mishra Dr. K.G. Mandal Dr. M. Raychaudhuri Dr S. Raychaudhuri	34th Annual Convention of the Bhubaneswar Chapter of Indian Society of Soil Science (ISSS), at DWM, Bhubaneswar	DWM, Bhubaneswar & ISSS, Bhubaneswar Chapter	18 September, 2012
Dr. Ashwani Kumar Dr. M. Das Dr. M. Raychaudhuri Dr. S. Raychaudhuri Dr. A.K. Thakur Er. Ranu Rani Sethi Dr. S. Ghosh Dr. Ashok K. Nayak Dr. S.K. Srivastava	International Workshop on Understanding water-energy-GHG nexus for future water and food security	Indian Society of Water Management and The University of Melbourne, Australia, at NASC complex, New Delhi	27-28 September, 2012
Dr. R.C. Srivastava Dr. S.K. Srivastava	30th Skoch Summit - reforms 2.0	Skoch Summit, New Delhi	18-19 September, 2012
Dr. A. Mishra Dr. S.K. Jena	13th CIC meeting of NAIP C-4 project on "Design and development of Rubber dams for watershed"	DWM, Bhubaneswar	6 October, 2012
Dr. S. Raychaudhuri	Meeting on Biological Soil Health assessment	NCOF, Ghaziabad organized by Ministry of Agriculture, New Delhi	9 October, 2012

Dr. P. Panigrahi	National Conference on Science for shaping the future of India	Utkal University, Bhubaneswar	18-19 October, 2012
Dr. A. Mishra	Meeting of Project Coordinators and CRP Principal Investigators	NBPGR, New Delhi	5-6 November, 2012
Dr. S. Roy Chowdhury	State level workshop on Climate change risk reduction through integrated water management :special focus on floods and waterlogging	AusAid-UNDP, New Delhi at Puri, Odisha	5-6 November, 2012
Dr. Ashok K. Nayak	National Seminar on Mountain Fisheries: Challenges and Opportunities for Livelihood Security	Directorate of Coldwater Fisheries Research, Bhimtal, Nainital, Uttarakhand	5-6 November, 2012
Dr. M.K. Sinha	3rd annual review meeting on panel data and leaning repositories for rural transformation in village and household economies in South Asia	International Crop Research Institute for Semi Arid Tropics (ICRISAT), Hyderabad	7-8 November, 2012
All Scientists of DWM	Video Conferencing, Public Lecture on Indian Agriculture: Feeding Crores Forever at DWM, Bhubaneswar	INSA, New Delhi	19 November, 2012
Dr. K.G. Mandal Dr. S.K. Rautaray Dr. P. Panigrahi	Third International Agronomy Congress on "Agricultural Diversification, Climate Change Management and Livelihoods", at IARI, New Delhi	Indian Soc. Of Agronomy in collaboration with ICAR, IARI and NAAS	26-30 November, 2012
Dr. S. Ghosh	National Workshop on Recent trends on impact assessment and best practices	CIFA, Bhubaneswar	12-13 December, 2012
Dr. M.K. Sinha	Schedule hormonaistion workshop	International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Hyderabad	12-14 December, 2012
Dr. A.K. Thakur	National Seminar of Plant Physiology	ANGRAU, Hyderabad and Indian Society of Plant Physiology, New Delhi	12-14 December, 2012
Dr. M.J. Kaledhonkar Er. Ranu Rani Sethi Dr.D.K.Panda Dr. Ashok K. Nayak Dr. S.K. Srivastava	Fifth International Groundwater Conference (IGWC, 2012)	Maulana Azad college of Arts, Science and Commerce, Aurangabad and Association of Geologists and Hydro-geologists (GEOFORUM) Maharashtra, at Aurangabaad	18-21 December, 2012
Dr. G. Kar Dr. M.K. Sinha Dr. K. G. Mandal	100th Indian Science Congress	The Indian Science Congress Association (ISCA) & the University of Calcutta, Kolkata	3 - 7 January, 2013
Dr. M.K. Sinha	Brain storming workshop on "Rural Labour Markets and Agriculture" followed by a Policy Dialogue	International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Hyderabad and Centre for Economic and Social Studies, Hyderabad.	17 – 18 January 2013
Dr. G. Kar	National Symposium on climate change and Indian agriculture : Slicing down the uncertainties	CRIDA, Hyderabad	22-23 January, 2013

Dr. A. Mishra Dr. S.K. Jena Dr. K.G. Mandal Dr. M. Raychaudhuri	Review Meeting of 12th Implementation Support Mission of the World Bank for NAIP Projects at DWM, Bhubaneswar	DWM Bhubaneswar & PIU-NAIP, KAB-II, New Delhi	23-24 January, 2013
Dr. Ashwani Kumar Dr. A. Mishra Dr. S. Mohanty Dr. P. Panigrahi	47th Annual Convention of ISAE and International Symposium on Bio energy-Challenges and Opportunities	DRR, Hyderabad	28-30 January, 2013
Dr. G. Kar	XIth Agricultural Science Congress	NAAS, New Delhi and OUAT, Bhubaneswar	7-9 February, 2013
Dr. P. Nanda Dr. R.K. Panda Dr. S.K. Rautaray Dr. M. Raychaudhuri Dr. S. Raychaudhuri Dr. M.K. Sinha Dr. S. Mohanty Dr. P. K. Panda Dr. Ashok K. Nayak Dr. P. Panigrahi	Data analysis for Water Management using SAS	NAIP Consortium "Strengthening Statistical Computing for NARS" at DWM Bhubaneswar	18-23 February, 2013
Dr. Ashwani Kumar Dr. S.K. Jena	NAIP-IFPRI brain storming workshop on " Methodology to assess impact of capacity building under NAIP"	NAIP, ICAR, New Delhi	21-02-2013
Dr. Ashwani Kumar Dr. S.K. Rautray Dr. M. Raychaudhuri Dr S. Raychaudhuri	Meeting with the President and officials of Hydrographic Confederation of Segura (CHS), Murcia, Spain	CEBAS – CSIC, Murcia, Spain	1 March, 2013
Dr. Madhumita Das Dr. K.G. Mandal Dr. P. K. Panda	ARRW Golden Jubilee International Symposium on "Sustainable rice production and livelihood security: challenges & opportunities" at CRRI, Cuttack, Odisha	The ARRW in collaboration with ICAR, CRRI, IRRI & NAAS	02-05 March, 2013
Dr. Ashwani Kumar Dr. S.K. Rautaray Dr. M. Raychaudhuri Dr. S. Raychaudhuri	Workshop under REOPTIMA.	Dutch Project Partners of REOPTIMA at Wageningen University, The Netherlands	4 March, 2013
Dr. R.C. Srivastava Dr. M.Das Er. Ranu Rani Sethi	Workshop on Groundwater Security and Sustainability in Odisha-Vision 2025	Central Groundwater Board and Central Groundwater Authority, South Eastern Region, Bhubaneswar, Odisha	20 March, 2013
Dr. S.K. Jena	NAIP C-4 Annual review meeting and workshop	NAIP, ICAR, New Delhi	25-26 March 2013

List of Sponsored / Collaborative / Consultancy Projects

Title	Budget (Rs. in lakh)	Duration	P.I. / CCPI	Sponsored by
Design and development of rubber dams for watersheds	81.47	2008-2014	Dr. S.K. Jena	NAIP, ICAR, New Delhi
Sustainable Rural Livelihood and Food Security to Rainfed Farmers of Orissa	29.09	April 2008 to December 2013	Dr. S. Mohanty	NAIP, ICAR, New Delhi
Strengthening statistical computing for NARS	57.30	April 2009-March 2014	Dr. D.K. Panda	NAIP, ICAR, New Delhi
Georeferenced soil information system for land use planning and monitoring soil and land quality for agriculture	35.16	April 2009-March 2013	Dr. M. Raychaudhuri	NAIP, ICAR, New Delhi
Farmers' Participatory Action Research Programme (2nd Phase)	48.3	December 2010- 2012	Dr G. Kar	Ministry of Water Resources, GOI, New Delhi
Improving water productivity under canal irrigation command through conservation and recycling of runoff, seepage, rainwater and groundwater using tanks and wells	45.49	2010-2013	Dr. K.G. Mandal	Ministry of Water Resources, GOI, New Delhi
Decision Support System for Assessing Impact of Low Quality Water Used in Irrigated Agriculture on Food Production	27.10	March 2010-Dec. 2013	Dr. Ashwani Kumar	DST, GOI under Indo–Bulgarian Inter-Governmental Programme of Cooperation in Science and Technology
Tracking Change in Rural Poverty in Household and Village Economies in South Asia	30.00	April 2010 to March 2014	Dr. M.K. Sinha	Bill and Melinda Gates Foundations(USA)
National Initiative for Climate Resilient Agriculture	600	2011-2017	Dr. G. Kar	ICAR, New Delhi
Development of Decision Support System (DSS) for irrigation water management in Hirakud Canal Command area	11.70	January 2012 to December 2015	Dr. R.K. Panda	ISRO, NRSA, Hyderabad
Reuse options for marginal quality water in urban and peri-urban agriculture and allied services in the gambit of WHO guidelines	19.78	2012-2014	Dr. Ashwani Kumar	DST, GOI under New Indigo
Improving the capacity of Indian State level water authorities on systemic and adaptive governance to climate change	Aus $ 499490	2012-2014	Dr. Ashwani Kumar	Australia Centre of International Agricultural Research (Aus-Aid Project)
Decision Support System for Enhancing Water Productivity of Irrigated Rice-Wheat Cropping System	56.90	June 2012-May 2016	Dr. M.J. Kaledhonkar	National Fund for Basic, Strategic & Frontier Application Research in Agriculture" ICAR, New Delhi
Impact of climate variability and anthropogenic factor on groundwater resources of India	30.00	Nov. 2012-Oct. 2015	Dr. D.K. Panda	ICAR-Challenge project
Appropriating the use of Sakthi Sugars Limited - distillery effluent in different cropping practices	2.00	24 months	Dr. M. Das	Sakthi Sugars Limited

Events Organized

Brain Storming Session on 'Water Policy – Issues & strategies for Future'

A brain storming session on 'Water Policy – issues & strategies for future' was organized on 12th May 2012 at the XXV Foundation Day of the Institute. Dr. A.K. Singh, DDG (NRM), ICAR, New Delhi was the Chief Guest. Dr. I. C. Mahapatra, Ex-VC of BAU, Ranchi and OUAT, Bhubaneswar, Dr. K. Pradhan, Ex-VC, OUAT, Bhubaneswar, Engineer in Chief, Department of Water Resources, Government of Odisha, Director (Horticulture), Government of Odisha, Director, WALMI, Cuttack, Odisha were the other dignitaries on this occasion. The Heads, In-Charge of local ICAR Institutes were also present. Dr. Ashwani Kumar, Director presented an overview of 25 years' achievements during the event. Farmers from various districts were also participated and expressed their concerns on the issues.

DWM Progressive Farmer's Honour

Farmer's initiative to adopt improved water management practices and enhancing farm income was appreciated by giving 'DWM Progressive Farmer's Honour' for 2012 to ten farmers of six districts viz. Khordha, Jagatsinghpur, Nayagarh, Dhenkanal, Kendrapara and Puri of Odisha on 12 May 2012. Dr. M. Das, Program Leader, OFTD coordinated this event.

Agri-Business Camp

An Agri-Business Camp was organized at the Institute, in which ITMU I/Cs of ICAR institutions of Eastern Region along with the prospective entrepreneurs participated on 2 May, 2012. Dr. R. K. Panda organized this event.

International Inception Workshop under REOPTIMA

International Inception Workshop under the project "Reuse options for marginal quality water in *urban and peri-urban agriculture and allied services*" (REOPTIMA) was held at this Institute during 29th August to 1st September, 2012 (extended to 2nd September, 2012). The other project partners from Wageningen University, The Netherlands, CEBAS-CSIS, Murcia, Spain and NIOH, ICMR, Ahmedabad alongwith eminent experts from IWMI, WTC, TNAU, Universities, Research

Organisations and representative from line departments discussed and deliberated on various issues on wastewater management and applications to prepare a roadmap for activities under the project. The project team at DWM comprising of Dr. Ashwani Kumar, Dr. S. Raychaudhuri, Dr.(Mrs) Mausumi Raychaudhuri and Dr. Sachin Rautaray organised the workshop.

Stakeholders Meeting on Wastewater Management

A stakeholder meeting was organized with the waste water managers, policy makers and technical experts from Government Departments, DWM Scientists and experts from Spain and Netherlands during the 'International Inception Workshop under New Indigo' The theme of the meeting was 'Wastewater management including applications'. Representatives from Water Resource Department, Central Water Commission, Directorate of Research for Women in Agriculture, State Pollution Control Board, State Agriculture/Horticultural Directorate, Central Rice Research Institute, Cuttack. 38 experts participated in the meeting.

Another meeting was organized for consultation with scientific community. Experts from IWMI, Hyderabad, experts from Spain and Netherlands, National Institute of Occupational Health, Ahmedabad, Water Technology Centre TNAU, Coimbatore, Orissa University of Agriculture and Technology, Kalinga Institute Industrial Technology, Utkal University and other organization along with scientists from Directorate of Water Management, Bhubaneswar city, Odisha interacted during the meeting on the theme 'Wastewater management including applications'. 38 experts participated in the meeting.

Exposure/Field Visit of European Scientists

Exposure/Field visit of a group of European Scientists from The Netherlands and Spain and Indian Scientists from Ahmedabad, Hyderabad, Tamil Nadu was

organised to Wastewater Treatment Plants in Bhubaneswar and Cuttack and farmers field at Joypurpatna on 28th August to 2nd September, 2013. The visiting scientists interacted with the farmers, visited Bhubaneswar sewage fed Gangua canal and farmers' participatory experimental fields of Directorate of Water Management.

Exposure/Field Visit of Bulgarian Scientists

Exposure/Field visit of a group of Bulgarian Scientists from University of Sofia, Bulgaria was oragnised to AICRP GWU Centre at MPUAT, Udaipur, Rajasthan to visit the experimental sites and to interact with the researchers and farmers using low quality water for irrigation under arid condition.

Meeting on Consortia Research Platform on Water

A two days meeting on Consortia Research Platform on Water was organized at DWM Bhubaneswar during 9th-10th September 2012 under the Chairmanship of Dr. Ashwani Kumar, Director DWM. Six experts namely, Dr. A.K.Sikka, the then Technical expert of NRAA, New Delhi; Dr. S.R.Singh, Former VC of RAU, Pusa; Dr. H.S.Chauhan, Former Dean, College of Agricultural Engineering, Pantnagar Agricultural University; Dr. N.Sarangi, Former Director, CIFA, Bhubaneswar; Dr. P.K. Mahapatra, Former Dean, College of Agriculture, OUAT,

Bhubaneswar; and Dr. J.M.L. Gulati, Dean, College of Agriculture, OUAT, Bhubaneswar deliberated in this meeting on various researchable issues which needs to be addressed under different themes. Dr. Atmaram Mishra, Principal Scientist of DWM coordinated the meeting.

34th Annual Convention of the Bhubaneswar Chapter of ISSS

34th Annual Convention of the Bhubaneswar Chapter of Indian Society of Soil Science (ISSS) was organised at DWM, Bhubaneswar on 18 September, 2012.

International Workshop on Adaptive Governance

An International workshop on "Improving the capacity of Indian State level water authorities on systemic and adaptive governance to climate change" during 5-7th February 2013 at Hotel SURYANSH, Chandrasekharpur, Bhubaneswar, Odisha was organized by Indian Society of Water Management (Odisha chapter) in collaboration with University of Melbourne, Australia sponsored by Aus Aid project. Delegates from different department of Water Resources, Govt of Odisha and Rajasthan, OUAT, DWM and University of Melbourne participated.

Seminar cum Monthly Meet

To maintain high level of research standards, interpersonal interactions among scientists was a priority for DWM where scientists of other research/academic organizations were also invited. Total 14 number of Seminars and Monthly Meetings were organized during April 2012 to February 2013. During the seminars 9 external eminent experts including three scientists from European countries, former VCs, 14 lectures from Scientists in DWM, and 9 students from different Universities delivered presentation/lectures on various prioritized research issues, exposures and research achievements . One more will be organized in March 2013.

Training Programmes on Watershed Development

- A 5-day long training programme on 'Land and water management for sustainable watershed development' was organized at DWM, Bhubaneswar from 15th -19th May, 2012, sponsored by Odisha Watershed Development Mission, Govt. of Odisha, Bhubaneswar. Twenty five engineers/officers participated in that training programme. Different aspects of watershed management for increased productivity were discussed in that training. Dr. Gouranga Kar, Principal Scientist and Dr. P.S.B. Anand, were the Course Coordinators for that training programme.

- A Six days long training programme was organized on 'Water Use Management under IWMP' at Bhubaneswar from 18th - 22nd December, 2012 sponsored by National Rainfed Area Authority, Planning Commission, Govt. of India. Twenty six engineers/officers from 12 states participated in that training programme. Different aspects of irrigation management for increased productivity and prevention of waterlogging were discussed in that training. Dr. A.K. Sikka, Technical Expert, Watershed, National Rainfed Area Authority, Planning Commission, Govt. of India and presently Deputy Director General (NRM), ICAR, New Delhi was the Chief Guest in the valedictory programme of

the training. Dr. Gouranga Kar, Principal Scientist and Dr. P.S.B. Anand, Senior Scientist were the Course Coordinators for the training programme.

Farmers Training Programmes Organised

- Four one-day farmers training programmes on 'Rainwater management for sustainable agriculture and rural livelihoods' were conducted at Mahadia, Dhenkanal on 16.2.2013, at Pasa Singh, Dhenkanal on 17.2.2013, at Kotapala, Dhenkanal on 2.3.2013 and at Khamara, Dhenkanal on 3.3.2013 in which a total of 127 farmers including 51 women farmers were trained. Dr. S. Mohanty organized this programme.
- One day farmers' training programme - cum Researcher-Farmer Interface Meeting on Waterlogged Area Management was organized at Kuapada, Baleswar District, Odisha on 16th March 2013 in which 61 farmers from the area participated in the training programme. Dr. S. Roy Chowdhury, Dr. S. Ghosh, Dr. P.S.B. Anand, Dr. R.K. Mohanty and Dr. A.K. Nayak organized this programme.

Training of Students

A M. Tech student from NIT, Warangal, Andhra Pradesh was trained to for a period of 21 May to 30 June 2012 on wastewater management in this Institute.

- Summer training was imparted to B. Tech student from 1 – 30 June 2012 on water management.
- 44 B. Tech students from Sikkim were exposed to various achievements of DWM as a part of their study tour on Dec. 22, 2012.

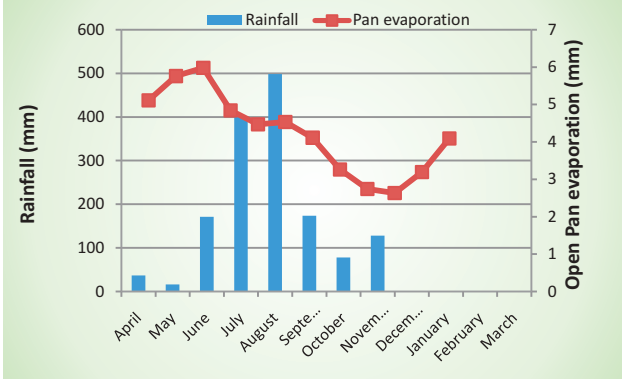
Exhibition Organised

- Exhibition of Institute's significant accomplishments was made in the WATER EXPO 2012 at Pragati Maidan, New Delhi, organized by the Ministry of Water Resources during an Annual International Event i.e., INDIA WATER WEEK- Water, Energy and Food Security: Call for Solutions 10-14 April 2012.
- Exhibited DWM accomplishments on the occasion of foundation day celebration of CRRI on 23 April 2012.
- Exhibited DWM's achievements in the XI Agricultural Science Congress held from 7 – 9 February 2013 at OUAT Bhubaneswar
- Exhibited DWM's achievements in the state level agricultural fair held from 19 – 22 March 2013 at Janta Maidan, Bhubaneswar

Weather

Meteorology data 2012-13

The daily rainfall and USDA open pan evaporation data recorded at DWM Central Research Farm, Deras, Khordha were collected and analyzed. The total monthly rainfall and mean monthly evaporation data are presented in figure. The total of rainfall occurred was 1503mm during 2012-13 and August month was found wettest with the highest rainfall of 498.5mm. The monthly average pan evaporation data varied from 2.63 mm in January to 5.98 mm in the month of June.



Promotion / Transfer / Retirement

- Dr S.K. Rautaray Dr. M.J. Kaledhonkar, Dr. S.K. Jena and Dr. R.K. Mohanty were promoted to Principal Scientist under CAS with effect from 01.01.2009, 21.01.2009, 20.2.2010, and 20.1.2012 respectively
- Dr. P.S. Brahmanand was redesignated as Senior Scientist with pay band Rs.37,400-67,000/- and RGP of Rs. 9000/- with effect from 19.12.2011.
- Dr. S. Ghosh, Dr. D. K. Panda, and Dr. H. Chakroborty was promoted from RGP Rs. 7000 to Rs. 8000 and re-designated as Senior Scientist with effect from 10.07.2009, 24.10.2009 and 31.07.2011 respectively.
- Dr. A. K. Nayak was promoted from RGP Rs. 7000 to Rs. 8000 w.e.f 27.12.2010 and re-designated as Senior Scientist with effect from 01.04.2011.
- Er. R.R. Sethi was promoted from RGP Rs. 7000 to Rs. 8000 with effect from 07.10.2009.
- Smt. Sunanda Naik was promoted to T (7-8) w.e.f. 18.07.2011.
- Dr. P. K. Panda, Senior Scientist (Agronomy) was transferred from CSWCR&TI Research Centre, Agra to Directorate of Water Management, Bhubaneswar on 16th July, 2012.
- Dr. Deepa Samant, Scientist was transferred to CHES, Bhubaneswar on14.5.2012.
- Shri B.S. Parswal, T-6 (Technical Officer-Hindi) was transferred to Krishi Bhavan, ICAR, New Delhi on 03.12.2012.
- Dr. S.K. Srivastava, Scientist was transferred to NCAP, New Delhi on21.01.2013.

Personnel

Director
Dr. Ashwani Kumar

Principal Scientist

Dr. R.C. Srivastava
Dr. Atmaram Mishra
Dr. M. Das
Dr. S. Roy Chowdhury
Dr. P. Nanda
Dr. R.K. Panda
Dr. S.K. Rautaray
Dr. M.J. Kaledhonkar
Dr. G. Kar
Dr. S.K. Jena
Dr. R.K. Mohanty

Senior Scientist

Dr. (Mrs.) M. Raychaudhuri
Dr. S. Raychaudhuri
Dr. S. Mohanty
Dr. M. K. Sinha
Dr. K.G. Mandal
Dr. P.K. Panda
Dr. A.K. Thakur
Dr. P.S. Brahmanand
Dr. S. Ghosh
Dr. D.K. Panda
Dr. A.K. Nayak
Dr. H. Chakraborty[c]

Scientist (SS)

Er. Ranu Rani Sethi
Dr. P. Panigrahi
Dr. O.P. Verma

Scientist

Dr. Deepa Samant[a]
Dr. S.K. Srivastava[a]

Technical (T-9)

Dr. M.S. Behera
Er. D.U. Patil

Technical (T-7-8)

Mrs. Sunanda Naik

Technical (T-6)

Mr. B.S. Parswal[a]

Technical (T-5)

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

Technical (T-4)

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

Technical (T-3)

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

Technical (T-1)

Mr. A. Parida

Administrative Officer

Mr. S.K. Mathur

Finance & Accounts Officer

Mr. S.K. Das

Assistant Administrative Officer

Mr. R.C. Behera

Private Secretary

Mrs. M. Padhi

Personal Assistant
Mr. Trilochan Raut

Assistant

Mr. A. Mallik
Mr. J. Nayak
Mr. B.P. Sahoo

Upper Division Clerk

Mr. R.K. Dalai
Mr. A.K. Pradhan

Lower Division Clerk

Mr. N.K. Mallick
Mr. C.R. Khuntia
Mr. B.S. Upadhyaya
Mr. S.C. Das

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

a- Transferred; b- Lien; c-Passed away

Finance

Sl. No.	Head of A/c.	Non-Plan		Plan	
		Budget 2012-13	Expenditure 2012-13	Budget 2012-13	Expenditure 2012-13
1.	Establishment Charges	480.00	468.30	-	-
2.	O.T.A	0.05	0.05	-	-
3.	Pension & Retirement Benefits	23.00	21.86	-	-
4.	T.A.	2.70	2.70	8.00	8.00
5.	Research & Operational Exp.	7.20	7.20	20.00	20.00
6.	Administrative Expenses	18.90	18.90	49.00	49.00
7.	Miscellaneous Expenses	2.15	2.15	1.00	1.00
8.	H.R.D.	-	-	2.00	2.00
9.	Equipment	-	-	15.25	15.23
10.	Works	-	-	49.00	49.00
11.	Library Books & Journals	-	-	5.75	5.77
	Total	**534.00**	**521.16**	**150.00**	**150.00**
12.	**AICRP on Water Management**	-	-	**1470.00**	**1470.00**
13.	**AICRP on GWU**	-	-	**365.00**	**365.00**

AICRP WM-PC Unit

Sl. No.	Head of A/c.	Sanctioned (Non-Plan) (2012-13)	Actual Expenditure (Non-Plan) (2012-13)
1.	Establishment Charges	32.00	32.00
2.	T.A.	0.40	0.40
3.	Research & Operational Exp.	0.60	0.60
	Total	**33.00**	**33.00**

जल प्रबंधन निदेशालय
Directorate of Water Management

(भारतीय कृषि अनुसंधान परिषद् / Indian Council of Agricultural Research)
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