Bulletin No. 3 | 2018

SOIL AND WATER CONSERVATION BULLETIN

INDIAN ASSOCIATION OF SOIL AND WATER CONSERVATIONISTS

218, KAULAGARH ROAD, DEHRADUN - 248 195, UTTARAKHAND, INDIA

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SOIL AND WATER CONSERVATION BULLETIN

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त्रिलोचन महापात्र, पीएच.डी.
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सचिव एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
Secretary & Director General

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Foreword

Research on developing soil and water conservation technologies has reached a certain level of maturity which is evidenced in form of contained land degradation due to concentrated efforts of researchers and developmental agencies under the supportive Govt. policies.

However, to keep pace with new and dynamic challenges in natural resource management, there is need to promote mass scale participatory research, adoption and fine tuning of the technologies to suit to the diverse situation across the country. Large number of technology modifications, farm level innovations and success stories remains unnoticed. Bringing them to public domain in desired format has potential of motivating different stakeholders in adopting and promoting soil and water conservation technologies. An opportunity of bringing rich experiences on planning, implementation, impact evaluation of soil and water conservation interventions in watershed development mode has been smartly encased by the Indian Association of Soil and Water Conservationists (IASWC).

I appreciate the efforts and idea of IASWC for publishing Soil and Water Conservation Bulletin annually containing information on advancement in SWC technologies, field experiences and views of the renowned professionals, with objective of sharing farmer's friendly resource conservation technologies with different stake holders.

I convey my heartiest congratulations to IASWC and editors for their untiring efforts in bringing out the 3rd issue of this publication containing updated information on various aspects of soil and water conservation and hope that the IASWC will continue the efforts of bringing future issues to contribute towards natural resource conservation and management in the national interest.

(T. MOHAPATRA)

Dated the 28th December, 2018
New Delhi

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सामुदायिक विकेन्द्रित जल तथा मिट्टी प्रबंधन द्वारा नदी पुनर्जीवन एवं जलवायु परिवर्तन अनुकूलन से किसानों को स्थायी समृद्धि

जलपुरूष श्री राजेन्द्र सिंह*

किसी भी देश की प्रगति या अवनति में वहां की जल सम्पदा का काफी महत्व होता है। जल की उपलब्धि या प्रभाव के कारण ही बहुत सी सम्यतायें एवं संस्कृति बनती और बिगड़ती है। इसलिए हमारे देश की सांस्कृतिक चेतना में जल का काफी ऊंचा स्थान रहा है। वर्षा जल को उसी स्थान पर रोक लेते थे। हमारे पूर्वज जानते थे कि तालाबों से जंगल व जमीन का पोषण होता है। भूमि के कटाव एवं नदियों के तल में मिट्टी के जमाव को रोकने में भी तालाब मददगार होते हैं। जल के प्रतिएक विशेष प्रकार की चेतना और उपयोग करने की समझ उनकी थी। इस चेतना के कारण ही गांव के संगठन की सूझ–बूझ से गांव के सारे पानी की विधिवत उपयोग में लेने के लिए तालाब बनाये जाते थे। इन तालाबों से अकाल के समय भी पानी मिल जाता था। इनकी देख–भाल, रख–रखाव, मरम्मत आदि के कामों से गांव के संगठन को मजबूत बनाने में मदद मिलती थी।

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जैसा कि गांवों की व्यवस्था से संबधित अन्य बातों में होता था, उसी तरह तालाब के निर्माण व रख–रखाव के लिए भी गांववासी अपनी ग्राम सभा में सर्वसम्मति से कुछ कानून बनाते थे। ये कानून 'गंवाई दस्तूर' कहलाते थे। ये दस्तूर 'गंवाई बही' में लिखे जाते थे, या मौखिक परम्परा के जरिये पीढ़ी चले जाते थे। गांव में आने वाले बाहरी व्यक्ति को भी इन गंवाई दस्तूर का पालन करना पड़ता था। ये गंवाई दस्तूर चूंकि सामान्य बुद्धि के अनुसार कायम होते थे। इसलिए करीब–करीब हर गांव में एक से ही होते थे। अतः सामान्य तौर से तो लोग इससे परिचित ही होते थे, नही तो भी बाहर से आने वाला सहज ही उन्हें समझ लेता था।

अलवर जिले के इस क्षेत्र में तालाब संबंधी कुछ पुराने गंवाई दस्तूरों से ज्ञान हुआ है कि तालाब की 'आगोर' में कोई जूता लेकर प्रवेश नहीं करता था। शौचादि के हाथ अलग से पानी लेकर आगोर के बाहर धोये जाते थे। आगोर में किसी गांव सभा की अनुमति के बिना मिट्टी खोदना मना होता था। आगोर में किसी गांव सभा की अनुमति के बिना मिट्टी खोदना मना होता था। आगोर से नहीं बल्कि तालाब के जल ग्रहण क्षेत्र तक में शौचादि के लिए जाना मना था। किसी प्रकार गंदगी फैलाने वाले को तालाब की सफाई करके प्रायश्चित करने का सुझाव दिया जाता था। प्रायश्चित के लिए तालाब की पाल पर पेड़ लगाने तथा बड़ा तक उसकी देख–भाल करने की परम्परा थी।

तालाब के जल–ग्रहण क्षेत्र से भूमि कटकर नहीं आये और तालाब में जमा नहीं हो, इसकी व्यवस्था तालाब बनातें समय ही कर दी जाती थी, जिससे लम्बें समय तक तालाब उथले नहीं हो पाते थे। जब तालाब की मरम्मत करने की आवश्यकता होती थी, तो पूरा गांव मिल–बैठकर, तय करके यह काम करता था। तालाब से निकलने वाली मिट्टी खेतों में डालने या कुम्हारों के काम में आती थी।

तालाब को गांव की सार्वजनिक सम्पति माना जाता था। गांव के लोग जब किसी दूसरे गांव को जाते थे, तो सबसे पहले तालाब को अपने गांव की सम्पति में गिनाया जाता था। जिस गांव का जैसा तालाब होता था, वैसा ही उस गांव को माना जाता था। गांव का तालाब अच्छा है, तो उस गांव को समृद्ध संगठित, शक्तिशाली माना जाता था। गांव के महत्वपूर्ण निर्णय लिए जाते थे।

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यह परम्परा 1890 तक तो बराबर चली। इसके बाद अंग्रेजों का ध्यान हमारे गांवाई संगठनों, स्वैच्छिक संस्थाओं तथा लोगों के अभिक्रम को खत्म करनें की

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*तरूण भारत संध, अलवर, राजस्थान

तरफ गया। उन्होंने पूरी सक्रियता से इन सब सहज चलने वाली गांवाई व्यवस्थाओं को खत्म करने की योजना विभिन्न प्रकार से बनाई–कहीं नहर सिंचाई योजना तो कहीं बड़े बांध आदि के स्वप्न दिखाकर, तो कही हमारी उच्च सांस्कृतिक धरोहर, तालाब के जल की निंदा करके और कहीं हमारे देश की शिक्षापद्धति को प्रदूषित करके हमारे ही देशवासी तथा–कथित शिक्षित कहे जाने वाले लोगों द्वारा हमारी संस्कृति की बुराई कराके, समृद्ध तालाबों की सम्पन्न परम्परा चालू रही। इन तालाबों से सिंचाई भी होती थी। इस तरह तालाब गांव की विकेन्द्रित अर्थव्यवस्था का हमारे ये तालाब जीते–जागते उदाहरण थे। राजस्थान के जिन क्षेत्रों में केवल दो–चार सेन्टीमीटर वर्षा होती थी, उनमें भी इन तालाबों के सहारे लोग व पशु जीवित रहते थे। जोधपुर, बाड़मेर, जैसलमेर के महा मरूस्थल क्षेत्र कम वर्षा के बावजूद आज की अपेक्षा ज्यादा विकसित थे। पानी कम होते हुए भी इस क्षेत्र की पुरानी हवेलियां, महल, बड़े–बड़े बाजार, अन्तर्राष्ट्रीय व्यापार केन्द्र यहां की तालाब व्यवस्था के कारण ही सम्पन्न हुए थे और उसकी उपयोगिता के प्रमाण थे।

सन् 1890 तक अंग्रेजी शिक्षा का प्रभाव देश मे बढ़ गया था और अंग्रेजों का षड़यंत्र सफल होने लगा था। सबसे पहले अंग्रेजी शिक्षा का प्रभाव हमारे यहां के राजाओं, सामन्तों जागीदारों आदि पर पड़ा। जो पहले अकाल के समय तालाबों के निर्माण पर अधिक ध्यान देते थे, ये अब अपनी राजधानी के शहरों की चार दीवारी बनाने आदि कामों को महत्व देने लगे। इनके पूर्वजों ने जो तालाब बनाये थे वे बिन, देख–रेख के टूटने लगे, और जो एक बार टूट गया उसका पुनःनिर्माण नहीं हुआ। इनको समय ने और मिट्टी की गाद ने भर दिया। इस प्रकार पुराने तालाब खत्म होते गये।

हमारे देश में यह कहावत प्रचलित है कि ‘‘जैसा राजा, वैसी प्रजा’’। यह कहावत चरितार्थ हुई और ग्रामवासियों में भी तालाबों के प्रति उदासीनता बढ़ती गई। इसी प्रकार गांवों के तालाब नश्ट हुए और अंग्रेजों की नीति गांवों में भी अपना रंग दिखाने लगी। ग्रामसमाज के टूट जाने के कारण तालाबों का निर्माण, रख–रखाव और मरम्मत बंद हो गये। गांव के तालाबों के साथ–साथ गांव के संगठन भी बिखरने लगे।

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स्वतंत्रता की लड़ाई में केवल बापू ने अपनी बातचीत और भाषणों में अवश्य गांव के तालाब को प्रतिष्ठित किया था, लेकिन अन्य लोगों का इस तरफ कोई विशेश ध्यान केन्द्रित नहीं हुआ। अंग्रेजी शिक्षा और अंग्रेजियत में पले हमारे दूसरे नेता हमारी समाज व्यवस्था की खूबी को समझ नहीं पाये, बल्कि उसे हीन मानकर उसकी निंदा करते रहे। उस समय बापू ने चर्खें के साथ–साथ गांव के तालाब–चारागाह के रख–रखाव को भी रचनात्मक कार्यक्रमों से जोड़ा होता तो अच्छा होता, हांलाकि उनकी खुद को तो इन सब बातों का ध्यान था। आजादी मिलने के समय ही बापू ने तत्कालीन प्रधानंमत्री जवाहार लाल नेहरू का ध्यान ग्राम–व्यवस्था को पुनर्जीवित करने की और दिलाया था, लेकिन नेहरू पश्चिमी सभ्यता से प्रभावित थे। उनकी प्राथमिकता भाखड़ा जैसे बांध बड़ी–बड़ी सिंचाई योजनाओं से तालाबों पर सबसे अधिक प्रहार हुआ।

बड़े बांध बनाने पर भारत सरकार सन् 2008 तक अरबों–करोड़ों रूपये खर्च कर चुकी है। इन योजनाओं से दो करोड़ हैक्टर जमीन सिंचित होने का सरकारी दावा था। वास्तव में कितनी जमीन की सिंचाई ये योजनायें कर रही हैं। यह कहा नहीं जा सकता, क्योंकि जिस प्रकार इनके आंकड़े इक्ट्ठे किये जाते हैं, उसके कारण सारी बात शंकास्पद है। इस अर्से में 246 बड़ी योजनायें शुरू की गई थीं, उनमें सिर्फ 65 योजनायें अभी तक पूरी हुई हैं। इन बड़ी योजनाओं में अब जो घाटे की धारा बह रही है वह चौंकाने वाली है। एक वर्ष में हजारों करोड़ का घाटा कहां से, कैसे पूरा होगा ? यह बात निश्चित ही जागरूक व्यक्ति को चिन्तित करती रहती है। लेकिन इन योजनाओं से बड़े–बड़े ठेकेदारों को मुनाफा, इन्जीनियरों को घूस और नोकरी तथा नेताओं को लूट में हिस्सा मिलने के साथ वाह–वाही जो हासिल होती है, और गांवों के पानी से बड़े उद्योगपतियों को सस्ती बिजली मिलती है। बड़े देशों की और बड़े कारखानों की बड़ी मशीनें, सीमेंट आदि की बिक्री करना, नहर बनाना, जिसमें गांव के गरीबों की जमीन जाये–इस तरह सारा लाभ चंद बड़े घरानों को मिलता है। यही सब हमारे नीति–निर्धारकों की ‘विकास’ की परिभाषा है।

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बड़े बांधों से ''सिंचाई'' का बहाना तो सिर्फ लोगों की आंखों में धूल झोंकने के लिये था। अगर सही तथ्य समाने आते जायें तो वास्तव में बड़े बांधों के कारण कुल–मिलाकर सिंचाई पहले की अपेक्षा कम की हुई है क्योंकि इन बांधों से नदियों के प्रवाह रूक जाने के कारण इन प्रवाहों के दोनों ओर की लाखों एकड़ जमीन और उसमें स्थित कुएं सूख गये हैं तथा भूगर्भ जल का स्तर पिछले दस–बीस बरसों में पचास से एक सौ फीट तक नीचे चला गया है। इन बड़े बांधों का असली उद्देश्य तो किसान की स्वावलम्बी व्यवस्था थी उसे समाप्त करके किसान का भाग्य इन लोगों के हाथों में सौंप दिया गया।

इन सीधे–सादे लेकिन असरकारक तालाबों की अब भी उपेक्षा करने की भूल की जा रही है। 1950 में भारत में कुल सिंचित क्षेत्र की 17 प्रतिशत सिंचाई तालाबों से की जाती थी। ये तालाब सिंचाई के साथ–साथ भू–गर्भ के जलस्तर को भी बनाये रखते थे, इस बात को ठोस प्रमाण उपलब्ध हैं। 1950 से पहले तो हमारे तालाब ही सिंचाई के प्रभावी साधन थे। सूदूर भूतकाल में तो 8 प्रतिशत से अधिक सिंचाई का क्षेत्रफल 1890 तक निरन्तर बढ़ता रहा था। इस स्वावलम्बी सिंचाई योजना का अंग्रेजों ने जानबूझकर खत्म करने का जो षड़यंत्र रचा था, उसे स्वतंत्र भारत के योजनाकारों ने बरकरार रखा है और वर्तमान, जनविरोधी, ग्राम–गुलामी की सिंचाई योजना को तेजी से लागू किया है।

गत वर्षों के भयंकर अकाल ने एक बार फिर तालाबों की याद दिलाई है। इस पर जगह–जगह कुछ लोगों ने अध्ययन किये हैं। इन अध्ययन–कर्ताओं में श्री वान ओप्पन तथा सुब्बाराव का मानना है कि तालाबों से सिंचित जमीन असिंचित भूमि की अपेक्षा तीन गुनी अधिक उपज देती है। सूखे इलाकों में खास तौर से तालाबों के महत्व को समझने वाले अनेकों स्वैच्छिक समूह प्रकाश में आये है जो इस ओर काफी चिन्तित हैं, और कुछ न कुछ कर रहे हैं। थानागाजी तहसील में तालाब निर्माण का कार्य कर रही है।

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कुल मिलाकर हमने गत वर्षों में छोटे–बड़े लगभग दस हजार से ऊपर तालाब जोहड़, छोटे बांध राजस्थान में बनायें या मरम्मत कराये है। इनमें कुल दस करोड़ रूपया लगा है, लेकिन इनके लाभ देखें जाये तो हमें स्वयं को आश्चर्य होता है। उदाहरण के लिए, वर्ष 1986 में गोपालपुरा गांव के सिंचाई के तथा पीने के पानी वाले कुएं सूख गये थे। गांव के जवान लोग मजदूरी के लिए दिल्ली तथा अहमदाबाद चले गये थे। जमीन में कुछ पैदा नहीं हो रहा था, तभी इस गांव में तालाब के निर्माण का कार्य जारी किया गया और सन् 1987 के जून तक गोपालपुरा गांव में तीन बड़े तालाब बनाये। गांव वाले इन्हें बांध कहते है तथा एक छोटा तालाब बनकर तैयार हो चुके थे। इनके निर्माण कार्य मं दस हजार रूपये की कीमत का गेहूं दिया गया। जुलाई 1987 में इस क्षेत्र के अन्दर कुल 13 सेंटीमीटर वर्षा हुई। यह सारी वर्षा एक साथ ही 48 घंटे के अंदर हो चुकी थी। इनके पानी से जमीन 'रिर्चाज' यानी पुनः सजल हो गई, और गांव के आस–पास के 20 कुओं में जलस्तर ऊपर आ गया।

वर्षा का पानी जो तालाबों में इक्ट्ठा हुआ था, वह अपने साथ जंगल व पहाड़ियों से पत्ते, गोबर आदि मे बहाकर ले आया था, जो तलाबों की तली मे बैठ गया। बड़े तालाब खेतों की जमीन पर बने हुये थे। इसलिए नवम्बर तक पहुंचते–पहुंचते तालाबों का पानी तो नीचे की जमीन की सिंचाई करने के काम में ले लिया गया और तालाब के पेटे की जमीन में गेहूं की फसल बो दी। एक फसल में केवल इन तालाबों की जमीन से ही 300 (तीन सौ) क्विंटल अनाज पैदा हुआ जिसकी कीमत बजार भाव से करीब पौन लाख होती है। इसके अलावा तलाब में पूरे वर्ष पानी भरा रहा। इसे पशुओं के पीने के पानी के लिए बनाया गया था। इस प्रकार गांव के पशुओं को पूरे वर्ष पीने का पानी सहज उपलब्ध होता रहा। गांव का पीने का पानी वाला कुआं जो सूख गया था वह अब पानी भरा रहता है। कुओं का जल स्तर अब 90 फीट नीचे से उठकर 20 फीट तक पहुंच गया है।

तालाबों के चारो तरफ हरी घास उगने लगी है। पेड़ हरे–भरे होकर तेजी से बढ़ने लगे हैं। तालाबों का पानी जंगली पशुओं तथा पक्षियों को अपनी तरफ आकर्शित करता है, जिसमें एक उजड़े हुए गांव का वातावरण सुहावना बन गया है। पक्षियों द्वारा फसल को नुकसान पहुंचाने वाले कीड़े खाये जाने तथा पक्षियों की बीट से जमीन के पानी के उपयोग की व्यवस्था फिर से

सामुदायिक भावना और परस्पर सहयोग का वातावरण बर रहा है। पीने का पानी लेने के लिए पहले दूर जाना पड़ता था, जिसमें गांव की महिलाओं की बहुत सी समय शक्ति नष्ट होती थी। यह परेशानी अब खत्म हुई है। इसी तरह हर वर्ष गांव से मजदूरी करने लोगों को बाहर जाना पड़ता था, पर अब इन्हें गांव में ही काफी काम मिलने लगा है। नीमी जैसे कई गांव जिनमें पहले मजदूरी करने जयपुर जाते थे। अब ये जयपुर के सेठों को रोजगार देने वाले बन गये हैं। इस प्रकार इन तालाबों के कारण अनेक लाभ हुए हैं।

यह क्षेत्र पहाड़ की तलहटी में और ढालू होने के कारण तेज वर्षा के पानी जमीन को काटकर बहां ले जाता था। जमीन का उपजाउपन वर्षा के पानी के साथ बाहर चला जाता था, इसलिए जमीन में नमी की कमी रहती थी, तथा फसल का बीज ही क्या घास तक नहीं उगती थी। यहां वर्षा कम होती है, और जो होती है, वह भी एक साथ और तेज होती है, फिर पूरा साल सूखा पड़ता रहता है। इसलिए इस क्षेत्र में तालाब अत्यन्त आवश्यक एवं खास तौर से उपयोगी है। तालाबों से अब भूमि का कटाव भी रूक गया है।

इसी प्रकार किशोरी गांव में एक ''चैकडैम'' बना है, जिसे बड़ा तलाब कह सकते हैं। यह भी जुलाई 1987 में पूरा तैयार हो चुका था। इसके निर्माण में कुल लागत (पचास हजार रूपये) आई, जिसमें आधी लागत ग्राम के श्रमदान से जुटाई गई। इस तालाब के भराव क्षेत्र में ही 250 क्विंटल अनाज पैदा हुआ । यह तालाब एक ऐसी तेज धारा को रोकता है, जिसने गत वर्षों में एक सौ एकड़ से अधिक भूमि को बंजर (खेती के आयोग्य) बना दिया था। जमीन में बड़े–बड़े नाले व खड्डे हो गये थे। वह जमीन स्वतः ही समतल होने लगी है। जमीन में बड़े–बड़े नाले व खड्डे हो गये थे। वह जमीन स्वतः ही समतल होने लगी है। अब वह खेती योग्य हो गई है। कहा जा सकता है कि इस तालाब के भराव क्षेत्र में ही 250 क्विटल अनाज पैदा हुआ। यह तालाब एक ऐसी तेज धारा को रोकता है, जिसने गत वर्षों में एक सौ एकड़ से अधिक भूमि को बंजर (खेती के आयोग्य) बना दिया था। जमीन में बड़े–बड़े नाले व खड्डे हो गये थे। वह जमीन स्वतः ही समतल होने लगी है। अब वह खेती योग्य हो गई है। कहा जा सकता है कि इस तालाब ने पूरी एक सौ बीधा जमीन खेती के योग्य बना दी है। कुाओं का जलस्तर ऊपर आ गया है। इस तालाब में रूकने वाला पानी जो पहले नीचे जाता जिस सैकड़ों बीधा भूमि को बिगाड़ता था, वह बिगाड़ा भी अब रूक गया है।

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चम्बल के गांवों मे जो साथी बन्दूक लेकर फिरते थे अब इन्होंने बन्दूक छोड़कर फावड़े से तालाब बनाने शुरू किये, तो इनके काम से करौली जिले की सपोटरा तहसील के गांवों के जीवन मे सुख समृद्धि शांति आ गई। डकैत कहलाने वाले भाई सज्जन–किसान और देवता बन गये। अब इनकी महेश्वरी नहीं शुद्ध–सदानीरा बनकर बहने लगी। खिजुरा गांव बहुतों को दूध–अनाज देने वाला बना गया है। इन्होंने हजारों को अपने गांवों मे बुलाकर कुंभ किया। बेपानी से पानीदार बन गये। अब तक 6500 वर्ग किमी0 क्षेत्रफल में एक हजार अठ्ठावन गांवो ने अपने हाथों से दस हजार से ज्यादा तालाब बनाकर सात छोटी–छोटी नदी अरवरी, सरसा, रूपारेल, भगाणी, जहाजवाली, साबी और महेश्वरी नदियां पुनर्जीवित हो गई। अब भूजल का स्तर ऊपर आकर नदियों को सदानीरा बना रहा है। बढ़ते ताप और बिगड़ते मौसम के मिजाज को भी तालाबों की नमी हरियाली बनाकर ठीक करती है। वातावरण के कार्बन को पेड़ अपने पत्तों, तनों और जड़ों में जमाकर लेते हैं। अतः तालाब जैसा छोटा स्थानीय काम वैश्विक समस्या बिगड़ते मौसम के मिजाज और धधकते ब्रहामाण्ड को सन्तुलित करने का उपचार तालाब हैं।

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हमने अब तक जो दस हजार तालाब बनाये हैं, उनके अनुभव पर से हम पूरे अधिकार के साथ कह सकते हैं कि किसी भी तालाब के निर्माण में जितनी रकम खर्च होती है, उसकी पूर्ति, यदि सामान्य वर्षा हो जाये, तो एक वर्ष में हो जाती है। हम आंकड़ों की भाषा नहीं जानते, लेकिन इस काम में लगे श्रम से अधिक आर्थिक लाभ के साथ–साथ गांव की एकता का सुखी आनन्दमय वातावरण तथा बे–सहारा पशु–पक्षियों को तालाब पर किलोलें करते देखकर मन बाग–बाग हो जाता है। इस आनन्दाभुति के कारण आगे से और हजारों से लाखों तालाबों के निर्माण की शक्ति हममें आ गई है। अमेरिका के साथी पैट्रिक मेकौली ने हमारे तालाबों का अध्ययन करके लिखा है। तालाब में हजार लीटर

पानी पकड़ने में तीन रूपये खर्च हुआ है। बड़े बांधों में इस पानी को पकड़कर उपयोग कर्ता पहुंचाने में तीन सौ से अधिक खर्च होता है। अतः तालाबों में पानी पकड़कर उपयोग करना ही सबसे सस्ता और स्थाई उपाय है।

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इस भौतिक और भावनात्मक लाभ के साथ–साथ इस काम ने आज की शोषणकारी और विकृत व्यवस्था का नंगा चित्र भी सामने ला दिया है। दरअसल राजनेताओं को गांववासियों की बन रही शक्ति पता नहीं क्यों नहीं सुहाती है ? प्रशासनिक अधिकारियों तथा तकनीकी लोगों को तो गांव–वासियों की शक्ति और परम्परागत स्वावलम्बन की पद्धति अखरती ही रही है। जब ये तालाब बनने आरम्भ हुए थे, तो एक बार राजस्थान सरकार के सिंचाई विभाग के अधीक्षक अभियन्ता से इन्हें अवैध कहकर तोड़ने का नोटिस दिया था। जिलाधीश ने भी इस बात के पैरवी की थी। इन्हें तोड़ने के लिए राज्य–सचिवालय मे काफी सरगर्मी रही, पर गांव वालो के डटे रहने के कारण फिर जोच हुई और छः माह बाद विकास आयुक्त का पत्र आया कि यह अच्छा कार्य है, इसमें सरकार का सहयोग है।

देखने और समझने में आया है कि जब सरकार को मजबूरी हो जाती है, तो जिस काम को पहले बुरा, अहितकर, यहां तक की कभी–कभी 'देशद्रोही' बतलाया गया हो वह भी उपयोगी बन जाता है। ठीक यहीं इस तालाब प्रकरण में हुआ। जब मुख्यमंत्री को यह बात मालूम हुई कि तालाब लोगों ने मिलकर बनाये हैं और तालाब तोड़े गये तो तालाब टूटने से पहले वहां के लोग मरने को तैयार हैं, तो ये 'अवैध' तालाब वैध होने के साथ–साथ बहुत अच्छे हो गये। इस अच्छे कार्य में सरकार का सहयोग प्राप्त करने की सलाह भी हमें साथ में मिली। संयुक्त राष्ट्रसंघ जिन जोहड़ों को नारू रोग का जनक मानकर जोहड़ों को पूरा रहा था। उन्हें ही जोहड़ नाम से 'बेस्ट प्रकटिस' कहना शुरू किया है। सवाल यह उठता है, कि आज हर अच्छे रचानात्मक काम के लिए पहले संघर्ष क्यों करना पड़ता है।

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बड़ें बांध और नहरों से होने वाली सिंचाई का खर्च चालीस हजार रूपये प्रति हैक्टेयर पहुंच गया है। इसके अलावा तवा, नर्मदा भांखड़ा आदि से निकलने वाली नहरों का दुश्परिणाम भी लोगों ने देख लिया है। इसे समझकर जगह–जगह इन बांधों का विरोध भी हो रहा है। विरोध करने वाले छोटे बांध या सिंचाई के तालाबों की बात भी सुझा रहे हैं। आशा है जब हमारे योजनाकार ही इस बात को मान जायेंगे और तालाब बनाने को अच्छा काम कहेंगे, तथा जो पैसा अभी बड़े बांधों पर खर्च हो रहा है उससे बहुत कम खर्च में तालाबों के जरिए उतना ही काम करने की संस्तुति करेंगे। लेकिन वह दिन तभी आयेगा जबकि हम सरकार की कोई मजबूरी बनेंगे। अब हमें बड़े बांधों पर रोक लगाने के लिए सरकार की मजबूरी ही खोजनी पड़ेगी तभी तालाबों को भी संरक्षण मिलेगा।

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'यह सारी सृश्टि मेरे लिए बनी है, मैं जितना और जिस प्रकार चाहूं उसके उपयोग का मेरा अधिकार है' – यह गलत धारणा ही आज की कई आर्थिक समस्याओ की जड़ में है। वास्तव में सृश्टि मनुश्य के लिए नहीं है, सृश्टि का अपना स्वतंत्र प्रयोजन है। मनुश्य उसका एक अंग है, अतः सृश्टि का आदर करके जीना है।

कुल मिलाकर सारी सृश्टि एक है, उसके विभिन्न अंश परस्पर संबधित ही नहीं परस्पर अवलम्बित है। सृश्टि एक है, उसके विभिन्न अंश परस्पर संबधित ही नहीं है। सब अवलम्बित है। सृश्टि 'मेरे लिये' नहीं है। वास्तव में वह 'किसी के लिये' नहीं है, सबके लिए है। इसलिए मनुश्य को प्रकृति से उतना ही लेना चाहिए जितना उसकी जीवन–धारणा के लिए आवश्यक हो। और जो लिया जाये वह भी सेवा करके, त्याग करके, बदले में अपनी ओर से कुछ न कुछ करके अर्थात यज्ञ करके।

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जितना हम अपने जीवन में जल उपयोग करें उतना ही हम अपने श्रम से पसीना बहाकर, तालाब बनाकर, प्रकृति के कार्य में सहयोग देवें। जितना लें उतना ही, वैसा ही प्रकृति को तालाब बनाकर हम लौटाते हैं। इसलिए तालाबों की परंपरा समयसिद्ध और आज भी खरी है। जहां समाज लगता है। तालाब

बनाकर अपने को पानीदार बना लेता है। तालाब तोड़ने वालों का सामना करके भी अपना तालाब बचा लेता है।

हमारे तालाब दुनिया के सबसे बड़े बांध से हजारों–लाखों बेघर होते हैं। हाजारों तालाब बेघरों को घर–बार, पेड़–पौधे, रोटी–पानी देकर आबाद बनाते हैं। बाढ–सुखा़ रोकते हैं। मौसम का मिजाज सुधारते हैं। ब्रहामण्ड का ताप सन्तुलित बनाते हैं।

भारत का किसान जब तक खेती को संस्कृति मानकर जल व मिट्टी का संरक्षण करता रह तभी तक उसकी स्थायी बिना धरती को बिगाड़े स्थायी समृद्धि के रास्ते पर आगे बढ़ता रहा था। तभी तक भारत का किसान दुनिया को सिखाने वाला प्राकृतिक उत्पादन कर्ता था। आज किसान को अपने उस मूल ज्ञान की तरफ पुनः देखने व दिशा मे काम करने की जरूरत है।

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Doubling Farmer's Income in Rainfed Areas in the Context of Climate Change

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INTRODUCTION

Our country will celebrate its 75th Independence Day on 15th August, 2022. Our current Honorable Prime Minister Shri Narender Modi has given this task to agriculture researchers, policy-makers, extension-activists and others to double the income of farmers in comparison to their income in the year 2015. Formula of income calculation is subtract expenditure of production from gross-profit earned by selling the produced commodity. For enhancing income; two options are there; either enhance the gross profit or reduce the expenditure. This is very simple mathematical calculation.

Agricultural income can be enhanced by two ways; one by increasing productivity (more crop production from constant agriculture area) and by area expansion (taking more production from more agriculture area). Further area expansion of agricultural crops is not possible instead maintaining a constant status is a challenge due to rampant urbanization, industrialization, road-highways construction etc. Some area-expansion may be possible by bringing non-traditional marginal areas under cultivation like hills, deserts, ravines, coastal belts etc. but at the cost of high investment. This is called horizontal crop-diversification. If farmer processes his farm produce through value addition to any other commodity, this is called vertical crop-diversification. Example wheat processed to form flour; tomatoes processed to sauce; mangoes processed to pickles, chutney, candy etc. This vertical crop diversification is being looked as most important option for income enhancement. Another way of enhancing agriculture income is to reduce the cost of crop production. Cost of production includes two types of costs; one is fixed costs which include expenditures like rent on land revenue, farm buildings, tractors and machinery, lease, cesses, taxes and other expenditures and second one is variable costs like expenditure on inputs used *i.e.* seeds, manures & fertilizers, tillage (bullocks, tractors, machinery etc.), pesticides (insecticides, fungicides, weedicides etc.), transportation, farm laborer (family members or hired laborers), irrigation, depreciation on farm implements and buildings, marketing, interest on working capital, crop-insurance etc.

Climate change context

There are almost unanimous opinion that rising atmospheric greenhouse gas concentrations are impacting global climatic conditions, altering the temporal and spatial patterns of temperature, rainfall, evaporation, and other climatic variables. Although some regions in the world particularly India is likely to experience extreme rainfall events under future changing climate, but this increase in rainfall is likely to be expressed in terms of high intensity rainfall events which may add to the drought as well as flood frequency. Further, in many regions, elevated temperatures are likely to be accompanied by decreases in rainfall thus increases the severity of water shortages and high temperature stress. This is considered to be one of the most serious problems related to climate

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change, as water is a primary factor needed for agricultural production. Indeed, agriculture uses 70% of the Earth's available fresh water. Growth, development and economic yield of crops are largely influenced by water availability in a semi-arid dry land agricultural system. Therefore, understanding the processes of field water balance, developing mechanism for water harvesting and judicious use is critical in such a system.

Rainfed farming

Rainfed regions are those where crop production is exclusively dependent upon rainfall. In India, rainfed regions cover 177 districts across all agro-climatic zones of the country. However, they are mostly concentrated in arid and semi-arid areas. Most of these districts are country's poorest. Rainfed regions account for 68% of the total net sown area in the country, according to the Union Ministry of Agriculture (Fig.1). Low productivity of rainfed area though a major limitation is presently being seen as an opportunity for enhancing production and income.

A recent assessment on agriculture done by S.M. Jharwal, Principal Advisor to the Government of India, shows that out of a net sown area of 141 million hectares (M ha), 86 M ha is rainfed. Of the 190 M ha of gross cropped area, the ultimate irrigation potential is assessed at 140 M ha. This potential takes into account major, medium, and minor irrigation systems, using surface as well as ground water sources. So far, the irrigation potential of about 103 M ha has been created, but the actual gross irrigated area is only 77 M ha. Based on these assessments, it emerges that currently 113 M ha of gross cropped area is rainfed, and even if we create a full irrigation potential of 140 M ha, about 85 M ha would remain rainfed (based on the current utilization of 75%). However, rainfed areas change depending on rainfall and water availability in reservoirs.

State-wise assessment shows that 13 states account for about 92% of the total rainfed area. These include the main states of Maharashtra (14.49 M ha), Madhya Pradesh (9.31 M ha), Rajasthan (12.15 M ha), Karnataka (7.46 M ha), Uttar Pradesh (4.42 M ha), Andhra Pradesh (6.48 M ha), Gujarat (6.58 M ha) and West Bengal (2.54 M ha).

Rainfed agriculture plays an important role in India's economy and has potential to significantly add to the income enhancement. Rainfed crops account for 48% of the total area under food crops and 68% of the area under non-food crops in the country. Nearly 50% of the total rural workforce and 60% of the livestock in the country are concentrated in the dry districts. Rainfed areas are a paradox. Further, crop-wise analysis shows that major coarse cereals are mostly grown in rainfed areas. Coarse cereals are still the main source of food for India's poor, residents of rainfed areas. For instance, 92, 94 and 80% of the total area under sorghum, pearlmillet, and maize respectively is rainfed. Similarly, 86% of the area under pulses is rainfed. About 83%

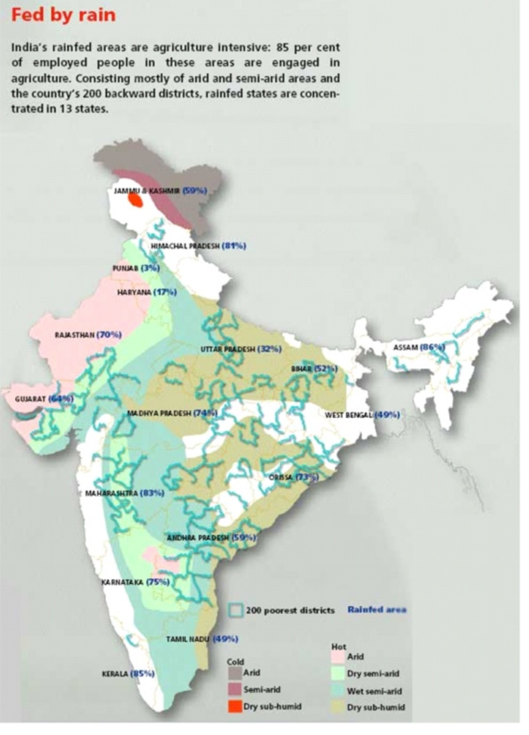

Fig. 1. Rainfed regions of India (Source: NRAA)

groundnut and 99% soybean are grown under rainfed conditions. About 73% area under cotton is rainfed. Though rainfed areas contribute in a major way to India's agriculture, the difference between the output of rainfed and irrigated areas is remarkable which need to be bridged by enhancing productivity of rainfed areas to reduce regional disparity in India (Fig. 2).

A redeeming feature of the semi-arid tropic regions is that there is a wide variation in crop yields within the region. For example, the average yield of sorghum varied from 370 kg ha^{-1} in farmers' fields to 1,460 kg ha^{-1} in demonstration fields and 1,060 kg ha^{-1} with assured input supply. There is still considerable scope for increasing productivity in fields because the yields actually being achieved for many crops in many states are much below their realizable potential (even of existing varieties if best cultivation practices are used). In wheat, the unutilized potential is only 6% in Punjab, but rises to 84% in Madhya Pradesh. In Maize, the gap is only 7% in Gujarat, but 300% in Assam. In rice, the potential yield increase is over 100% of actual yield in Assam, Bihar, Chhattisgarh and Uttar Pradesh.

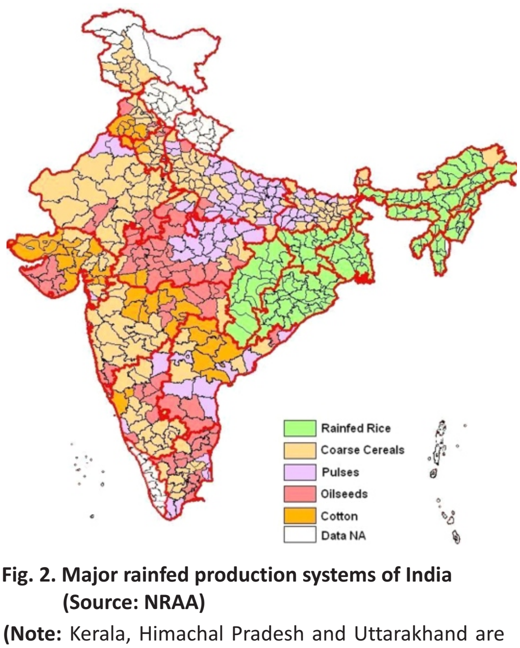

Fig. 2. Major rainfed production systems of India (Source: NRAA)

(Note: Kerala, Himachal Pradesh and Uttarakhand are mainly horticulture-based production systems)

This is reflected in the fact that the yield of new varieties released in recent years has plateaued. Past strategies, which ushered the Green Revolution in the 1970s and 1980s, are not working anymore. Thus, there is a need to identify and focus on new strategies to achieve these goals. In areas that witnessed the Green Revolution, the productivity levels are high. However, over the past decade yields have been stagnating and in some cases even declining. Past resources of growth productivity like expansion in irrigation, and increased use of fertilizers and chemicals for pest control are no longer relevant for further improvement in productivity and income. Policy regimes, which helped achieve increased productivity, are now not only irrelevant but are also contributing negatively to resource quality.

Change in cropping pattern

There has been an enormous shift in crops and cropping patterns in rainfed areas. Commercial crops like sunflower, soybean, and groundnuts have replaced the rainfed staple coarse cereals. More recently cotton is replacing sorghum in its traditional areas. Mixed cropping, which was universally practiced in rainfed areas, is now limited to hot arid and humid regions besides tribal regions. With the popularization of bore wells in rainfed areas, rice and horticultural crops like fruits and vegetable have come up. Thus, ecological access to food has become acute. In well-irrigated ecosystems, food habits have changed enormously -rice has replaced coarse cereals. In fact, in the process, the marketability of coarse cereals has become a problem. Even though the minimum support price (MSP) exists for these crops, there is no attempt to procure them in many areas. "MSP is hardly implemented in a few statesin true spirit. For coarse cereals it is almost nonexistent. This makes the market, and incentive for rainfed crops unsuitable," says Ramesh Chand of the National Centre for Agricultural Economics and Policy Research.

The National Rainfed Area Authority (NRAA) has chalked out a district-wise contingency plan to mitigate the impact of late monsoon by dividing the sowing period into three phases and provided a detailed advisory on the planting of different crops. As the country's 60% of farm land depends on monsoon, NRAA, an autonomous body under the Ministry of Agriculture, has worked out the comprehensive plan asking farmers to sow specific crops in select regions. According to the contingency plan, farmers are advised to sow basmati paddy crop in Central Punjab and short-duration paddy variety along with greengram and blackgram, pigeonpea in eastern Uttar Pradesh, respectively, between July 15 and 31. Moreover, hybrid bajra and sorghum can be planted in the Bundelkhand region of Uttar Pradesh and Madhya Pradesh during this period. Short-duration bajra, moong and guar can be sown in Haryana, Chandigarh and Delhi and urd, sunflower, maize and pigeonpea in some of the paddy-growing areas of Bihar. Similarly, moong, bajra, guar and maize can be planted in some districts of Punjab, Himachal and Uttar Pradesh in the first fortnight of August, while short-duration varieties of sorghum, bajra and moong can be sown in the Bundelkhand region of Uttar Pradesh and Madhya Pradesh. Suitable soil and water conservation measures including water harvesting structures and *in-situ* green water technologies are integral part of contingency and sustainability.

Crop intensification-big Step to doubling farmers income: Case study at north-western Himalayan region by ICAR-IISWC, Dehradun

Rainfed maize (*kharif* season; mid-June to mid-September)-wheat (*rabi* season; mid-November to April) is a dominant cropping system of north-western Himalayan states covering around 6 lakhs ha. Inclusion of vegetable pea as catch crop in between maize and wheat crops (mid-September to mid-December) for crop diversification and profit enhancement, will not only increase cropping intensity (from two to three crops in a year without irrigation) but also enhance level of soil organic carbon (SOC) and soil moisture holding capacity due to incorporation of legume residues (around 1 t ha^{-1}) in the soil which in turn will reduce soil erosion. But in rainfed condition, farmers are very reluctant to grow vegetable pea as catch crop in between maize and wheat crops due to extraction of conserved soil moisture by vegetable pea and limited residual soil moisture available for succeeding wheat crop for germination and seedling development. So, there are wide research and technology gaps in the fields of rainfed farming. Soil and water conservation techniques can be twinkled for enhancing cropping intensity and simultaneously doubling farmer's income, for small land holders of the Himalaya.

Long term work of ICAR-Indian Institute of Soil and Water Conservation, Dehradun revealed that conservation technologies such as contour farming, conservation tillage, mulching, vegetative barriers, crop geometry, legume inter cropping or strip cropping etc. on 2-8% sloping arable lands not only reduced runoff by 8-40% and soil loss by 6-35% but also improved productivity by 3-28%. From 2015-16 to 2016-17, an experimental trial was conducted at research farm, Selaqui on 4% land slope to evaluate the effect of different agro-geo-textiles on runoff and soil loss reduction in maize crop. Results revealed that by placing one meter wide *Arundo donax (Narkul* or *Nadda)* mats in zero-tilled maize crop (Fig. 3) at one meter vertical

Fig. 3. Layout of agro-geo-textiles (AGT) on 1 m vertical interval or for 100 m long plot, laid AGT after every 25 m length

interval; runoff amount was reduced to 5-8% and soil loss was reduced to nearly negligible, compared to zero tilled maize crop grown without placing erosion controlling mat (26-28% runoff and 6-8 t ha^{-1} soil loss). By this conservation technique which may be called conservation agriculture plus, most of the rainwater was stored into soil profile which was used to raise catch crop of vegetable pea in between rainfed maize-wheat crops without significantly affecting wheat crop yield. So, further exploration of conservation benefits of time specific erosion controlling mat prepared from locally available sources such as *Arundo donax* is need of the hour which could conserve *in-situ* soil moisture (green water) and additionally create employment opportunities for rural youth by linking soil and water conservation with profit making enterprises and diversifying traditional rainfed maize-wheat rotation of Himalayan region (Table 1).

A dense, well-established, vegetation cover can though generally provide long-term protection against soil erosion. However, the establishment of vegetation cover or crop canopy is difficult during early rainfall events and often counteracted during the early plant growth stages by the erosive forces of rain and runoff. Seeds and seedlings can be damaged or even washed away, so vegetation growth on steep erodible slopes is limited due to sheet erosion of top 5 cm fertile soil. During this period of high erosion risk, erosion control mats are a possible temporary alternative for insignificant vegetation cover and can offer immediate soil protection on moderate to steep slopes. Erosion controlling mats reduce the direct impact of raindrops, enhance water infiltration into the soil surface and thereby they reduce runoff generation and soil detachment.

Despite synthetic geo-textiles dominating the commercial market, geo-textiles constructed from locally available organic materials are highly effective in erosion control and vegetation establishment and it is a low cost alternative. Natural fibers are more effective than synthetic in controlling erosion and tested as the preferred method because of their 100% biodegradability and better adherence to the soil. Additionally, bio-mats if spread over significant area, can help to decrease the penetration of intense solar radiation to the ground, suppress extreme soil temperature fluctuations, reduce water loss through evaporation, and thus, conserve soil moisture,

Table 1: Economics (Rs. ha^{-1}) of different treatments

Treatments	Cost of cultivation	Gross return		Net return		B:C ratio	
		2015-16	2016-17	2015-16*	2016-17	2015-16	2016-17
Sole maize - wheat	53,304	50,051	84,244	-3253	30,940	0.93	1.58
Sole maize - vegetable pea - wheat	85,969	73,172	1,06,740	-12,797	25,086	0.90	1.30
Maize + cowpea as vegetative barrier on 1 m vertical interval - vegetable pea - wheat	86,169	83,731	1,26,028	-2438	44,174	1.02	1.54
Maize + grass weed as vegetative barrier on 1 m vertical interval - vegetable pea - wheat	85,969	84,412	1,23,341	-1557	41,687	1.03	1.51
Maize + maize stover geo-textile barrier on 1 m vertical interval - vegetable pea - wheat	1,00,844	99,164	1,50,754	-1680	54,225	1.03	1.56
Maize + Arundo donax (Rag-weed) geo-textile barrier on 1 m vertical interval - vegetable pea - wheat	1,00,844	1,32,526	1,56,230	31,682	59,701	1.37	1.61
Maize + coir geo-textile barrier on 1 m vertical interval - vegetable pea - wheat	1,05,519	1,12,607	1,39,847	7088	38,643	1.11	1.38

*2015-16 was drought year due to very less rainfall in wheat growing season.
Conservation tillage practices: Zero tillage in maize; minimum tillage in vegetable pea and wheat resulted in saving of Rs. 9000 ha^{-1} in comparison to conventional tillage.

which can create ideal conditions for plant establishment and growth. These mats are readily available in their local area, they are simple easy to manufacture and cost-effective and provide immediate erosion control. If harvested correctly, these resources are readily available and can be used in the long-run. These mats can be constructed locally at an economically viable price and also have the potential of reuse after one or two seasons due to their slower degradation. There are plenty of technological options available for soil and water conservation and productivity enhancement but most often the enhanced production is not converted in terms of enhanced income. The inadequacy of post-harvest handling infrastructures, lack of suitable market facilities and lack of skill and resources for vertical diversifications at producer's level are major bottleneck in the ambitious target of doubling farmer's income.

CONCLUSIONS

Income enhancement from farming is the main motivator rather than production. Though the crop productivity may be significantly improved by the adoption of appropriate location specific soil and water conservation measures, vertical crop diversification with strong forward and backward linkages are must for actualization of doubling farmer's income. Second Green Revolution may be possible from these untapped potential resources of the country by suitable adaptation strategy against climate change and land degradation.

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Ravine Management: Farmers Perspective

R.S. Kurothe*

INTRODUCTION

Soil degradation is a process that describes human induced phenomenon that lowers the current and future capacity of the soil to support human life. The human induced processes like large-scale irrigation, deforestation, enhanced industrial growth, etc. have resulted in over-exploitation of natural resources with little consideration for maintaining the eco-balance. This has lead to salinisation, flooding, drought, water logging and accelerated soil erosion. Such process in turn reduces agricultural productivity and causes social insecurity.

In order to develop technologies to combat with the problem, it is imperative to assess the extent of soil degradation, which can be defined mainly by the type and degree of soil degradation. National Bureau of Soil Survey and Land Use Planning, Nagpur assessed the soil degradation status in Gujarat state by assessing the type, degree and relative extent of different degradation problems (Sharma *et al.*, 1994). Here, the type of soil degradation refers to the process that causes the degradation *e.g.* displacement of soil material by water and wind, *in-situ* deterioration by physical, chemical and biological processes. The degree of degradation refers to the present state of degradation *e.g.* slight, moderate, strong and extreme. Relative extent refers to the percent area affected by a type of soil degradation within the mapped unit *e.g.* very occasional, occasional, common, frequent and dominant. The severity of soil degradation is expressed as low, medium, high and very high by the combination of the degree and the relative extent of the type of degradation process.

Very extensive degradation of the land has occurred in Gujarat along banks of the rivers, Mahi, Banas, Sabarmati, Vatrak, Tapi and Narmada. This extensive degradation has resulted in gully erosion commonly known as ravines. The National Commission on Agriculture estimated that in Gujarat alone 0.40 Million ha (M ha) land is affected by ravines. There is no historical record to show when the deterioration started but it is reasonable to assume that indiscriminate use of land leading to disturbances of the ecology, back water effect and geological effect have been the reasons for formation of ravines. The process once started continues with increasing speed. District wise and river wise gullied area in Gujarat is presented in Table 1 and 2, respectively.

Table 3 below lists ravine areas in different states of India as estimated by different sources.

Can these ravine land be reclaimed?

- Despite of extreme form of degradation, these land offer potential for productive utilization and economic upliftment of the ravine dwellers.
- The production potential estimated of ravine areas in Uttar Pradesh, Madhya Pradesh and Rajasthan was estimated longback (1960s) to be 3 million tonnes (mt) of food grains annually.
- With advent of new tools, cultivation practices and technologies generated for reclamation and productive utilization, this figure can conveniently be proportionately higher per unit land.
- In addition, fruits, fodder, fuel, timber and raw material for industrial can be produced.

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- By not reclaiming these ravines, the revenue loss was estimated (Planning Commission, 1965) to be about ₹ 157 crores a year.
- The reclamation strategy for a ravine land largely depends on degree of terrain deformation, soil quality, accessibility to water and other resources.

The target of ravine reclamation is to arrest degradation process, promote ecological restoration, positive on-site and off-site hydrological influences and to establish socioeconomic balance with a defined benefit sharing mechanism.

Reclamation and Management of Ravines

Gullies and ravines are highly advanced stage of water erosion from flat lands. Erosion from mild sloping lands starts as sheet and rill erosion. If not taken note of and stopped in the beginning by adoption of simple cultural and biological methods, larger volumes of water concentrate and flow through rills. They grow deeper, wider and longer as they merge with adjoining rills and take shapes of gullies and ravines. Thus, gullies and ravine are unmistakable indications and symbols of very bad management of land resources.

Table 1: District-wise gullied area of Gujarat (ha)

S.No.	District	Area surveyed (upto 31.10.1965)			
		Govt.	Village	Private	Total
1	Vadodara	12321	15989	48915	77225
2	Kaira	5933	15918	24394	46245
3	Sabarkantha	9615	7637	23679	40931
4	Banaskantha	5522	4354	5580	15456
5	Mehsana	7996	5563	8665	22224
6	Ahmedabad	3839	2769	4019	10627
7	Bharuch	5633	5182	23173	33988
8	Panchmahals	1226	2429	9584	13239
9	Surat	2119	2337	21508	25964
10	Valsad	238	176	4716	5130
		54442	62354	174233	291029

Table 2: River-wise gullied area of Gujarat

S.No.	River	Gullied area (ha)
1	Mahisagar	61888
2	Narmada	58142
3	Watrak	56497
4	Sabarmati	36891
5	Saraswati	15908
6	Dhadhar	12086
7	Banas	10697
8	Tapi	9363
9	Kim	9127
10	Mindhola	3477
11	Purna	2495
12	Ambica	2469
13	Auranga	2370
14	Kotak	1788
15	Par	1836
16	Rupen	1121
17	Khari	568
18	Chikakhadi	96
19	Miscellaneous area	4202
		291021

Table 3: Ravine areas in different states of India

S.No.	State	NCA 1976	Chaturvedi *et al.,* 2014	NRSC, 2000	NRSC 2008	ICAR-IISWC 2014
1	Uttar Pradesh	12.30	12.30	3.25	1.199	3.40
2	Madhya Pradesh[1]	6.83	6.83	5.274	1.453	3.12
3	Rajasthan	4.52	4.52	6.6	1.525	2.74
4	Gujarat	4.00	4.00	0.39	0.339	1.101
5	Maharashtra	0.20	0.20	-	-	-
6	Punjab	1.20	1.20	-	-	-
7	Bihar[2]	6.00	6.00	-	-	-
8	Tamil Nadu	0.60	0.60	-	-	-
9	West Bengal	1.04	1.04	-	-	-
10	Odhisha	-	0.11	-	-	-
11	Others	-	0.19	-	-	-
	Total	36.69	39.8	-	-	-

[1]Area included Chhattisgarh; [2]Area included Jharkhand

The huge volumes of soil removed from the gullies get deposited in the natural watercourses and choke the streams and rivers resulting into periodic floods and losses of lives and properties. The silt travels little longer distances and settles in the reservoirs. Their storage capacity is reduced, and useful life becomes progressively shorter.

Technical approaches for the treatment and rehabilitation of ravine land depends on the scientific criteria of land capability classification, which decides what portion of ravine should be reclaimed for agriculture and what portion of ravine should be put under perennial vegetation, taking into consideration the physical characteristics, soils and location of the particular gully or a ravine system.

Three regional research centres of ICAR-Indian Institute of Soil and Water Conservation, Dehradun, situated at Agra (Uttar Pradesh), Kota (Rajasthan) and Vasad (Gujarat) are working on technologies for reclamation and rehabilitation of ravines along Yamuna, Chambal and Mahi rivers, respectively. Findings and experiences relevant to Gujarat ravines are discussed here.

Classification of gullies and their suitability for reclamation

Any system of gullies has an independent catchment having a regular main stream, which is termed as drainage system. In each drainage system it is observed that gullies with well-defined side slopes, bed width and depth occur in certain regular order. In the upper reaches of the drainage system the gullies are wide shallow with varying side slopes. The middle part of the drainage system is usually relatively deeper, wider and has uniform side slopes normally up to about 25%. The lower portion of the drainage system is usually very deep, has steep side slopes and is associated with intricate branched gullies.

Gullies are classified based on their cross section, forms, gully head characteristics, length, width and depth. However, classification of gullies, developed at Vasad research centre, after critically observing ravines along most of the river banks in Gujarat by Tejwani and Dhrvanarayana (1961) is presented in Table 4.

Experiences of Vasad centre showed that very small and small gullies can conveniently safely and economically are reclaimed for cultivation or can be put under agricultural land use, while medium gully can be put under horticultural land use system after reclamation. Deep and narrow gullies can best be reclaimed by closure to biotic interference.

Land capability classification in ravines

Other factors being common in a ravine system, slope of the land and the nearness of a gully to any area determine its capability. The specifications detailed in Table 4 are applicable to the ravine lands of Gujarat where the problem is specific in nature (Tejwani and Dhruvanarayana, 1961).

Reclamation of small gullies

Small and very small gullies which are not >3 m deep can successfully be reclaimed for cultivation of crops. Reclamation process can be started first from the checking of extension of gullies in fertile land by forming a contour/ peripheral bund followed by clearing, minor levelling and putting up diversion cum check

Table 4: Classification of Gullies in Gujarat

Symbol	Description	Specifications
G_1	Very small gullies	Upto 3 m deep. Bed width not greater than 18 m. Side slopes vary.
G_2	Small gullies	Upto 3 m deep. Bed width greater than 18 m. Side slopes vary.
G_3	Medium gullies	Depth between 3 to 9 m. Bed width not less than 18 m. Sides uniformly sloping between 8 to 15%.
G_4	Deep and Narrow gullies	(a) 3 to 9 m deep. Bed width less than 18 m. Side slopes vary. (b) Depth greater than 9 m. Bed width varies. Side slopes vary. Mostly steep or even vertical with intricate and active branch gullies.

bund of about 1.5 m^2 cross section spaced at horizontal spacing of 30 to 45 m in gully beds. Grass ramps and pipe outlets are provided for overflow of runoff in excess of 30 cm pounding at the end of bund near the gully sides. Consecutive grass ramp or pipe outlets are made diagonally opposite to each other so that the path of runoff is lengthened, and its flow velocity is reduced so as not to cause any scouring. At the end of the gully a earth cum masonry check dam (composite check dam) is constructed to retain the silt, debris and runoff etc.

Reclamation of medium gullies

A small gully transforms in to medium gully along the length of the main drainage system. A medium gully is reclaimed by clearing and leveling the bed and constructing a series of composite earth cum brick masonry check dams at vertical intervals of 1.2 m, (which gives a horizontal interval of 120 m on 1% slope of the gully bed) and terracing the side slope (8-15%). After clearing and levelling the bed medium gully is ready for cultivation.

Reclamation of deep and narrow gullies

About 70% ravine affected area in Gujarat falls under land capability class VI and class VII that are devoid of vegetation and as such need more attention. as these lands are only fit for permanent vegetation. Reclamation of these lands consists of closure to biotic interference, controlling erosion and establishing a good vegetative cover of natural grasses and tree species.

Features of Peripheral bund

Peripheral bunds are recommended as one of the soil and water conservation measures for Class II, Class III and Class IV lands in semi arid and sub humid areas. Its purpose is to retain the precipitation in situ for crops and reduce soil erosion by guiding the flow of runoff in to the gully from a selective safe point.

Peripheral bunds ranging from 0.56 to 1.28 m^2 were tried and evaluated for their performance at the Vasad research farm (Tejwani *et al.,* 1960) and It was found that Contour and peripheral bund of 0.93 m^2 with required pipe outlets and grass soding of *Dicanthium annulatum* and *Cenchrus ciliaris* are best suited for the soil and climatic condition of this region.

Gully plugs

Gully plugs made of various material *e.g.* brush wood, live hedge, earth sand bags and brick masonry have been tried. The size and material for the gully plugs depends on the width, length and bed slope of the gully and anticipated runoff. In narrow gullies whose width did not exceed 3.0 m live hedge consisting of *Euphorbia* species were planted across the gully bed in three rows spaced 90 cm apart and the stems at 90 cm in each row alternatively staggered. On evaluation it has been found that all types of gully plugs were effective either in retaining or retarding the runoff. However, brush wood and sand bags gully plugs were not found economical in long run as the former were found to be severe susceptible to white ants and later were subject to deterioration due to effect of weather and their life was short compared to other material.

Earthen gully plugs with grass soding are found the cheapest and the best. The study at the centre indicated that earthen gully plugs of 1.1 m^2 cross section with a grassed ramp of 22.5 cm below the top level and spaced at 45-60 m horizontal interval are suitable for gullies in which runoff from top is not expected. For the gullies expected to receive runoff from the top gully plugs of 2.2 m^2 cross section and pipe outlet of 15 cm diameter should be provided.

Terracing of side slopes

The uneven side slopes of the medium gullies can be converted in to terraces for various land uses. At the research farm Vasad such side slopes of medium gullies having 8 to 15% slope were converted into bench terraces at vertical interval of 0.9 to 1.2 m. The terraces were given a back slope of 1 in 50 and a longitudinal grade of 1 in 200 towards the grassed outlet. A ridge bund of 0.3 m^2 cross section was provided at the edge of each terrace. Terrace faces were given a slope of 1.5:1. To make the terrace construction economical, terracing was done only in case where a minimum uniform slopping length of 120 m was available. These terraces can be put under horticulture land use or cultivated with precaution.

During the process of terracing, the topsoil on the surface is covered with the poor sub soil This requires a planned programme to raise the fertility level of soil involving good crop rotations and heavy manuring.

Grasses to stabilize bench terraces

The terraces require careful maintenance for atleast initial two years of construction in view of the unsettled conditions of the soil. The ridge bund, terrace faces, graded outlets and earthen check dams needs to grow with suitable grasses to stabilize them.

Soding of grasses like *Penicum antidotale*, *D. annulatum* and *Cynodon dactylon* were done at the research farm with and without application of fertilizers to stabilize the ridge bunds/toe bunds and terrace faces. Among three grasses *D. annulatum* significantly proved to be the best as judged by canopy and soil binding capacity for stabilizing the bench terraces (Sharma *et al*., 1980).

Composite check dams for stabilization of gully bed

Check dams are constructed across the medium and deep gully to reduce the erosive velocity of runoff water, which in time transform the longitudinal gradient of the gully bed to a uniform slope. These check dams in turn are very useful in reducing carrying capacity of flowing water and direct retention of debris, silt and runoff behind the structure, which ultimately increase the percolation and groundwater. Further due to retention of silt behind the structure the width of channel becomes wider.

A well structured composite check dam comprises mainly of masonry spillway portion with head wall, sidewall, wingwall, apron, toe wall etc. This spill way is supported by earthen portion on both sides. The correct shape and size of check dams has to be adopted commensurate with peak flows, location and material used.

Closure to biotic interference

The best use of deep and marrow ravine lands is to retire them to permanent vegetation of grass and trees. The natural tree species of ravine lands of Gujarat comprise of *Acacia nilotica, Acacia senagal, Acacia leucophloea, Azadirachta indica, Albizzia lebbeck, Feronia elephantum, Prosopis cineraria* etc.

A. niltoca, Acacia benthamii, Ailanthus excelsa, Albizzia lebbek, A. indica, D. sissoo. D. stricuts, E. camaldulensis (Benglore), E. citriodora, E. hybrid, Pongamia glabra, Emblica officinalis, Salmalia malabaricum and Tectona grandis (Tamhane *et al.,* 1964).

Experiments at Vasad have shown that closure to biotic interference is very effective in improving the vegetative covers. This can be further improved by suitable cultural treatments.

The most promising forest species find out at Vasad are *D. strictus, Eucalytpus hybrid, Tectona grandis, D. sissoo* etc. These species if planted in the ravine beds require good moisture regime for the first two years after planting.

It has been found that good moisture regime can be maintained in these plantations if gully plugs and check dams are constructed. These structures not only provide favourable moisture regime in the initial years of planting but also continue to do so in the latter years.

In the construction of erosion control structure, composite check dams have been found to be the best. These structures are constructed so as to make the level benches in the gully bed.

Socio-economics of technology transfer

A 35 ha extremely degraded ravine waste land with deep gullies near the highly ravinous banks of Mahi river at Sarnal in Thasra taluka in

Gujarat was reclaimed, by a group of stakeholder farmers organized as Sarnal Tree Growers' Cooperative Society under guidance and technical supervision of ICAR-Institute of Soil and water Conservation, Research Centre, Vasad with various water and soil conservation measures. Several fuel, fodder and dual forest species were planted on staggered contour trenches in 1987 through 1989.

The afforestation conservation measures helped *in-situ* conservation of moisture leading to comparatively better vegetation at the plantation site as compared to outside area. The basal area coverage in the plantation site worked out to be three times more than that in the similar outside area close to plantation. The growth parameters of trees also proved better in the treated area.

Evaluation of the plantation, done at 1995-96 prices considering 10% discount rate and 15 years period, revealed viability of the afforestation conservation measures (B:C-1.7; IRR-18%, PBP-14 yrs), considering only direct physical benefits of fuel, fodder and small timber. The annual payout at constant price worked out to be ₹ 11,284.

Farmers' perspective and Policy issues

Can farmer afford to loose his fertile land ?

As the land cost increasing day by day and loss of land to urbanization a farmer cannot afford to loose his land due to heavy erosion and ravine formation.

Is the reclamation viable ?

It has been demonstrated by 3 ravine centres of ICAR-IISWC at Vasad, Kota and Agra that ravine land extension can be stopped and ravines could be used for productive purposes by various technologies developed by the Institute. These technologies give various viable options to farmers depending upon his capacity to spend. These provide a long term as well as short term plan for reclamation.

Land ownership

Ravine lands are owned by farmers and Govt. Departments. Individual farmer may develop his land by forming a group of his neighbors whose land is also forms a part of ravines as collective action in treating these lands is always better.

Ravine lands that belong to Government, Panchayat, Forest Department needs much more attention and may be given on lease to a group of farmers who can reclaim it and get a right on usufructs so obtained fron ravine management. Various NGOs may be allowed to help farmer's groups in reclaimimng ravines.

Control of wild animals

When the ravines are reclaimed and used as forest wild life flourishes is that area. This may create problems for farmers. So the framework for proper management of wild life is a must for these areas. A policy for controlled population of wild animals will help in this regard.

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Methods of Soil Moisture Estimation

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INTRODUCTION

By measuring soil moisture at regular interval and at several depths within the root zones, information can be obtained as to the rate at which moisture is being used by the crops at different depths. This provides the base for determining when to irrigate and how much water to be applied. For practical purpose, irrigation should be given when about 50% of available moisture in the root zone is depleted. The amount of water to be applied is directly related to the water already present in the soil. The methods of measuring soil moisture are divided in to:

A) Direct Methods

I) Gravimetric methods: In the gravimetric method, basic measurement of soil moisture is made on soil samples of known weight or volume. Soil samples from the desired depths are collected with a soil auger. Soil samples are taken from desired depth at several locations of each soil type. They are collected in air tight aluminum containers. The soil samples are weighed and they are dried in an oven at 105^{o}C for about 24 hours until all the moisture is driven off. After removing from oven, they are cooled slowly to room temperature and weighed again. The difference in weight is amount of moisture in the soil. The moisture content in the soil is calculated by the following formula:

$$\text{Moisture content on weight basis} = \frac{\text{Wet weight - Dry weight}}{\text{Dry weight}} \times 100$$

Problems: Wet weight of a soil sample with can is 210 gm and weight with can is 180 gm weight of empty container is 40 gms calculated moisture content of soils sample?

Solution:

Weight of wet soil sample = wet weight – weight of empty can:

= 210-40

= 170

Dry weight of soil sample = Dry weight – weight of can:

=180-40

=140

$$\text{Moisture content (\%)} = \frac{\text{Wet weight of soil} - \text{Dry weight of soil}}{\text{Dry weight of soil}} \times 100$$

$$= \frac{170 - 140}{140} \times 100$$

$$= \frac{30}{140} \times 100$$

= 21.4 %

II) Volumetric method: Soil sample is taken with a core sampler or with a tube auger whose volume is known. The amount of water present in soil sample is estimated by drying it in the oven and calculating by following formula.

Moisture content = Moisture content (%) by weight x bulk density (%) by volume.

Problems: Undisturbed soil sample was collected from a field, two days after irrigation when the soil moisture was near field capacity. The inside dimension of core sampler was 7.5 cm diameter and 15 cm deep. Weight of core sampling cylinder weight of the core-sampling cylinder was 1.56 kg. Determine the available

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moisture holding capacity of soil and the water depth in centimeter per meter depth of soil.

Solution:

Weight of moist soil = 2.76-1.56 = 1.20kg

Weight of oven dry soil = 2.61-2.56 = 1.05 kg

$$\text{Moisture content} = \frac{1.20 - 1.05}{1.05} \times 100$$

= 14.28%

Volume of core sampler = ... X d2 x h

= X7.5X7.5X15

4

= 662 cu. cm

$$\text{Apparent specific gravity} = \frac{\text{Wt. of dry soil in grams}}{\text{Volume of soil in cu. cm}}$$

$$= \frac{1.05}{662} \times 1.58$$

Available moisture = Ap. Sp. Gr. x moisture content

= 1.58 x 14.28

= 22.56 cm / m depth of soil

The method is though accurate and simple it is used mainly for experimental purpose. Sampling, transporting and repeated weighing give errors. It is also laborious and time consuming. The errors of the gravimetric method can be reduced by increasing the size and number of samples. However the sampling disturbs the experimental plots and hence many workers prefer indirect methods.

III) Using methyl alcohol: Soil sample is mixed with a known volume of methyl alcohol and then measure the change in specific gravity of school with a hydrometer. This is a short cut procedure but it is not in common use.

IV) Using calcium chloride: Soil sample is mixed with a known amount of calcium chloride. Calcium chloride reacts with water and removes it in the form of acetylene gas. The moisture is determined has come in common use.

B) Indirect Methods

In those methods, no water content in the soil is directly measured but the water potential or stress or tension under which the water is held by the soil is measured. The most common instrument used for estimating soil moisture by indirect methods are:

1) Tensiometer
2) Gypsumblock
3) Neutronprobe
4) Pressure plate and pressure membrane apparatus

In all these methods, the reading from above instruments and corresponding soil moisture content is determined by oven drying method are plotted on a graph. Subsequently, these calibration curves are used to know soil moisture content from the reading of these instruments.

1) Tensiometer: Tensiometer is also called irrometers since they are used in irrigation scheduling. Tensionmeters provide a direct measure of tenacity (tension) with which water is held by soil. It consist of 7.5 cm porous ceramic or clay cup, a protective metallic tube, a vacuum gauge and a hollow metallic tube holding all parts together. At the time of installation, the system is filled with water from the opening at the top and rubber corked when set up in the soil. Moisture from cup moves out with drying of soil, creating a vacuum in the tube which is measured with the gauge. Care should be taken to install tensiometer in the active root zone of the crop. When desired tension is reached, the soil is irrigated. The vacuum gauge is graduated to indicate tension values up to one atmosphere and is divided in to fifty divisions each of 0.2 atmosphere value. The tensiometer works satisfactory up to 0.85 bars of atmosphere.

Merits of Tensiometer

1. It is very simple and easy to read soil moisture *in-situ*.
2. It is very useful instrument for scheduling irrigation to crops which require frequent irrigations at low tension.

Limitations

Sensitivity of a tensiometer is only up to 0.85 atmospheres while available soil moisture range is up to atmosphere and hence is useful more on sandy soils wherein about 80% of available water is held within 0.85 ranges.

2) Gypsum Blocks: Gypsum blocks or plaster of Paris resistance units are used for measurement of soil moisture *in-situ*. These were first invented by Bouycos and Mick in 940. The blocks are made of various materials like gypsum, nylon fiber, glass, plaster of Paris or combination of these materials. The blocks are generally rectangular shaped. A pair or electronics is usually made of 20 mesh stainless steel wire screen soldered to copper lead wire. The common dimensions of screen electrodes are 33.75 cm long and 0.25 cm wide. The usual spacing between the electrodes is 2 cm. A similar block is 5.5 cm long, 3.75 cm wide and 2 cm thick.

Principal of working: It works on principal of conductance of electricity. When two electrodes A and B are placed parallel to each other in a medium and then electric current is passed, the resistance to the flow of electricity is proportional to the moisture content in the medium. Thus, when the block is wet, conductivity is high and resistance is low. Generally these read about 400 to 600 ohms resistance at field capacity and 50,000 at wilting point. The readings are taken with portable Wheatstone Bridge Bouycos water Bridge operated by dry cells. While placing the gypsum block in soil, care should be taken that the blocks must have close contact with undisturbed soil. After placing, the blocks get wetted with soil moisture due to capillary movement. Pure gypsum block sets in about 30 minutes. The gypsum block is sensitive to soil to moisture from 1.0 atm tension to 20.0 atm. However, the gypsum blocks are not reliable in wet soils.

3) Pressure membrane and pressure plate apparatus: Pressure membrane and pressure plate apparatus (developed primarily by Richards) is generally used to estimate field capacity, permanent wilting point and moisture content at different pressures. The apparatus consists of air tight metallic chamber in which porous ceramic pressure plate is placed. The pressure plate and soil samples are saturated and are placed in the metallic chamber. The required pressure, say 0.33 bar or 15 bars is applied through a compressor. The water from the soil sample which is held at less than the pressure, applied trickles out of the outlet till equilibrium against applied pressure is achieved after that, the soil samples are taken out and oven dried for determining the moisture content.

4) Neutron meter (neutron scattering method): Soil moisture can be estimated quickly and continuously another with neutron moisture meter without disturbing the soil. Another advantage is that soil moisture can be estimated from large volume of soil. This meter scans the soil to about 15 cm, diameter around the neutron probe in wet soil and 50 cm in dry soil. It consists of a probe and a scalar or rate meter. The probe contains fast neutron source, which may be a mixture of radium and beryllium or Americium and beryllium. Access tubes are aluminum tubes of 50 to 100 cm length and are placed in the field where moisture to be estimated. Neutron probe is lowered into access tube to the desired depth. Fast neutrons are released from the probes, which scatter into the soil. When neutrons encounter nuclei of hydrogen atom of water, their speed is reduced. The scalar or the rate meter counts the number of slow neutrons, which are directly proportional to water molecules. Moisture content of soil can be known from the calibration curve with counts of slow neutrons.

Limitations: The two drawbacks of the instruments are that it is expensive and moisture content from shallow top layers cannot be estimated. The fast neutrons are also slowed down by other source of hydrogen (present in the organic matter). Other atoms such as chlorine, boron and iron also slow down the fast neutrons, thus overestimating the soil moisture content.

5) Gama Ray absorption method: It is the technique of measurement of changes in soil water content by change in amount of gamma radiation absorbed. The amount of radiation passing through soil depends on soil destiny which varies chiefly with change in water content. It is suitable where change in bulk destiny is very small.

6) Feel and appearance method: A practical estimate of moisture content is obtained by the feel and appearance of soil samples taken from the desired depths. The soil sample is squeezed in the hand and its feel and appearance are taken into consideration. In this method, actual moisture content is not determined.

7) Soil moisture characteristic curve: The energy status of water and amount of water in the soil are related with the soil moisture characteristic curve. As the energy status of water decreases (moisture towards more negative values) soil water content also decreases. In other words, as soil moisture content deceases, more energy has to be applied to extract moisture from the soil. The relation between suction (externally applied force) and water content of the soil are represented graphically by a curve which is known as a soil are moisture characteristic curve.

Hysteresis

The relation between energy status and moisture content can be obtained in two ways, (i) in absorption by taking an initially saturated soil sample and applying increasing suction to dry the soil gradually and (ii) in absorption by gradually wetting an initially dry soil. The measurement of energy status and moisture content during this process are taken and plotted on graph. The curves obtained through desorption and sorption is different for the same soil sample. The moisture content at a given suction is greater in desorption than in absorption and this phenomenon is known as hysteresis.

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Technological Options for Rain Water Management in Rainfed Agriculture

S.M. Taley*

Meeting food demand of the country's growing population and sustaining our limited non-renewable natural resources for future generations were never so challenging. The National Agriculture Policy of India envisages a growth rate of 4% per annum to achieve a target of 377 million tonnes of food grain production by 2050. However, degradation of our finite land and water resources at a faster rate is resulting in loss of food, fodder, fibre and fuel-wood production potential, and affecting the livelihood and environmental securities of millions of people. Soil erosion by water is the most serious form of land degradation, resulting in loss of crop productivity by 0.2–10.9 q/ha (66% total production loss) for cereals, 0.1–6.3 q/ha for oilseeds (21% total production loss) and 0.04–4.4 q/ha for pulses (13% total production loss) estimated across all the states, which has a direct bearing on food security of the country.

The drought proneness of the Maharashtra state is a critical additional stress factor that adversely affects productivity, livelihoods, and the rural economy. Ironically, the cultivated areas lie predominantly in drought-affected districts. Aridity appears to be encroaching upon adjacent areas: districts that previously had moderately assured rainfall, such as Vidarbha have been affected by declining and unpredictable rainfall with debilitating impacts on the local economy. Maharashtra experienced severe and successive years of drought in 1970-1974 and 2000-2004.

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The state Employment Guarantee Scheme (EGS), a relief and rehabilitation program of state support, was introduced in 1972 in response to a devastating drought. In July 2007, in the process of constituting a *'dushkal mahamandal'*, or Drought Corporation, Group of Ministers (GoM) listed 166 of the state's 355 talukas as 'drought-prone'.

Maharashtra agriculture is primarily rainfed covering 85% of cultivated area. Vidarbha region of Maharashtra constitute 93% of agriculture under rainfed condition. Since major agriculture is rain dependent, the rainwater technologies play very vital role in sustainable rainfed farming. Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola evolved number of options for rainwater management which constitute *in-situ* water conservation, safe disposal of runoff, water storage structure and recycling of runoff from farm ponds for protective irrigation of rainfed crops. Average annual rainfall in Vidarbha is 700 to 1700 mm which has great potential for growing two crops.

The widespread failure of the monsoon in 2009 and increasing frequency of occurrence of extreme events in recent years have reinforced the need for better preparedness, planning and response to mitigate the adverse impacts of such events. Four coping strategies for preparedness for climatic risks are disaster preparedness, mitigation practices, contingency planning and responses, and disaster risk mainstreaming. Therefore, for sustainable rainfed farming there is urgent need to adopt rainwater management technologies by providing the knowledge to the community about 'More crop per drop' which solve water crises in agriculture by way of:

1. Modification in land configurations and cultivated practices for *in-situ* conservation in rainfed agriculture.
2. Management of *ex-situ* rainwater for enhancing crop productivity in rainfed agriculture.
3. Impact of Rainwater conservation measures on ground water recharge/potential.

Need of Climate Resilient Technologies

The need of applying protective irrigation for raising crops during non-rainy periods or when rains failed was felt even in the distant past. With the growth of population and consequent for large agricultural production, the requirement of at least a protective irrigation has increased great deal. Irrigation in rainfed farming is required not only in low rainfall areas and during non rainy seasons but also during long breaks in rains in good rainfall areas. Hence, onward the crucial management of our water potential is need of the day because:

i) Annual receipts of rainfall may remain same or may even decline if the deforestation continues with the present rate.

ii) Demands for water will be increasing tremendously for drinking and living conditions, as well as for expanding industrial complexes and

iii) Substantial improvement in productivity and stability of farming shall have to come from increasing utilization of water at least for protective irrigation in rainfed agro-ecosystem.

In this context, it is necessary to put continuous efforts for the development and promotion of the climate resilient technologies in rainfed agriculture with special focus on soil and water conservation (*in-situ* and *ex-situ*) technologies for sustainability.

Impact of Climate Resilient Technologies

The Front Line Demonstrations (FLDs) were conducted in different villages of Akola, Washim, Amravati, Yeotamal and Wardha districts on different *in-situ* soil and water conservation measures in participatory mode. In all 647 farmers from 71 villages participated in this programme.

Before Commencement of Rains:

i) Water conservation ditch

Wide and deep shrinkage cracks due to the high clay content and montmorillonite clay mineral cause rapid exhaustion of moisture. When wet, deep black soils attain very low infiltration rates and rainwater stagnates for prolonged periods, affects soil aeration and cause loss of crops in 15 to 20% of inter-bund area. The runoff from the first showers passes through the summer cracks resulting in extensive breaching and failure of all the bunds and ultimately results in formation of gullies.

In water conservation ditch, water does not back up upstream of the ditch, there is no water stagnation, water entering the cracks on the sides of the ditches causes no breaching but helps to charge the soil profile, moisture at downstream side benefiting the crops in the area and waste weirs are dispensed with as surplus water flows as thin sheet over the length of ditch. In water conservation ditch the rain water is stored *in-situ* without the problems associated with contour/ graded bunds. Technological details are given in Recommended Technologies Evolved at Dr. DPKV, Akola on Rain Water Management.

ii) Economical sub-surface tillage in vertisols

Impact:

- Yield > 45.72% (Soybean)
- RWUE – 74.19%
- Soil moisture > 16.72%
- Runoff
- Soil loss < 100%
- Nutrient loss
- Cost per ha: ₹ 5000/- (Addi.)

Reduction in:

- Bulk Density, mg/m^3 – 1.35 < 1.27
- Soil Resi., KPa – 2720.5 < 2079.40 (at 0-15

cm depth); 2870.5 < 2247.35 (at 15-30 cm depth)

Increase in:

- Field Capacity, % - 29.08 > 29.25

Sub soiling benefits associated are the alleviation of soil compaction and improved soybean yields. In order to have the sustainable agriculture, maintaining the soil property in favourable proportion the present investigation has been planned. The finding generated will be of applicable value for vertisols.

iii) Usually rainy season opens with the erosive storms and causes the heavy erosion and runoff. Usually farmers incorporate compost in his land prior to commencement of the monsoon. *In-situ* recharge of soil and rainwater needs following land configurations prior to commencement of the rains. This can be adopted by farmers using bullock / tractor drawn plough. These *in-situ* soil and water conservation measures can also be applicable for the *kharif* crops.

The land configurations like the preparation of square basins (20 m x 20 m) on flat land, cultivation across the slope and opening of furrows across the slope at 25 to 30 m HI in one directional slope and contour cultivation with opening of contour furrows at 25 to 30 m HI in multi directional slope of land significantly enhance the crop productivity, improve water use efficiency and retained higher moisture at the time of sowing and during dry spell. These land configurations can also be useful for *kharif* crops.

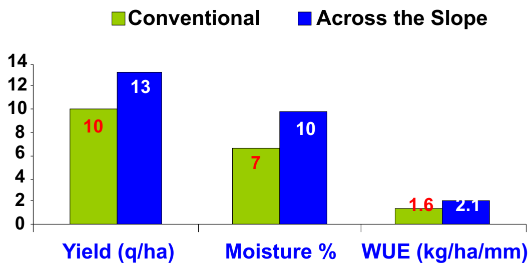
After commencement of Rains:

1. *In-situ* Rain Water Conservation Practices

In-situ conservation of rainwater needs reforms in cultivation practices in such a fashion that maximum rainfall gets infiltrated in to the soil profile and it becomes available to the crop during prolonged monsoonic break. The continuous efforts were made during 2008-09 and 2009-10 to achieve the goals with following specific objectives, to solve the water crises in rainfed agriculture.

i) Cultivation across the slope

Across the slope sowing of crops significantly enhanced crop productivity, improved rain water use efficiency and retained higher moisture during dry spell. This method can be easily adopted by farmers using conventional tools.



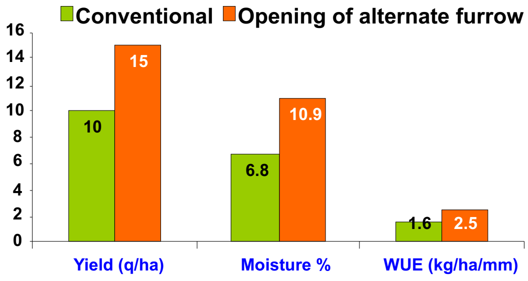
Advantages:

- Crop productivity by 32 to 57%.
- RWUE by 31.25%.
- Soil moisture by 44%.
- Reduced soil erosion by 50 to 52%.
- Runoff by 25 to 30%.
- Nutrient loss by 45 to 48%.
- This method can be easily adopted by farmers using conventional tools to Retained higher moisture during dry spell.
- Technologies promoted through 486 demonstrations in 122 villages from 14 taluka of 6 district on 1646 ha area with participation of 300 farmers.

ii) Opening of alternate furrows after sowing

Opening of alternate furrows 30 days after sowing retain higher moisture during dry spell, enhances rain water and crop productivity**.**

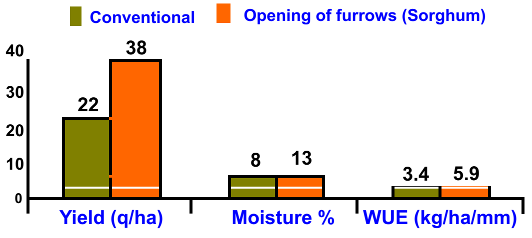
- Enhanced B:C ratio -1.19 to 1.49
- GWP – (₹ ha-mm^{-1}) INR 26.28 to 36.80
- Cost per ha – ₹ 4500/- (Addi.)



- Technology promoted through 30 demonstrations in 11 villages from 4 talukas of 4 district on 123 ha area with the participation of 27 farmers.

iii) Opening of furrows 30 days after sowing

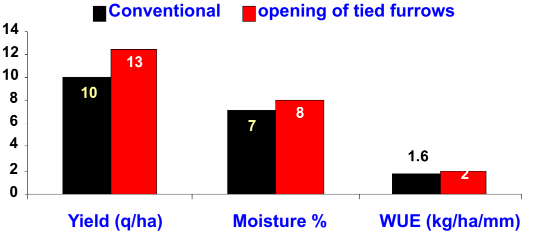
Opening of continuous furrows 30 days after sowing retained higher soil moisture during dry spell, enhanced rain water productivity and increased yield of sorghum and cotton. This can be adopted by farmers using traditional tools.



- Cost per ha. - ₹ 5100 (Addi.)
- Technology promoted through 12 demonstrations in 8 villages from 4 talukas of 3 district on 48 ha area with the participation of 12 farmers.

iv) Opening of tied furrows after sowing

Opening of tied furrows 30 days after sowing enhanced moisture content, rain water productivity and crop yield.



- B:C Ratio – 1.19 to 1.39
- GWP – INR 26.28 to 31.52 (₹/ha-mm)
- Cost per ha – ₹ 500/- (Addi.)
- Technology promoted through 21 demonstrations in 13 villages from 4 talukas of 3 district on 83 ha area with the participation of 16 farmers.

v) Contour cultivation

Contour cultivation enhanced rain water productivity, moisture availability during dry spell and increase crop yield. It reduces 55% run off, 70% soil loss and 60% nutrient loss.

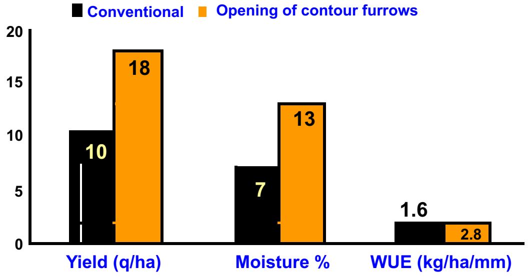
- B:C ratio – 1.19 to 1.80
- GWP – INR 26.28 to 45.56 (₹/ha-mm)
- Cost per ha – ₹ 4800/- (Addi.)
- Technology promoted through 78

demonstrations in 16 villages from 4 talukas of 3 district on 318 ha area with the participation of 75 farmers.

vi) Opening of alternate furrow in contour sowing

Opening of alternate contour furrows 30 days after sowing retained 93% higher moisture, increased 80% crop productivity and enhanced rain water productivity.

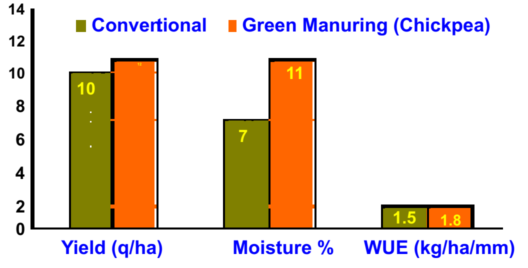
- B:C ratio – 1.19 to 1.84
- GWP – INR 26.28 to 47.30 (₹/ha-mm)
- Cost per ha – ₹ 5100/- (Addi.)
- Technology promoted through 20 demonstrations in 9 villages from 3 talukas of 3 district on 79 ha area with the participation of 18 farmers.



vii) Green Manuring

Green manuring not only Improves soil fertility but also retains 55% higher moisture for rabi crops and enhance rain water productivity.

- Technology promoted through 29 demonstrations in 9 villages from 3 talukas of 2 districts in saline tract of Purna river valley on 112 ha area with the participation of 29 farmers.



viii) Cultivation on continuous contour trenches (Agro-horticulture system)

Continuous contour Trenches on waste land at 10 m Horizontal Interval enabled farmer in Mehkar tahsil of Buldana district to use waste land for Agro-horti. System (Custard apple+Maize). Agro-horticulture systems promoted thorugh demonstrations on 60 ha. of waste land on CCt's.

2. Runoff Harvesting and Recycling

a) Farm pond for protective irrigation

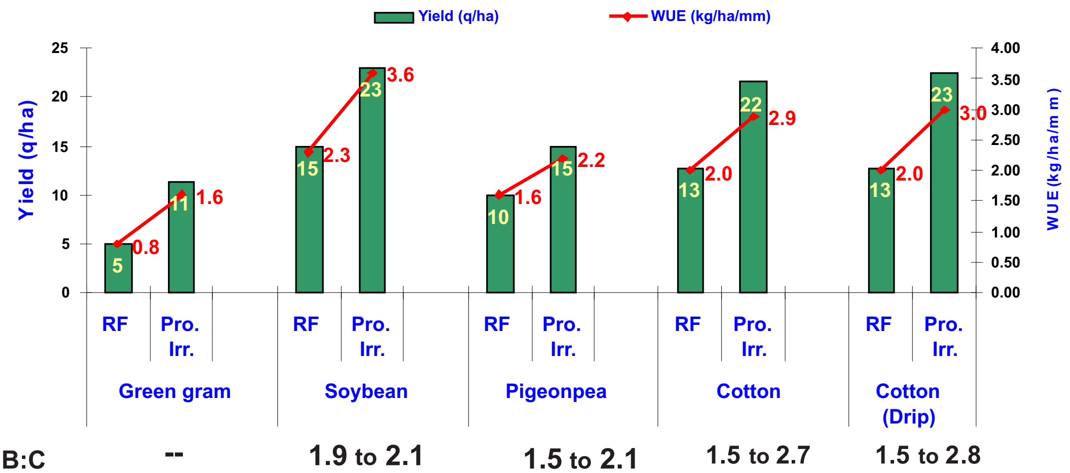
Farm ponds constructed by Department of Agriculture are used for protective irrigation by recycling of runoff through sprinkler and drip irrigation during dry spell. One protective irrigation of 30 mm depth in medium to deep soils and 50 mm depth of irrigation in shallow soils during moisture stress in *kharif* and *rabi* season resulted into the significant improvement in yield. The water requirement of the crops at critical stages is given in the following table. During rainy season it is experienced that crops are suffering either in the beginning or later stage, it requires atleast one protective irrigation to sustain till the subsequent rains.

i) *Kharif*

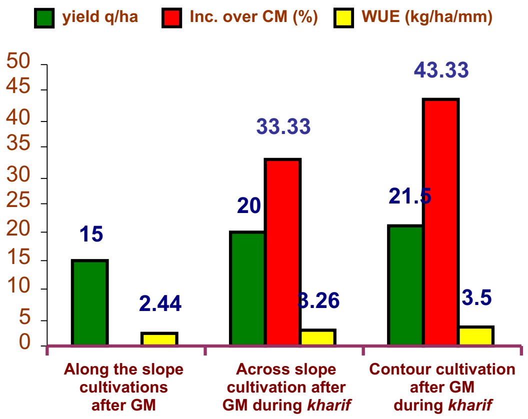
By providing one protective irrigation of 30 mm depth in medium to deep soils during dry spell in *kharif* the yield levels, water use efficiency and B:C ratio were observed significantly enhanced over the period of four years by 100 farmers as shown below.

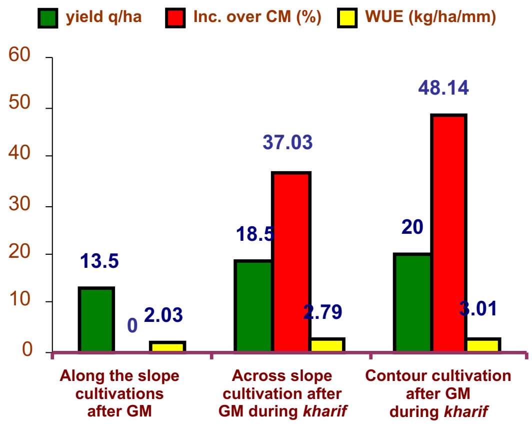
Water requirement of crops at various stages

Crops	CWR (mm)	Critical stage	DAS	Water requirement (mm) at critical stages in *kharif*		Per ha. water required for one protective irrigation	
				30 mm	50 mm	30 mm	50 mm
Cereals							
Sorghum	450	Booting	40-45	90	150	300	500
		Blooming	55-65				
		Milky, Drought Stage	65-80				
Maize		Tasseling	40-65				
	450	Silking	66-95	90	150	300	500
		Grain development	96-105				
Pulses							
Redgram	200	Flowering	35-40	60	100	200	500
		Pod setting	55-65				
Chickpea	200	Late vegetative phase	35-40	30	50	300	500
Black gram	200	Flowering	35-40	60	100	300	500
		Pod setting	55-65				
Green gram	200	Flowering	35-40	60	100	300	500
		Pod setting	55-65				
Oil seed crop							
Ground nut	400	Flowering	30-45				
		Peg formation	45-55	90	150	300	500
		Pod development	60-80				
Sunflower	350	Pre-flowering	25-35	60	100	300	500
		Post-flowering	55-65				
Soybean	450	Blooming	25-35	60	100	300	500
		Seed formation	55-65				
Castor	500	Flowering	35-40	60	100	300	500
		Seed development	40-65				
Cotton	600	Flowering	60-80	60	100	300	500
		Fruiting period	110-130				



Graph : Effect of the protective irrigation through sprinkler and drip systems during *kharif*





Technology promoted through 48 demonstrations (*kharif* and *rabi*) in 32 villages from 5 taluka of 3 districts on 240 ha area with the participation of 45 farmers.

3. Reduction in Evaporation from Pond by using Neem Oil

Background: The water surface in the farm pond of 30 x 30 x 3 m and 20 x 20 x 3 m. with the capacity of 0.741 and 1.971 TMC.

Loss of water from farm pond is through seepage and evaporation. About 19% water is lost by evaporation. Seepage can be controlled by using plastics, tiles etc. To reduce the evaporation losses, neem oil should be spread @ 30 to 40 m/m^2 area.

Impact:

- Reduction in evaporation – upto 15%
- Technology promoted through 15 demonstration in 15 villages from 5 taluka of 3 districts.

4. Drainage Management

i) Drainage management with ridges and furrow system

Lower side of the field suffers from water stagnation causing anaerobic condition. Farmers loose crop on one fifth of area due to poor drainage. System for safe disposal and storage of excess rain water is essential. However, ridges and furrow or BBF system saves the crop from stagnated water. Sorghum crop sown on ridges and soybean on BBF survived as water was stagnated in furrows and safely disposed.

Adoption : Adopted by the farmers on about 2700 ha area to improve the drainage and to save the crop during rainy season at least on 20% area at the lower part of their field.

Drainage improved by BBF / raisebed at lower part

Drainage improved by ridges and furrow at lower part

5. Rehabilitation of drainage network

Background: Widening, Deepening of drainage network and other water bodies like Farm ponds and construction of RCC Cement Nallah Bandh (CNB) in series will play a major role in catching runoff and storing rainwater in beats. From one check dam atleast about 8 to 10 ha irrigation potential can be created directly or indirectly through surrounding wells.

Encouraging trends of utilization pattern of check dams (CNBs) constructed under various programmes in recent decades reiterates the need for rehabilitation of drainage network and construction of small-scale runoff harvesting structures. This activity is found very effective for the augmentation of water resources and to moderate the hydrology of the large farms of the University.

Impact: Outcome of this study with respect to enhanced ground water table in the wells due to increase in gravity yield of the aquifer, increase in surface storage in the drainage network and improved stable ground water table due to reduced hydraulic gradient.

Recommended Technologies Evolved at Dr. DPKV, Akola on Rain Water Management

i) Watering through earthen pots for multi purpose and dry land tree species (MPTS) in non-arable lands

Year and place of release: 33rd Joint AGRESCO held during 9-11 June 2005 at MAU, Parbhani

Background: **I**n the alternate land use systems on one hand it is necessary to develop perennial plantation on non arable lands. However on other hand it is also true that due to the scanty and vagarious monsoon the survival of plantation under rainfed condition is difficult. Therefore present investigation were designed by providing the limited quantity of water (5 lit./p) once in a week for the sake of the survival and establishment Watering through basin, earthen pots and drip irrigation with grass mulching, was studied. Findings generated will be of applicable value for MPTS in rainfed conditions. Results revealed that MPTS like Ramkati (*Acacia nilotica),* Neem (*Azadirchta indica),* Ber (*Zizyphus mauritiana)* and Anjan tree (*Hardwickia binata)* given favourable response in terms of survival and growth for the watering through earthen pots and found superior to other systems of watering.

Similarly the dryland fruit trees like Custard apple *(Annona squamosa),* Aonla (*Emblica officinalis*) and Karvand (*Carrica carrandus*) given the favourable and at par response in terms of survival and growth for watering through earthen pots and drip irrigations.

Recommendation: For the satisfactory establishment of plantation on CCT's in non arable lands it is recommended to provide per plant 5 liters of water once in a week for MPTS and twice in a week for dry land fruit trees at least for first two years through earthen pots with grass mulching under rainfed conditions.

Adoption

- Higher survival
- Enhanced the height and collar diameter
- Water saving
- Higher water use efficiency
- Adopted on 25 ha. area at Dr. P.D.K.V. farm and by farmers on 60 ha in water scarce area of Akola and Amravati district.

ii) Development of silvipasture models

i) Silvipasture models for improving livestock productivity in rainfed region

Year and place of release: 33rd MAU, Parbhani

Background: The low productivity of livestock in rainfed regions is primarily due to insufficient quality fodder supplies. The information on establishment, management and utilization aspects of silvipasture systems lacks in a holistic perspective. Therefore present investigation was designed to establish silvipasture systems on shallow and medium soil and utilize them in small ruminant grazing model. The findings generated will be of applicable value in improving forage resource base for sustainable and higher livestock productivity in the region. The models found most suitable in rainfed conditions were recommended for Vidarbha region.

Recommendation:

For the establishment of silvi-pasture system

- *Acacia nilotica* + *Cenchrus ciliaris* + *Stylosanthes hamata* model is recommended for light soil.
- *Annona squamosa* + *Cenchrus ciliaris* + *Stylosanthes hamata* model is recommended for medium soil in the rainfed area.

Impact:

- Sustainable models for rainfed condition
- Higher grazing utilization
- Higher livestock productivity

Adoption: Adopted on 21 ha at Dr. PDKV farm and by 29 farmers on 41 ha area in 8 villages of Akola district.

iii) Development of runoff prediction models for small agricultural watersheds

Year and place of release: 35th Joint AGRESCO held on 1st to 3rd June 2007 at MPKV, Rahuri

Background: The best fitted 4th degree polynomial equation were useful to academicians, researcher and the extension workers those we wanted to predict the runoff from the particular soil type for designing of the soil and water conservation structures etc. In this context these models were developed and validated with the measured runoff and recommended for the small agricultural watersheds.

Development of runoff prediction models

Recommendation: The following 4th degree polynomial equations are recommended to predict runoff from the shallow and medium soils (x is rainfall and y is runoff in mm).

i) Shallow soil

a) Crop - Sorghum/Maize/Pearl millet

i) T_1 – Sowing along the main slope :-

$$Y = -0.73 + 1.23\,X - 0.03\,X^2 + 0.003\,X^3 - 8.46E\text{-}07\,X^4$$

ii) T_2 – Contour cultivation along the leucaena hedge at 1 m V.I.

$$Y = -2.26 + 0.29\,X - 0.004\,X^2 + 5.10\,E\text{-}05\,X^3 - 1.28\,E\text{-}07\,X^4$$

ii) T_3 – Contour cultivation along the vetiver hedge at 1 m V.I.

$$Y = -5.81 + 0.63\,X - 0.014\,X^2 + 0.00014\,X^3 - 4.08E\text{-}07\,X^4$$

b) Crop - Cotton

i) Sowing along the main slope :-

$$Y = -3.18 + 0.62\,x - 0.0082\,x^2 + 5.08\,E\text{-}05\,X^3 - 8.88\,E\text{-}08\,X^4$$

ii) Contour cultivation along the leucaena hedge at 1 m V.I.

$$Y = -2.27 + 0.30\,X - 0.0029\,X^2 + 1.67\,E\text{-}05\,X^3 - 2.90\,E\text{-}08\,X^4$$

iii) Contour cultivation along the vetiver hedge at 1 m V.I.

$$Y = -3.028 + 0.297\,X - 0.00304\,X^2 + 1.68\,E\text{-}05\,X^3 - 2.91\,E\text{-}08\,X^4$$

ii) Medium soil

a) Crop - Cotton

i) Sowing along the main slope :-

$$Y = -6.31 + 0.76\,x - 0.010\,x^2 + 6.98E\text{-}05\,X^3 - 1.25E\text{-}07\,X^4$$

ii) Contour cultivation along the leucaena hedge at 1 m V.I.

$$Y = -0.81 + 0.15\,X - 0.001\,X^2 + 8.93E\text{-}06\,X^3 - 1.92E\text{-}08\,X^4$$

iii) Contour cultivation along the vetiver hedge at 1 m V.I.

$$Y = 0.03 + 0.14\,X - 0.00095X^2 + 7.69E\text{-}06\,X^3 - 1.65E\text{-}08\,X^4$$

iv) Sowing across the main slope :-

$$Y = -4.33 + 0.58\,X - 0.0094\,X^2 + 6.25E\text{-}05\,X^3 - 1.13\,E\text{-}07\,X^4$$

b) Crop - Sorghum

i) Sowing along the main slope :-

$Y = -6.31 + 0.76 x - 0.010 x^2 + 6.98E\text{-}05 X^3 - 1.25E\text{-}07 X^4$

ii) Contour cultivation along the leucaena hedge at 1 m V.I.

$Y = -3.81 + 0.46 X - 0.007 X^2 + 7.84 E\text{-}05 X^3 - 1.94 E\text{-}07 X^4$

iii) Contour cultivation along the vetiver hedge at 1 m V.I.

$Y = 11.81 - 1.07 X - 0.031 X^2 - 0.0002 X^3 + 6.71 E\text{-}07 X^4$

iv) Sowing across the main slope

$Y = -7.83 + 0.847 X - 0.02 X^2 + 0.0001 X^3 - 3.75 E\text{-}07 X^4$

Adoption : Being used by students and academic staff in their location specific research and also used by NGO's and Govt. officials for design and development of the soil and water conservation structures.

iv) Establishment of sown silvipasture systems on non arable and waste land

Year and place of release: 35th Joint AGRESCO held on 1st to 3rd June 2007 at MPKV, Rahuri

Background: Although livestock rearing is an important source of livelihood in rainfed areas, shortage and low quality of grazing lands due to paucity of soil moisture has been a major constraint. Looking to the very limited scope for expanding the area under pasture on arable lands, pasture development with improved material on waste and non arable lands are of great promise in meeting the forage requirement besides improvement in soil status and water conservation. Therefore the sown, reseeded and natural systems of silvipasture establishment with CCT's at 10 m HI were studied.

The findings generated will be of applicable value for the restoration of non arable and waste land with better soil, water and nutrient conservation. Results revealed that in sown systems of silvipasture establishment with the land treatment of CCT's at 10 m HI the runoff reduced by 93%, soil and nutrient losses reduced by 58 and 75-99%, respectively and improved the pasture quality, production and grazing utilization.

Recommendation: For the restoration of waste and non arable land in terms of better *in-situ* soil and moisture conservation it is recommended to establish the sown silvipasture.

Impact:

- Higher production stability
- Higher grazing utilization
- Improve quality of pasture and production
- Enhance the animal growth
- Enhance soil fertility
- Higher proportion of perennial grasses and legumes
- Higher *in-situ* soil, water and nutrient conservation.

Adoption: Adopted on 11000 ha by farmers, NGO's and Government agencies through various programmes.

v) Contour bund with anjan grass (*Cenchrus Cillaris*) in non arable land

Year and place of release: 35th Joint AGRESCO held on 1st to 3rd June 2007 at MPKV, Rahuri

Background: The contour bunds of 0.18, 0.23 and 0.40 m^2 cross section supported by CCT's with 30cm berm were constructed on non arable land at 5 to 6 m H.I. and supported with plantation. The perennial grasses, *C. cillaris* and vetiver were transplanted at the down stream side of the contour bunds during rainy season. The observations were recorded for reduction in C/S, with reference to the vegetation provided. The reduction in cross section of the contour bunds shown the favourable effect of vegetation on the stability.

The results revealed that the contour bunds of 0.18 m^2 cross section laid at 1 m V.I. in non-arable lands provided with CCT's and *C. Cillaris* (Anjan grass) were found more suitable than the bunds supported with vetiver. The perennial Anjan grass (*C. Cillaris*) is easy to establish by transplanting on the bunds in rainfed condition.

Recommendation: For the alternate land use planning it is recommended to construct the earthen contour bunds of 0.18 m^2 C/S planted with *Cenchrus cillaris* (Anjan grass) and CCT's at 1 m V.I. in non-arable land.

Impact:

- Provides protection to the earthen bund
- Possible to use and restoration of the non-arable land
- Availability of fodder
- Enhances *in-situ* soil and water conservation

Adoption :Adopted on 24 ha area at Dr. PDKV farm, by the Deputy Director Social Forestry, Akola in watershed development programme (600 ha) and 300 ha area by the farmers in Saline tract of Purna river valley.

vi) Continuous contour trenching for rehabilitation of waste lands

Year and place of release: 36th Joint AGRESCO held on 30th May - 1st June 2008 at Dr. PDKV, Akola (Nagpur).

Background: Waste lands are not able to produce biomass due to constraints in rainfall water management, soil, climate, topography and biotic interference. About 12 million ha of pastures and grass lands have low productivity due to lack of *in-situ* rainwater conservation.

The study under taken at University watershed revealed that the growths of the multipurpose trees like Karanj (*Pongamia pinnata*), Ritha (*Sapandus indica*), Bihada (*Terminalia ballerica*), Jamun (*Sizigium cuminis L.*), Kawath (*Feronia elephantum*) and Sisoo (*Dalbergia sisoo*) enhanced in terms of height and collar diameter. Similarly the soil moisture content in soil profile was found significantly enhanced in continuous contour trenches (60 x 30 cm) as compare to others land treatments.

Similarly the growth of Anjan tree (*Hardwickia binata*) and soil moisture content in the soil profile were found significantly enhanced in rainfed condition due to the construction of continuous contour trenches (60 x 30 cm) along the tree rows and opening of contour furrow in between the rows.

Recommendation:

1. For the satisfactory establishment of multipurpose tree species (e.g. Karanj, Ritha, Bihada, Jamun, Kawath, and Sisoo) in rainfed under waste land it is recommended to provide the land treatments of continuous contour trenches.
2. To enhance the growth of Anjan plantation (*Hardwickia binata*) in wasteland, continuous contour trenches along the trees and opening of contour furrow in between the two CCTs is recommended.

Impact:

- Higher *in-situ* soil and moisture conservation.
- Impounding runoff water for subsequent ground water recharge in down stream areas.
- Higher biomass in terms of enhanced height and collar diameter.
- Rehabilitation of the waste land with good stand of multipurpose tree species to meet out the various needs of the community.
- Higher *in-situ* soil, water and nutrient conservation.

Adoption: Adopted in watershed development and management programme on large scale

vii) Intermittent contour trenching (ICT's) for establishment of silvipasture systems trees in non-arable land

Background: ICT's allows for impounding of surface runoff water and will infiltrate in to soil profile. This process of slow release of stored water will lead to improvement in soil moisture conditions. The impounded water will initially increase the base flow. The higher soil moisture regime will assist in rapid seedling establishment and growth.

The study under taken revealed that growth of silvipasture tree species like Ramkati (*Acacia nilotica*), Ber (*Zizupus mauritiana*) and Neem (*Azadiricta indica*) and the soil moisture content in the soil profile was found significantly enhanced even in comparison to the CCT's.

Recommendation: For the satisfactory establishment of silvipasture tree species (e.g. Ramkathi, Ber and Neem) in non arable land in rainfed it is recommended to provide the land treatment of ICT's size (60 x 45 cm).

Impact:

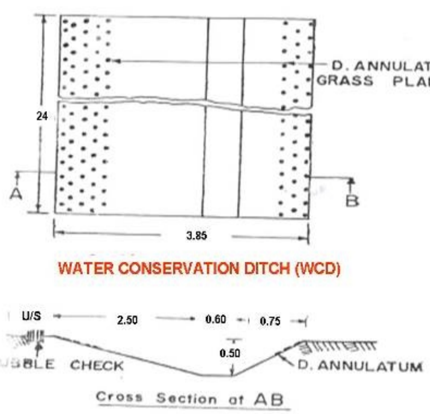
- Uniform *in-situ* moisture conservation
- Rapid establishment of seedlings and growth
- Formation of stable soil complexes
- Improve microsite conditions
- Improve base flow at down stream

Adoption: Adopted in watershed development and management programme on large scale.

viii) Water conservation ditch for deep black soil

Year and place of release : 37th Joint AGRESCO held on 28-30 May 2009 at MAU, Parbhani

Background: Wide and deep shrinkage cracks due to the high clay content and montmorillonite clay mineral cause rapid exhaution of moisture. When wet, deep black soils attain very low infiltration rates and rainwater stagnates for prolonged periods, affects soil aeration and cause



loss of crops in 15 to 20% of inter-bund area. The runoff from the first showers passes through the summer cracks resulting in extensive breaching and failure of all the bunds and ultimately results in formation of gullies.

In water conservation ditch, water does not back up upstream of the ditch, there is no water stagnation, water entering the cracks on the sides of the ditches causes no breaching but helps to charge the soil profile, moisture at down stream side benefitting the crops in the area and waste weirs are dispensed with as surplus water flows as thin sheet over the length of ditch. In water conservation ditch the rainwater is stored *in-situ* without the problems associated with contour/ graded bunds. Therefore ditch is found as a suitable conservation structure in deep black soils.

Recommendation: It is recommended to adopt the water conservation ditches up to 1.5 (top and bottom width 3.85, 0.60 and depth 0.5 m, slope u/s - 1:4, d/s - 1:1.5) in deep black soils of Western Vidarbha region, across the slope or on contour at 75 to 100 m h. I. for better growth of dry land fruit trees and yield of inter-crop under rainfed conditions.

Impact:

- Higher *in-situ* soil and water conservation
- No breaching due to piping
- Improve the base flow at down stream
- Enhance the water use efficiency
- Enhance the moisture content in soil profile.

Adoption: Adopted by 2 farmers on 10 ha area in Amravati district

ix) Performance of Anjan grass as a buffer lines supported to the plantation

Background: The low productivity of live stock in rainfed regions is primarily due to the insufficient quality fodder supplies and availability of seed. The perennial Anjan grass *(Cenchrus cilliaris)* is identified as appropriate species for pasture cultivation and to provide the protection to soil and water conservation measures. In this context the finding generated will be of applicable value in terms of enhanced sol moisture, fodder and seed production over the row planting. The results reveals that buffer lines of Anjan grass on contour bunds enhanced the fodder yield twice with better seed production and improved the soil moisture content by 54 to 112% in shallow and medium soil.

Recommendation: In shallow and medium soil, planting of buffer lines of Anjan grass on the contour bunds (with CCT's) is recommended to enhance the fodder yield and seed production under rainfed condition.

Impact:

- Availability of fodder and seed
- Uniform cover of Anjan grass
- Provides protection to the earthen bund
- Enhanced the soil moisture

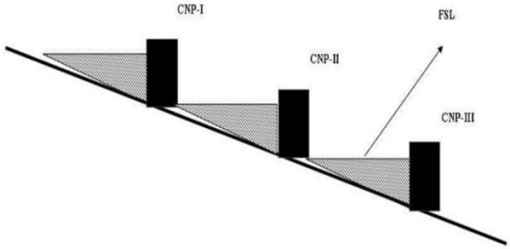
Adoption: Adopted on 25 h at Dr. PDKV farm and by the Deputy Director, Social Forestry, Akola on 400 km. length of bunding in watershed development.

x) Construction of cement nala plugs in series on drainage line year and place of release: 38th Joint AGRESCO, BSKKV, Dapoli held on 31st May - 2nd June 2010.

Background: For harnessing maximum runoff and to have more water recharge in to the soil profile through cement nala plug (CNP) for augmenting the ground water table it is necessary to construct the CNP in series.

xi) Farm pond technology for saline tract of Purna river basin

Background: The soils in saline tract of Purna river valley are saline sodic and ground water is alkaline. Provision of brushwood inlet spillway and reforms in cultivation practices observed suitable to improve the life span of farm ponds. The soil management in the saline tract of Purna river valley is difficult due to the seviour erosion rate, swelling, cracking and seizing characteristics.



During monsoon with the first intensive storm along with runoff there will be seviour soil erosion. Due to the cracking nature of soil piping takes place which causes damages to the farm pond and deposits silt in to the farm pond. Due to the high silt deposition rate life of the farm pond drastically reduces. To overcome these problems adoption of *in-situ* soil and water conservation practices like cultivation across the slope, contour cultivation, opening of furrow in between the crop rows and farm pond to harvest and recycle the runoff is beneficial.

Therefore, the present investigation was designed to study the improvement in the life span of the farm pond in saline tract of purna river valley.

The findings generated will be of applicable value for improving the life span of the farm ponds. Provision of brushwood spillway and reforms in cultivation practices found most suitable in saline tract of Purna river basin for rainfed agriculture.

Recommendation: In the saline tract of Purna river valley it is recommended to adopt across the slope or contour tillage in the catchment and to provide Brushwood inlet spillway to the farm ponds.

Impact:

- Reduced the silt deposition by 35 to 46%.
- Increased the life span of farm pond by 54 to 88%.
- Brushwood spillway was observed more stable and convenient over stone inlet spillway.
- Clean water available in farm pond for protective irrigation.
- Reduced in soil, nutrient and runoff losses from catchement of farm pond.

- Technology promoted in saline tract through 30 demonstrations in 25 villages from 3 taluka of 2 districts (Amravati and Akola). Presently more than 250 farmers in Saline tract of Purna river valley have adapted on their own.

xii) Determination of effective life span of CCT's in agro-horticulture system

Background: For up keeping the effectively and efficiency of the CCT's layout renovation of the system after specific period is necessary. In this context this investigation was design and carried out to study the rate of silt deposition, reduction in the cross section and life span of the CCT. The findings generated will be of applicable value in watershed development programme for the reopening of the CCT's. for up keeping the effectivity and efficiency.

Recommendation: In shallow soils under agro-horticulture systems the efficient life of the CCT's observed up to eight years.

Advantage: This recommendation is useful in watershed development and management programme for Government and non Government organization for reopening of CCT's in agro-horticulture system.

Adoption: This recommendation is being adopted by the Government development departments and NGO's in the watershed development and management programme.

xiii) Deep Cultivation upto 30 cm

Year and place of release: 41st Joint AGRESCO held on 30th May to 1st June 2013 at VNMKV, Parbhani

Background: Productivity, stability, income generated from rainfed farming are linked with the attempts of drought proofing providing the means of higher and prolonged residual moisture conservation to every farmer is must at least to the part of his holding alone, so that weather vagaries can be considerably modified and will come to the rescue of farmers.

Deep cultivation across the slope upto 30 cm depth retained higher soil moisture during dry spell, enhanced rain water use efficiency and increased yield of sole cotton, soybean and inter-crop over shallow cultivation upto 20 cm depth.

The results generated will be of applicable value in vertisols and in saline sodic soils of Purna river valley.

Recommendation: In medium deep soil, cultivation upto 30 cm depth is recommended for maximum in-situ water conservation.

Impact: Deep cultivation significantly reduced runoff (9 to 28%), soil loss (10 to 23%), nutrient losses (13 to 30%) and increased yield (8 to 18.22%). Deep cultivation upto 30 cm depth can be easily adopted by farmers using conventional tools or more conveniently by using sub-soiler with added benefits.

Adoption: Technology promoted in vertisols and saline sodic soils of Purna river valley through 110 demonstration in 26 villages from 4 taluka of 3 districts (Amravati, Akola and Buldhana) on 315 ha area. Presently the adoption is on about 5000 ha.

xiv) Life of CCT's in sown silvipasture system

Background: For up keeping the effectivity and efficiency of the CCT's layout renovation of the system after specific period is necessary. Information about life of the soil conservation structures like CCT's is necessary for planning and execution of the Watershed Development and Management programme. In this context this investigation was design and carried out to study the rate of silt deposition, reduction in cross section and life span of CCT's in sown silvipasture system.

The findings generated will be of applicable value in watershed development programme mainly focused on the development of silvi-pasture systems on the shallow degraded and non-arable lands supported with CCTs. Reduction in the depth and cross section under sown silvipasture system was observed to be 80 to 95% and 75.5 to 90.56%, respectively.

Recommendation: In assured rainfall zone of Vidarbha region the life of the CCT's in sown silvipasture system is recommended upto 10 years.

Clients: Various Government development departments and NGOs involved in the development, management and rehabilitation of the watershed.

xv) Mono & Two tier Rain water management system for different cropping pattern in saline tract of Purna river valley

Year and place of release: 42nd Joint AGRESCO held on 12th to 14th May 2014 at BSKKV, Dapoli.

Background: Rainfed area in purna river valley are highly diverse ranging from resource rich area with good agriculture potential to resource poor area with much more restricted potential with salinity and sodicity. The swing in onset, continuity and withdrawal pattern of monsoon make crop production a risky proposition. Therefore, *in-situ* conservation of rain water (Mono tier) and recycling of runoff from farm ponds for protective irrigation (Two tier) during dry spell are necessary which needs the reforms in cultivation practices in such a fashion that maximum rainfall gets conserved in to the soil profile and moisture becomes available to the crop during prolonged monsoonic break. The findings generated will be of applicable value for sustainable and economical rainfed agriculture.

Recommendation: For the higher and sustainable return the double cropping system of green gram – Chickpea and Soybean – Chickpea along with contour and across slope cultivation with protective irrigation from farm pond is recommended for the saline tract of Purna river valley.

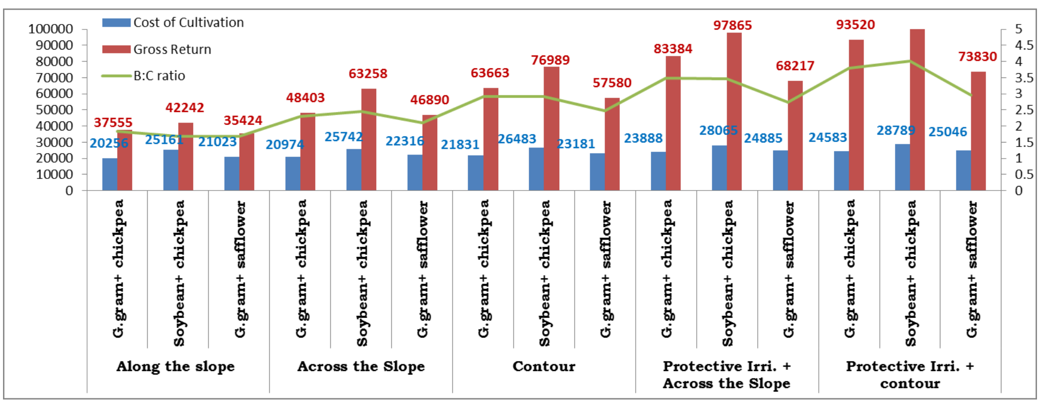
Adoption: Looking to the benefits of mono & two tier syystems of water management over the period of 5 years more than 50,000 farmers adopted the technology has been adopted on more than 50,000 ha. area through the network of about 17,000 farm ponds in saline sodic soils of Purna river valley.

xvi) Growth of dry land tree species as influenced by various soil moisture conservation techniques under rainfed condition

Year and place of release: 43rd Joint AGRESCO held on 28th to 30th May 2015 at MPKV, Rahuri.

Background: Due to the vagaries of monsoon it is difficult to establish the dry land fruit trees for want of insufficient moisture for the growth of the trees. In this context the experiment was conducted by providing the various soil and moisture conservation techniques to harvest the rain water and to enhance the moisture content in soil profile and their by growth of these tree species.The results generated will be useful for the plantation of dry land tree species like Karanj, Sitaphal, Bel, etc. in rainfed conditions.

Recommendation: For the satisfactory growth of



Economics of cropping systems under Mono and Two Tier system of rain water management

dry land tree species (Karanj, Sitaphal and Bel) and higher moisture conservation in medium deep soil upto 1.5 to 2.0% slope, the half moon basin at downstream (45 cm away from plant, 20 cm wide and high) is recommended.

Clients: Various Government development departments and NGOs involved in the development and management of the watershed.

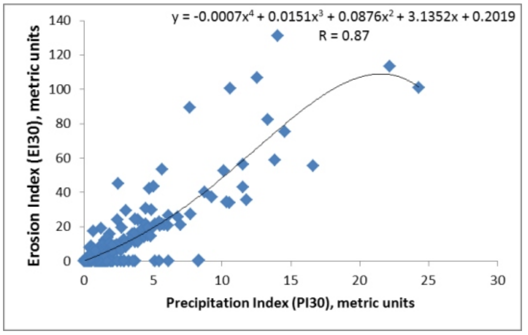
xvii) Evaluation of erosion potential for Akola district

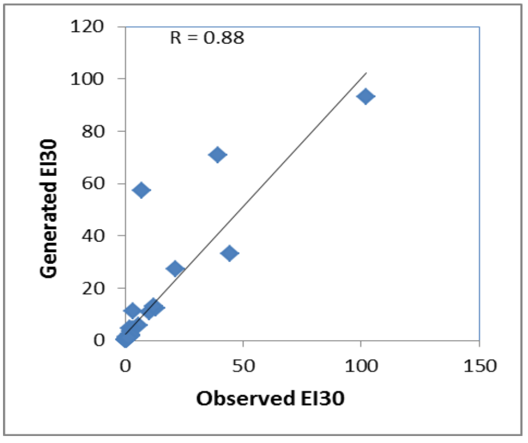
Year and place of release: 43rd Joint AGRESCO held on 28th to 30th May 2015 at MPKV, Rahuri.

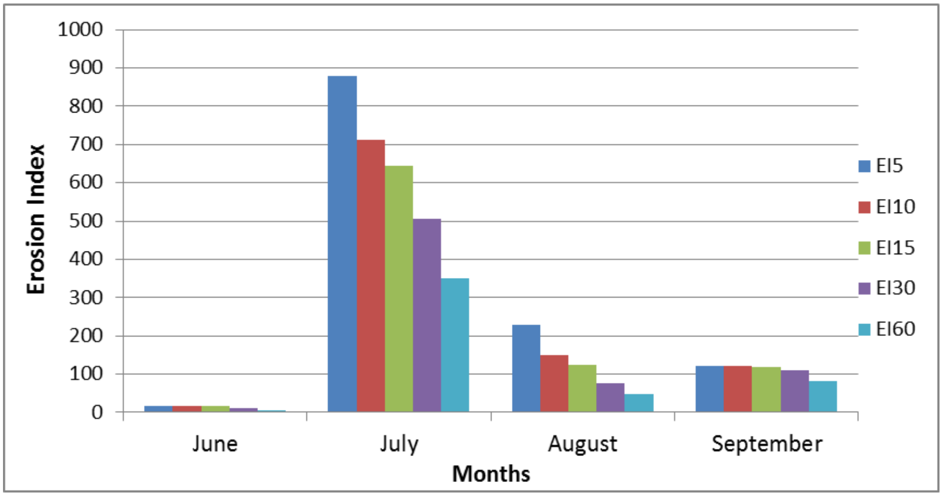
Background: The existing method of estimating erosion index is laborious and time consuming, involved the preparation of detailed intensity tables, estimating kinetic energy there from and calculating EI values for individual storms.

A more simple, quick and time saving method for estimating EI is needed for soil conservation planner to predict this information factor of USLE. In view of above the experiment was undertaken to reduce the laborious computational process arriving at EI values without sacrificing accuracy, from the total daily precipitation and maximum intensity for selected time intervals.

Average monthly plot of EI5, EI10, EI15, EI30 and EI60 values will help in choosing the best time for establishment of anti-erosion vegetation and planning of cropping pattern. The results generated will be helpful for estimation of erosion index for 30 min rainfall intensity duration for Akola district.







Recommendation: Below best fitted 4th degree polynomial equation is recommended to predict the erosion index for 30 min duration for Akola district.

$y = -0.0007\ x^4 + 0.0151\ x^3 + 0.0876\ x^2 + 3.1352\ x + 0.2019$ (y = EI and x = PI).

xvii) Impact of sub-soiling in deep black soils

Year and place of release: 44th Joint AGRESCO held on 28th to 30th May 2016 at Dr. PDKV, Akola.

Background: A significant cause of low production and crop failure in rainfed agriculture is due to lack of water in the soil. This is caused by a combination of low and erratic rainfall, and poor utilization of the available water. Soil moisture management is, therefore, a key factor to enhance water and energy use efficiency and production. This means that the amount of water that enters the soil (infiltration) must be increased in the form of soil moisture. For this, opening the hard pan of deep soils using sub-soiler and allowing water to enter into the sub-strata of the soil is the best option. In view of this, the present study was conducted to find out the effect of moisture conservation by various tillage practices in soybean under rainfed condition.

Results indicate that Subsurface Tillage (1 Subsurface tillage at 90 cm horizontal distance + 2 Tyne + 1 blade harrow) in soybean and cotton crop is effective for higher *in-situ* soil, water, nutrients conservation and improving physical properties of the soil, crop growth, water and energy use efficiency and yield.

Recommendation: Due to compaction the hard pan formed in the mediu, to deep black soil of Vidarbha for the improvement in physical properties of soil and higher production and benefits of Soybean and Cotton crop, it is recommended to adopt sub-soiling at 90cm horizontal interval up to 55 to 60 cm with 2 type and 1 blade harrow before sowing.

Impact:

i. Runoff reduced by 99.27%.

ii. Soil loss reduced by 98.42% and Nutrient loss by 98.61 to 99.60%.

iii. Soil moisture enhanced by 25 to 47.59% at 15 to 60 cm depth.

iv. Increase in yield upto 55.51%.

xviii) Impact of rain water conservation techniques on production and water use efficiency under rainfed condition

Year and place of release: 45th Joint AGRESCO held on 29th to 31st May 2017 at VNMKV, Parbhani.

Background: *In-situ* recharge of rain water needs reforms in cultivation practices in such a fashion that maximum rainfall get infiltrated in to the soil profile and it becomes available to the crop during prolonged monsoonic break and controls water crises in agriculture by the way of 'more crop per drop'. In this context the experiment was carried out to study impact of rainwater conservation techniques on production, water and energy use efficiency. Results indicate that contour cultivation with ridges and furrows in Jawar crop is effective in controlling runoff, soil loss and improving crop growth, production and water use efficiency as compared to other treatments.

Recommendation: For higher *in-situ* soil and moisture conservation, yield, energy and water use efficiency contour cultivation with ridges and furrow after 30 days of sowing is recommended for *kharif* crops under rainfed conditions.

Impact:

i. Reduced runoff by 98.46%.

ii. Reduced soil loss by 99.76%.

iii. Reduced Nutrient loss by 99.02 to 99.95%.

iv. Increased soil moisture by 15.82 to 16.59%.

v. Increased yield by 39.75%.

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Micro Irrigation – Challenges and Opportunities in Indian context

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INTRODUCTION

Agriculture plays a crucial role in ensuring food and livelihood security of the large population in India. It employs nearly 2/3rd of the work force and accounts for nearly 17% of country's Gross Domestic Product. Types of crop, cropping pattern, farming systems and allied activities practiced in different parts of the country have their own identity depending on the agro-climatic conditions and socio-cultural impressions of the region. The northern region experiences extreme winters whereas tropical conditions prevail in the southern peninsular. The north-east region is characterized by hot and humid climate whereas north-western regions by dry and arid conditions. Rainfall is the primary source of water for agriculture. India receives most of its annual rainfall *i.e.* 73% from South West Monsoon, whereas coastal areas of the Peninsula and Tamil Nadu receive bulk of their annual rainfall from the receding South West Monsoon, periodic cyclonic disturbances and the North East Monsoon.

India is having one among the largest irrigation network in the world. Country is also blessed with a big network of river system with both glacier and spring fed rivers. More than 80% of the runoff is captured in 20 major river systems of India. The total runoff is estimated to be about 1869 BCM of which utilizable run off is about 1123 BCM. So far, the total storage of more than 260 BCM has been created through reservoirs across these river systems. Though substantial storage has been created through major and medium irrigation projects, yet ground water contributes 63% of the irrigation source in the country. It is estimated that net availability of ground water is 411 BCM of which about 228 BCM is being used for irrigation which is about 87% of the total draft.

The irrigated area accounting from both surface and ground water sources is estimated to be about 68 million ha (m ha) which constitutes only 48% of the net sown area of the country. About 65% of the food grain production comes from irrigated agriculture. While observing the characteristics of irrigated agriculture, it is seen that the growth in productivity is very marginal in the recent past which indicates that scopes of enhancing productivity in irrigated agriculture is limited. In contrary, rainfed agriculture which accounts for about 52% of the net sown area is contributing only about 35% of the food grain production as the productivity is much lower than that of irrigated areas. It is projected that the country will require a food grain production of about 310 million ton (m t) to feed more than 1.5 billion people by the end of 2030, amid the challenges of climate change, natural resource depletion, urbanization and shift in food habit. It is in this context, vital that rainfed agriculture needs a transformation to meet the growing demand of food production. Water being the most important input for agriculture, enhancement of productivity of water is the principal driver for achieving this transformation.

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Potential of Micro Irrigation (MI) in India

Agriculture sector which consumes currently more than 80% of the fresh water resources is likely to get a much reduced share due to competitive demand, where as the demand for water to meet the pressure to produce more food, horticultural produce and raw materials for the industries would increase many fold. To meet the challenge of higher production with reduced share of water, more thrust is required on enhancing water use efficiency (WUE) in agriculture sector.

The WUE for irrigation is only 30 to 40%, which is one among the lowest in the world. This may be visualized from the wide gap between irrigation potential created (IPC) and irrigation potential utilized (IPU). As against the gross created irrigation potential of about 118 m ha area, the gross irrigated area is only 96 m ha, resulting in a deficit of about 22 m ha. This can be bridged to the advantage of agriculture and farmers by adoption of micro irrigation and suitable agronomic practices. Besides, the indiscriminate use of water in irrigation command primarily through flood irrigation has resulted in water logging and soil salinity in about 8.5 m ha of the canal command.

Groundwater over exploitation has caused substantial depletion of water table and water quality deterioration in many areas. This is mainly due to wasteful management and non-scientific crop planning. Recent assessment report of Central Ground Water Board (CGWB) shows that 1,034 of 6584 assessed blocks are over-exploited. Besides, 253 are Critical, 681 are semi-critical and 96 blocks are completely saline. Since ground water is accessed through water lifting devices, it can be easily linked to micro irrigation for conservative use without any additional energy requirement.

Production in rainfed areas is low mainly due to poor productivity of water. About 55% of the rainfall received in the farmland is being used for agriculture and an allied activity *i.e.* nearly 45% of the rainfall is not put into productive use. If the rainwater is harvested in small storage structures and efficiently used, it will not only improve effectiveness of rainfall, but also create opportunities for protective irrigation during critical dry spells.

Agriculture accounts for 20-25% electricity consumption in India which is about 1,70,000 million kilowatt hour and is primarily used for irrigation. Use of micro irrigation can save 30% of energy consumption. Similarly, the NPK fertilizer consumption is about 27 m t annually which is highly subsidized and through adaption of micro irrigation the fertilizer consumption efficiency can be enhanced by about 28.5%.

Indian agriculture crumbles under the situation where there is shortage or failure of monsoon in particular season. This results in farmers' distress and below average crop yields particularly in areas/regions of Maharashtra, Karnataka, Andhra Pradesh, Gujarat, Madhya Pradesh, Karnataka, and Rajasthan where the frequency of drought is very high. Micro irrigation protects crops during critical dry spells with live saving irrigation from the saved water which is not feasible through flood irrigation *i.e.* serves as a major relief for drought prone areas of the country.

The per capita water availability in terms of fresh water has reduced from 1860 cubic meter/person/day in 2001 to 1474 cubic meter (cu m) in 2015. By 2050, it may go below 1140 cu m which is very close to water scarcity conditions. Shifting to micro irrigation will significantly reduce demand of water thereby making ways for meeting higher domestic and industrial demand.

This needs paradigm shift in programmes and policies in agriculture sector particularly for conservation of water through appropriate management, application and equitable distribution of this precious resource. Penetration of micro irrigation systems is still very low in India. The average penetration at the all India level is about 7.3% which is much lesser compared to countries like Israel, US, Brazil, China etc. With half the cultivable land in the country still being rainfed, there is mammoth potential for promoting micro irrigation in India.

Growth of Micro irrigation in India

Micro irrigation in India has seen a steady growth over the years. Since 2006, area covered under micro irrigation has grown at an average growth rate of 12.46%. In the initial phase as an individual development programme for promotion of micro irrigation till the concept of comprehensive irrigation chain development under the umbrella of Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) *i.e.* till 2013-2014, the average growth was observed to be 4.6%. After integration of all water related programmes under PMKSY, there has been a greater momentum in adoption of micro irrigation by farmers. During 2014-2015 to 2017-2018, the average growth in adoption of micro irrigation has been observed to be 26.5%. The coverage during 2017-2018 is more than 1 m ha which is highest ever reported in any financial year. The favorable policies by Central and State Govt's., availability of improved technologies and awareness among farmers have resulted in the increase in rate of growth in recent years. The state wise coverage of micro irrigation till 2017-2018 is given in Table 1.

Majority of the area covered under micro irrigation systems comes under sprinkler irrigation with 53.4%, while 47.65 comes under drip irrigation. Though the coverage under drip irrigation is more in recent years, sprinkler irrigation has shown a stronger growth of 13.75% compared to 12.58% to that of drip since 2006 (Fig. 1).

There is a wide variation in the compound annual growth of micro irrigation across states. From Table 2, it may be observed that the growth in the states of Uttar Pradesh, Madhya Pradesh, Tamil Nadu, Karnataka, Gujarat, Haryana, Chhattisgarh, Andhra Pradesh, Telengana, Odisha, etc. are encouraging, whereas lot of efforts are required to bring other states to this level.

Table 1: State wise micro irrigation coverage

S.No.	State	Area under Micro Irrigation		
		Drip	Sprinkler	Total
1	Andhra Pradesh	1150758	434191	1584949
2	Bihar	10496	104080	114576
3	Chattisgarh	21981	275362	297343
4	Goa	1186	1129	2315
5	Gujarat	636663	644473	1281136
6	Haryana	30038	564873	594911
7	Himachal Pradesh	5160	4130	9290
8	Jharkhand	18011	14401	32412
9	Jammu & Kashmir	23	57	80
10	Karnataka	581340	705300	1286640
11	Kerala	23083	8245	31328
12	Madhya Pradesh	293610	227815	521425
13	Maharashtra	1089600	455769	1545369
14	Odisha	23240	89409	112649
15	Punjab	35375	12906	48281
16	Rajasthan	228923	1607827	1836750
17	Tamil Nadu	412370	90836	503206
18	Telangana	163577	58333	221910
19	Uttrakhand	4834	3029	7863
20	Uttar Pradesh	21960	77067	99027
21	West Bengal	629	52688	53317
22	Arunachal Pradesh	613	0	613
23	Assam	373	848	1221
24	Manipur	288	30	318
25	Meghalaya	308	307	615
26	Mizoram	3064	1364	4428
27	Nagaland	444	5005	5449
28	Sikkim	6044	3042	9086
29	Tripura	444	1651	2095
30	Others	15169	30636	45805
	Total	4779604	5474803	10254407

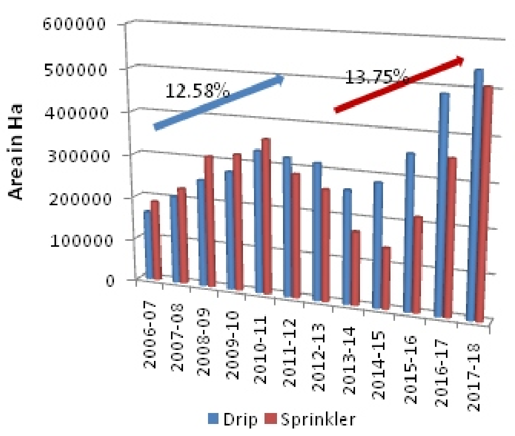

Fig. 1. Growth rate of Drip and Sprinkler

Table 2: State wise Growth of micro irrigation

S.No.	States	CAGR (%)
1	Uttar Pradesh	25.42
2	Madhya Pradesh	23.74
3	Tamil Nadu	19.46
4	Andhra Pradesh and Telengana	18.82
5	Karnataka	16.23
6	Gujarat	14.11
7	Haryana	11.79
8	Chhattisgarh	9.10
9	Odisha	7.88
10	Other States	3.90

Support for Micro Irrigation

To encourage adoption of micro irrigation, assistance is made available to farmers under Per Drop More Crop component of PMKSY. Financial assistance up to 55% for Small & Marginal farmers and 45% for other farmers is available for installation of Micro Irrigation under the scheme. Besides, some States provide top up/ additional incentives to farmers for encouraging them to adopt micro irrigation.

To provide impetus to the micro irrigation, a dedicated Micro Irrigation Fund (MIF) has also been instituted with NABARD with an initial corpus of ₹ 5000 crore for facilitating the states to mobilize additional resources for expanding coverage of micro irrigation. MIF will not only facilitate States in incentivising and mobilizing resources for achieving the target envisaged under PMKSY-PDMC, but also in bringing additional coverage through special and innovative initiatives by State Governments. States may use this fund for integrated projects linking with commodity, solar energy or irrigation command. Farmers Producers Organizations/Cooperatives/ Water User Associations/State Level Agencies may also access the funds with State Government Guarantee or equivalent collateral in the alternate. These organizations may access this fund for innovative cluster based Community Irrigation projects for micro irrigation coverage.

Impact of Micro Irrigation

The Department of Agriculture, Cooperation and Farmers Welfare in association with National Committee on Plasticulture Applications in Horticulture (NCPAH) undertook an impact assessment engaging M/s Global Agri. System Pvt. Ltd. The Impact Evaluation study was conducted during 2014 in 13 selected States covering 64 districts of the country. Some of the major findings are summarized in the following paragraphs.

With the intervention of Government to promote micro irrigation, an increase in utilization of degraded/marginal land into cultivable land has been observed. Besides, a considerable increase in cropping intensity has been witnessed in the farms adopting micro irrigation. Micro irrigation has contributed towards reduction in input cost like fertiliser, insecticides, pesticides, water, energy etc. Irrigation cost is reduced by 20-50% with average of 32.3%. Reduction in electricity consumption by about 31% has been observed due to use of micro irrigation system. Saving of fertilizers in the range of 7-42% (average of about 28%) was observed.

Micro irrigation has generated benefits to the farmers in terms of enhancement of the productivity. The average productivity of fruits and vegetables has increased about 42.3% and 52.8%, respectively mainly because of crop spacing, judicious use of water and other inputs, etc. The overall benefits accrued from the micro irrigation system are reflected in the income enhancement of the farmers. All the surveyed states reported increase in farmer's income in the range of 20 to 68% with an average increase of 48.5%.

Beneficiaries of all the states under study have shown decrease in utilization of the labour in pre-harvest practices that is labour saving on irrigation, weeding, fertilization and other operations. It shows that the use of human labour after the use of micro irrigation has decreased significantly and ranges between 7.41 to 18.75%. But, in post-harvest operations, right from harvesting to handling and disposal of the produce, there is an increase in labour utilization and it ranges between 21.19 to 50.23% due to the increase in production which requires more of the labour for harvesting, assembling and grading, handling, transportation and disposal of the produce.

Clogging of drippers mainly due to poor quality of water is a common problem confronted by the farmers during its operation. This problem is mainly taken care by injecting acid into drip irrigation system there by lowering the pH of the irrigation water and preventing precipitation of salts such as calcium carbonate, magnesium carbonate or ferric oxide. It was observed during the survey that the availability of sulphuric acid in the nearby towns is a major constraint and farmers are forced to purchase new spares by discarding clogged drippers. Therefore, studies need to be carried out to device efficient eco-friendly de-clogging measures so that farmers do not suffer from such problems.

Inadequate information about the operation, maintenance as well as the usefulness of micro irrigation is one of the main reasons for its uneven spread across regions in India. Farmers still do not have full knowledge on the usefulness and support available for micro irrigation in Government programmes.

Challenges

Sate wise coverage of micro irrigation in India is given at Table 1. Though there has been considerable stride in coverage of micro irrigation, yet the benefits are mostly accessed by the Southern and Western States *viz.,* Andhra Pradesh, Karnataka, Tamil Nadu, Telangana, Gujarat, Maharashtra and Rajasthan. It is observed that about 86% of the coverage is reported from these states in the last few years. The performance of states in the Eastern, Northern and North Western region is slow to moderate, while the progress in North Eastern and Hilly regions is almost negligible.

It may also be seen that the adoption of micro irrigation by farmers are predominantly for horticulture crops like fruit trees/plants, vegetables, flowers, etc. It is observed that adoption of micro irrigation is predominantly for horticulture crops where as coverage in agriculture crops is much less which is about 25-30% only. Farmers and field functionaries are still in the mindset that micro irrigation is primarily for horticulture crops. This mind set needs to be changed and farmers need to be motivated for its use in other field crops to minimise investment on energy, labour and agricultural inputs with higher productivity and to protect crops during water scarcity.

It is also observed that adoption of micro irrigation is primarily linked to tube wells. Though it is important for efficient use of ground water, yet the conservative use is equally important for small water harvesting structures. Small water bodies are meant for protective irrigation and adoption of conventional irrigation will not help its optimal use as the limited water source will be exhausted in one/two irrigation without any saving for irrigation in critical dry spells to protect the crops.

The presence of micro irrigation in canal command is almost negligible. Though adoption of micro irrigation in few commands is performing well, yet its replication to other commands is not happening. It is estimated that with the adoption of micro irrigation system in irrigated area with conventional cropping system, additional area of upto 15% in *kharif* and 23% in *rabi* can be brought under irrigation from the same source, at adoption level of 50%. And at adoption level of 25%, the coverage can be extended upto 8% in *kharif* and 12% in *rabi*.

Lot of industries are manufacturing micro irrigation systems or some elements of the system. But there is lack of organised institution to ensure use of standard quality material or post installation maintenance services. Some farmers are affected by the poor services of the industries/ companies. There is need for an organised institution to monitor the quality of materials provided to the farmers and safeguard their interest.

The investment and funding arrangement by Central and State Governments is much low compared to the enormous potential of micro irrigation existing in the country. Micro irrigation be considered as an important infra-structural development and must increasingly occupy the centre-stage in the development and management of water resources in the country towards poverty alleviation, food security and environmental sustainability.

The cost of micro irrigation system is high. Even if the subsidy is given, the farmers share is itself substantial and beyond the reach of many small and marginal farmers. There is need to bring low cost technology to make the system sustainable and affordable to the large segment of farming community.

Financing for farmers continues to be a major impediment. Farmers continue to have difficulty finding financing options and even once they do, the collateral is very high. Finding ways to ensure easier financing norms for farmers is a priority.

Lot of time is consumed in accessing the benefit of the scheme. Sometimes the implementation process goes through months, but the farm fallow period is very limited for installation. Farmers lose the interest to install the system considering the longer processing period. Therefore, ensuring timely completion of the process (before the beginning of April) is paramount to safeguard the interests of the farmers.

The growth of micro irrigation in the country is mostly driven by Government initiatives. Considering the huge potential, the private sector should be a partner in the development and diffusion of micro irrigation technologies and should work in partnership with the public sector and the NGOs.

Lack of energy support particularly electric power supply is a major bottleneck in adoption of micro irrigation technology. Many farmers even if interested for adopting the technology are deprived of it due to non availability of assured electric supply.

Way Forward

Lack of integration, synchronization or cohesiveness restricts the outcome of developmental programmes. For example, a water body is created but the conventional flood irrigation system is not replaced nor proper crop alignment is emphasized, for which the stored water is exhausted in two/three irrigations and fails to meet the requirements in critical dry spells to save crop damage. Thus integration of micro irrigation for precision water use and adoption of appropriate cropping system and conservation agriculture practices matching with the water availability will deliver optimal outcome of the inter-related interventions.

There is need to develop human resources and entrepreneurship at the village level for regular monitoring of the system and offering technical guidance to the farmers, as and when needed. The village youths/agricultural graduates may be given short crash courses on technical, operational and maintenance aspects, who will act also as local consultants. They will have the internet facility and give advice to the farmers in consultation with selected panel of experts using internet.

A strong coordination among irrigation and agriculture departments at district level and participatory irrigation management is required to popularize micro irrigation in canal commands.

WUAs / federations / cooperatives should be promoted at state and national level. A participatory approach including the public, private, NGO and civil society to promote research-extension-farmer-market linkages is inevitable. Since the system cost of micro irrigation is expensive, portable systems can be popularised through custom hiring services.

All tube wells are linked with water lifting devices and the same unit can be made use to operate micro irrigation system for conservative and efficient use of water. All efforts be made to convert flood irrigation system in tube well operated farms into micro irrigation. The GW critical blocks to be mandatorily shifted to micro irrigation on priority basis.

There is need for an organised institution/ mechanism to ensure availability of quality materials to the farmers, service support and safeguard their interest. The micro irrigation system manufactures should be involved in providing advice on agronomic packages to the farmers as an integral part of the system. Besides, inter-state visits should be arranged for a group of farmers to visit some of the progressive states. A large number of demonstrations on micro irrigation should be laid at strategic locations. One national agency may be identified and assigned the responsibility to look into the grievances and services related issues both for farmers and manufacturers and investigating it for needful advice to states/centre for taking appropriate action.

It needs to be ensured that only good quality micro irrigation systems having certification of Bureau of Indian Standards (BIS/ISO) are supplied to the farmers. It needs to be ensured that appropriate standards for micro irrigation system components are developed and notified from time to time. Moreover, the anomalies in some of the existing BIS need to be removed for preventing misuse of the standards. Post installation maintenance and extension support needs to be provided by the industry. At the grassroots level there should be service providers to address the local problems related to micro irrigation. These service providers could be young graduate or well-trained farmers.

There is a need for extending assured electric network in the interior agricultural landscape and/or creating alternate renewable energy sources like solar or wind energy for operating the system. Besides, cost effective and low head systems need to be developed and popularized for conservation of energy.

The design of the micro irrigation system and its various components such as filters, emitters, etc. should be easy and simple so that even the traditional farmers may successfully operate and maintain them. There is need for thorough research and development by scientists and industries to make the system more simple, robust and affordable at low prices.

The entire process, from application to installation and payment, are not operated online in many states. Use of systems such as geo-tagging and referencing allow real-time monitoring of programme and fast tracking installation process.

Finding ways to mobilize financial and technical resources to boost its adoption in low penetrating states is the need of the day. Till the time low cost technologies at affordable rate are available, higher financial assistance may be considered in the low and moderate penetrating states especially for the small and marginal farmers for few more years to get better acceptability of the technology.

Micro irrigation be given priority sector lending status to help the farmer with financing and benefits at par with crop loan like lower interest rate, interest subvention and credit guarantee fund etc. to ensure that banks are more comfortable providing funding to this sector.

Micro irrigation which is primarily used for horticulture crops needs to be incentivised through package of practices to encourage farmers to use in field crops. Making use of micro irrigation may be considered mandatory for water guzzling crops. This has been initiated by few states for adopting micro irrigation for sugarcane. It can be considered to be taken up as a policy initiative from State/National level for mandatory use of micro irrigation system for selected water intensive crops to avail government benefits.

Free or subsidized energy and water charges are major constraints in motivating farmers to save water. All agriculture commodities should indicate the water footprint and a definite range be prescribed for each commodity for being considered eligible for government procurement and even for export. This will encourage farmers to adopt micro irrigation technologies.

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Effect of Cropping System on Runoff, Soil Loss and Productivity in Kandhamal District of Odisha

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INTRODUCTION

Strip and intercropping of cereal crops with pulses/oilseeds are approved practices of breaking long slopes, which prevent soil loss, reduce runoff and enhance productivity. Samra (2002) reported that renovation of terrace and plantation of fruit plants, timber plants improved biomass production, net returns, growth of crop, productivity, reduction of runoff in the range of 1.5-10.8 times, peak flow rate by 20 times and soil loss in the range of 1.2 to 5.2 times, as well as water table rise. Subudhi *et al.* (1999) have reported that effect of vegetative barrier like Vetiver increased the rice yield, decrease the soil loss and decrease the runoff compared to farmers practice. Arora *et al.* (2002) reported that there is a growing need for rain water management since 96 m ha out of 142 m ha of net cultivated land of the country is rainfed. Scientific use of these resources will definitely increase the productivity and conservation of resources like soil and water. Kumar (2002) reported that impact of different soil& water conservation techniques *viz.,* contour bunding, terracing, land leveling, smoothening and gully plugging, sowing across the slope, vegetative barrier, increase the *kharif* crops by 25-30%. Establishment of vegetative barrier with mechanical measures were more effective in controlling soil erosion (3.8 t ha^{-1}) over conventional method (9.64 t ha^{-1}) and runoff thereby making more moisture available for crop growth. Anonymous (2005) reported that intercropping of groundnut with pigeonpea planted along contour gave the highest rice equivalent yield, lowest soil loss and runoff. Therefore, this experiment has been designed to know the effect of strip as well as intercrop of pigeonpea, rice and groundnut on runoff, soil loss and productivity on sloping agricultural land.

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MATERIALS AND METHODS

The present study was conducted in All India Coordinated Research Project, OUAT, Phulbani during the year 2006 on 2% land slope. The treatments tried were T_1-Sole crop of rice, T_2-Sole crop of pigeonpea, T_3- Sole crop of groundnut,T_4-Pigeonpea and rice in alternate strips, T_5- Pigeonpea and groundnut in alternate strips, T_6-Intercrop of rice and pigeonpea (5:2), T_7- Intercrop of groundnut and pigeonpea (4:2), T_8-Uncultivated fallow, T_9-Cultivated fallow. All crops were planted across the contour. Varieties used were ZHU-11-26 for rice, UPAS-120 for pigeon pea and Smruti (OG-52-1) for groundnut. The experiment design was Randomized Block Design with three replications. Plot size was 25 x 2 m. Recommended package and practices were given to the agriculture crops. Multislot division box and drums were put to measure the runoff and soil loss daily after each rainfall. The runoff collected daily at 8 am was measured from the drum and 1 litre of runoff from each drum were collected for silt analysis. Soil was measured from the silt sample collected after evaporating the sample in the heater. The rainfall was also measured. The relation between rainfall (mm), runoff (mm), rainfall (mm), soil loss (t/ha) and runoff (mm), soil loss (t/ha) were calculated.

RESULT AND DISCUSSION

Compared to three years data nine different cropping systems were evaluated to find out the suitable cropping system with minimum soil and runoff loss and maximum crop productivity (Tables 1 and 2).

On the basis of rice equivalent yield, intercropping of pigeonpea and groundnut (T_7) increased the yield by 186, 121 and 16% as compared to sole crop of rice (T_1), sole crop of pigeonpea (T_2) and sole crop of groundnut (T_3), respectively. Intercropping of groundnut with pigeonpea (T_7) enhanced the yield by 66% as compared to intercropping of pigeonpea with rice (T_6). Intercropping of groundnut with pigeonpea planted along contour gave the highest rice equivalent yield (59 q/ha) and lowest soil loss (6.272 t/ha) and lowest runoff of 230.36 mm (16.88% of rainfall) followed by pigeonpea and groundnut strip cropping planted along the contour with rice equivalent yield of 54.43 q/ha (Fig. 1).

Cultivated fallow gave the highest soil loss (15.753 t/ha) and highest runoff of 388.97 mm (23.47% of rainfall). The soil moisture content was low *i.e.* 10.4% and 10.5% in cultivated fallow (T_9) and uncultivated fallow (T_8), respectively (Table 2). The relationship among rainfall (mm) runoff (mm) and soil loss (t/ha) was obtained with high coefficient of determination and presented in Table 3.

CONCLUSIONS

It can be concluded that intercropping of groundnut with pigeonpea planted along contour may be practiced to increase crop yield and lowering the soil loss ands runoff in the hilly tribal areas of Kandhamal district.

Table 1: Rice equivalent yield (REY) under different cropping systems

Treatments	REY(q/ha)
T_1 - Rice (Rc) sole crop	20.63
T_2- Pigeonpea (Pp) sole crop	26.74
T_3-Groundnut (Gn) sole crop	50.78
T_4-Pp and Rc st cro	32.24
T_5- Pp and Gn st cro	54.43
T_6-Rc + Pp (5:2) intercropping	35.64
T_7-Gn+ Pp (4:2) intercropping	59.00
SE (m)±	3.081
CD (0.05)	6.344
Mean	39.92

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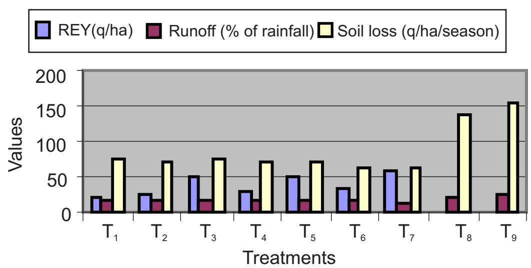

Fig. 1. REY, Runoff and Soil loss in different treatments

Table 2: Runoff and soil loss under different cropping systems

Treatments	Runoff (mm)	Runoff (% of rainfall)	Soil loss (t/ha/season)	Soil moisture (%)
T_1 - Rice (Rc) sole crop	259.41	19.01	7.465	12.4
T_2- Pigeonpea (Pp) sole crop	262.55	19.24	7.295	12.2
T_3-Groundnut (Gn) sole crop	264.51	19.39	7.609	12.5
T_4-Pp and Rc st cro	253.03	18.55	7.261	12.2
T_5- Pp and Gn st cro	244.79	17.94	7.04	13.4
T_6-Rc + Pp (5:2) intercropping	239.29	17.54	6.502	13.3
T_7-Gn+ Pp (4:2) intercropping	230.36	16.88	6.272	13.9
T_8- Uncultivated fallow	368.36	21.96	13.675	10.5
T_9- Cultivated Fallow	388.97	23.47	15.753	10.4
Mean	279.02	19.33	8.764	12.31

Table 3: Relation between Rainfall (X) mm, Runoff (Y) mm and Soil loss (Z) t/ha in different treatments alongwith co-efficient of determination (2006-07)

Treatments	Relations		
	Rainfall (X) mm and Runoff (Y) mm (Co.det.)	Rainfall (X) mm and Soil loss (Z) t/ha (Co.det)	Runoff (Y) mm and Soil loss (Z) t/ha (Co.det)
T_1 - Rice (Rc) sole crop	Y=-1.9+0.303X(0.954)	Z= -0.1+0.01X(0.924)	Z= -0.037+0.033Y(0.974)
T_2 - Pigeonpea (Pp) sole crop	Y=-1.9+0.306X(0.953)	Z= -0.074+0.01X(0.938)	Z= -0.036+0.032Y(0.986)
T_3 - Groundnut (Gn) sole crop	Y=-2.0+0.300X(0.951)	Z= -0.078+0.01X(0.923)	Z= -0.036+0.033Y(0.974)
T_4 - Pp and Rc strip cropping	Y= -1.8+0.294X(0.955)	Z= -0.073+0.009X(0.925)	Z= -0.038+0.033Y(0.975)
T_5 - Pp and Gn strip cropping	Y= -1.8+0.286X(0.959)	Z= -0.07+0.009X(0.927)	Z= -0.037+0.033Y(0.975)
T_6 - Rc+Pp (5:2) intercropping	Y= -1.7+0.280X(0.961)	Z= -0.065+0.008X(0.955)	Z= -0.03+0.031Y(0.992)
T_7 - Gn+Pp (4:2) intercropping	Y= -1.6+0.268X(0.964)	Z= -0.064+0.008X(0.953)	Z= -0.036+0.031Y(0.995)
T_8 - Uncultivated fallow	Y= -1.9+0.300X(0.947)	Z= -0.104+0.013X(0.932)	Z= -0.071+0.041Y(0.995)
T_9 - Cultivated fallow	Y= -2.1+0.359X(0.944)	Z= -0.102+0.015X(0.914)	Z= -0.043+0.043Y(0.972)

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Site Specific Nutrient Management in Mango - A Cursory Look

Tarun Adak[1], G. Pandey and Kailash Kumar

INTRODUCTION

The role of nutritional management for attaining a desirable productivity is obvious and farmers many a times researched for better nutritional management. Plantation crops, tree and agro-forestry systems needs special attention for nutritional trial as they required specific nutrients at critical phenological stages; that too in the basin of the tree. Nutrients are normally applied either within the tree basin of as foliar spray; interspaces don't need any nutrient application. Moreover, different locations require different nutritional management even for the same fruit cultivar. Knowledge on nutrient distribution across different nutrient regimes are needed for understanding the overall requirement (Adak *et al*., 2014). Therefore, location specific/ site specific nutrition management in the fruit orchard is the need of the hour (Kumar *et al*., 2011).

Soils sandy in nature or sandy loam having low clay content and organic carbon needs better organic management. Farm based organic inputs like FYM, green manuring etc. may helps in improving the organic carbon content vis-à-vis improves the soil physical properties for better nutrient release. Whenever, any nutrient input is applied to soil, it undergoes bio-geochemical transformation releasing the nutrients at a rate faster or slower depending upon the types of substrates applied. Again, changes in soil available nutrients acts as a function of soil physical properties, many a time impacted on the nutrient release pattern, water holding capacity, porosity improves the rate wherein under compaction (high bulk density), the activity may decrease. Variations in soil properties should be taken into consideration for further nutrient scheduling (Zornoza *et al*., 2009). Leaf tissues also plays an important role in the nutrition recommendations *vis-à-vis* productivity level. It influences the yield levels as well as quality components. Seasonal variations of nutrients in leaf tissues were also important to assess (Holb *et al*., 2009; Adak *et al*., 2014) in order to have an idea about the nutrients dynamism.

Dashehari mango trees planted at a spacing of 10×10 m. Different nutrition sources were applied to Dashehari mango planted on sandy loam soil for three seasons; composition of which was as follows: T_1-Control, T_2-FYM, T_3-Green Manure, T_4-NPK, T_5-NPK + FYM and T_6-NPK + Green Manure. Tree canopy and other pest control measures were taken acre off. Productivity, quality and soil properties were recorded. Data on tree productivity indicated variable trend; seasonal as well as treatments influences existed. Sustainable yield index varied between 0.11 to 0.80 indicating the variable response of different nutrient sources towards productivity level. Sustainable yield index of 38.9% in Dashehari mango was in >0.50 value. Lower SYI was recorded with 61.1% ages. Kumar *et al.* (2017) emphasizes the need to improve the SYI through proper nutrient management in soils of poor health. Addition of organic sources is beneficial in sandy soils or soils with low organic carbon as it improves the soil physico-chemical and biological properties over the years.

Quality components like TSS, acidity and ascorbic acid were ranged from 16.0 to 21.9 Brix,

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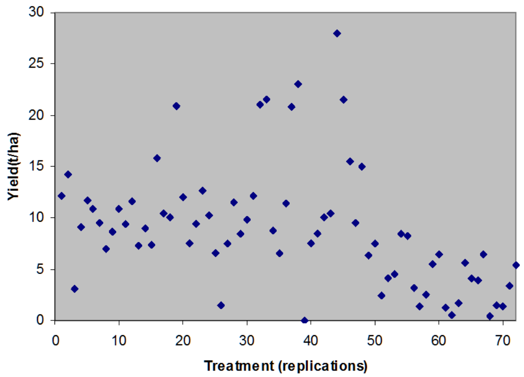
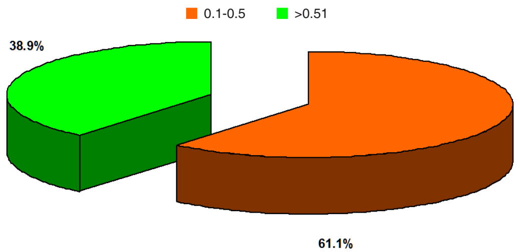


Productivity as a function of soil management system



SYI in Dashehari mango at Lucknow

0.111 to 0.205% and 15.4 to 39.8 mg/100g across treatments and seasons (Table 1). The influences of different nutrient sources on physico-chemical properties were revealed. It has been observed that addition of organic sources enhances the water holding capacity; porosity of 47.30 to 50.97%, bulk density and particle density of 1.35 to 1.45 and 2.67 to 2.76 g/cc was estimated (Table 2). Variations and improvement in some of the soil physical properties in fruit orchards were recorded by Adak *et al.* (2015) wherein the role of substrate dynamics comes into play to the changes in its properties.

Table 2: Influence of different nutrient sources on soil physical properties

	WHC (%)	BD (g/cc)	PD (g/cc)	Porosity (%)
T-1	20.32	1.44	2.73	47.35
T-2	22.46	1.42	2.72	47.84
T-3	21.75	1.38	2.72	49.37
T- 4	21.12	1.41	2.67	47.39
T-5	22.30	1.35	2.75	50.97
T-6	21.46	1.45	2.76	47.30

Table 1: Influence of site specific nutrient management on quality parameters of mango fruit *cv* Dashehari

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			TSS (°Brix)			
T-1	17.8 ± 0.82	4.6	18.7 ± 0.15	0.8	18.23 ± 0.21	1.1
T-2	18.0 ± 1.42	7.9	18.5 ± 0.21	1.1	18.50 ± 0.10	0.5
T-3	18.0 ± 1.73	9.6	19.2 ± 0.62	3.3	18.47 ± 0.15	0.8
T- 4	18.9 ± 1.60	8.5	20.3 ± 1.40	6.9	18.50 ± 0.44	2.4
T-5	18.2 ± 2.74	15.1	19.8 ± 1.10	5.6	18.57 ± 0.40	2.2
T-6	17.9 ± 2.17	12.1	19.4 ± 0.76	3.9	19.10 ± 0.17	0.9
			Acidity (%)			
T-1	0.188 ± 0.02	11.4	0.142 ± 0.02	16.5	0.125 ± .001	0.1
T-2	0.125 ± 0.01	11.6	0.150 ± 0.03	18.9	0.138 ± 0.02	12.9
T-3	0.162 ± 0.01	7.4	0.133 ± 0.01	8.5	0.125 ± 0.04	28.3
T- 4	0.162 ± 0.01	7.0	0.142 ± 0.01	8.5	0.13 ± 0.001	0.1
T-5	0.150 ± 0.03	16.7	0.150 ± 0.04	23.6	0.13 ± 0.001	0.1
T-6	0.188 ± 0.01	7.0	0.150 ± 0.05	33.0	0.15 ± 0.001	0.1
			Ascorbic acid (mg/100g)			
T-1	21.8 ± 2.33	10.7	27.4 ± 0.21	0.8	25.45 ± 3.32	13.1
T-2	23.8 ± 0.66	2.8	36.3 ± 4.95	13.6	25.45 ± 3.32	13.1
T-3	19.0 ± 3.20	16.8	35.5 ± 1.91	5.4	27.80 ± 2.01	0.0
T- 4	19.0 ± 1.67	8.8	33.3 ± 1.63	4.9	28.90 ± 4.95	17.1
T-5	29.0 ± 1.61	5.5	35.5 ± 1.56	4.4	28.95 ± 1.63	5.6
T-6	23.3 ± 1.91	8.2	31.1 ± 1.84	5.9	32.40 ± 1.01	0.1

SD stands for standard deviation; CV-co-efficient of variations

Foliar nutrient content showed differential response of the nutrition sources towards leaf tissue parts (Table 3 and 4).

Micro-nutrients were statistically above critical levels; therefore contributed towards quality fruit production. Available soil properties both in surface and sub-surface soils were significantly influenced by treatment combinations in mango orchard soil. Soil nutrients were above critical levels of their respective critical limit value of quality fruit production (Table 5-8).

Inclusion of organic sources improved their content. Surface soils had higher content than sub-surface one. Available Fe content varied between 4.65 to 13.84 ppm and 2.66 to 9.98 ppm in surface and sub-surface soil across three fruiting seasons. Available Mn had higher values of 7.74 to 19.26 and 5.3 to 16.89 ppm, respectively. Similarly, Zn and Cu content were also impacted by the treatments. Seasonal variations both in surface and sub-surface soils were recorded. Highest available Cu and Zn in surface soil was 7.92 and 2.14 while a range of 0.76 to 4.81 ppm and 0.24 to 0.93 ppm was recorded in subsurface soil. Distributions of micronutrients across deeper depths in mango orchards were described by Adak *et al.* (2014). In fact, sufficient/optimum micronutrients are needed to support the yield for future years. Soil organic carbon (SOC) content was improved over the years (Table 9).

Initially the NPK+FYM and NPK+GM treatment its content was 0.515, 0.457 and improved to 0.589 and 0.613%. SOC content varied between 0.414 to 0.613 across treatments and fruiting seasons in surface soils but there was tremendous decrease in its content (0.204 to 0.345) in sub-surface soil (Table 9). The co-efficient of variations was higher in leaf tissue and soil micronutrient content but lower CV% was recorded across SOC, P and K content. Similarly available P and K were higher in NPK+FYM and NPK+GM treatment as compared to control or their sole

Table 3: Influence of different nutrient sources on leaf tissue N, P and K content in mango fruit *cv* Dashehari

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			N			
T-1	2.19 ± 0.14	6.60	1.66 ± 0.17	9.95	1.98 ± 0.18	9.31
T-2	2.17 ± 0.27	12.63	1.54 ± 0.39	13.18	2.03 ± 0.33	16.17
T-3	1.87 ± 0.16	8.84	1.86 ± 0.22	11.63	1.98 ± 0.16	7.85
T-4	2.17 ± 0.37	17.07	1.70 ± 0.16	9.14	1.93 ± 0.12	6.25
T-5	2.01 ± 0.38	18.92	1.88 ± 0.32	17.19	1.92 ± 0.24	12.62
T-6	2.17 ± 0.17	7.90	1.70 ± 0.59	34.56	2.08 ± 0.12	5.74
			P			
T-1	0.10 ± 0.004	4.26	0.146 ± 0.011	7.62	0.12 ± 0.024	20.92
T-2	0.10 ± 0.008	7.29	0.156± 0.024	15.36	0.13 ± 0.004	3.08
T-3	0.10 ± 0.008	7.88	0.141± 0.009	6.37	0.14 ± 0.02	16.37
T-4	0.11 ± 0.010	9.48	0.169± 0.044	25.90	0.13 ± 0.02	15.90
T-5	0.09 ± 0.008	8.68	0.144± 0.024	16.54	0.14 ± 0.04	29.87
T-6	0.10 ± 0.005	4.64	0.150± 0.019	12.87	0.13 ± 0.03	26.35
			K			
T-1	0.56 ± 0.03	5.42	0.69 ± 0.13	18.17	0.54 ± 0.13	23.57
T-2	0.56 ± 0.04	6.60	0.76 ± 0.17	22.25	0.64 ± 0.10	15.67
T-3	0.64 ± 0.08	11.85	1.00 ± 0.65	65.20	0.66 ± 0.12	18.17
T-4	0.61 ± 0.05	7.72	0.90 ± 0.43	48.15	0.77 ± 0.06	07.51
T-5	0.53 ± 0.06	10.42	0.65 ± 0.12	18.89	0.86 ± 0.05	05.85
T-6	0.64 ± 0.12	18.93	0.88 ± 0.23	26.43	0.98 ± 0.09	09.09

SD stands for standard deviation; CV-co-efficient of variations

Table 4: Influence of different nutrient sources on leaf tissue micro-nutrients content in mango fruit *cv* Dashehari

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			Fe			
T-1	194.0 ± 51.3	26.4	195.3 ± 26.9	13.8	156.8 ± 30.3	19.3
T-2	207.3 ± 13.5	6.5	203.8 ± 35.5	17.4	197.3 ± 29.5	15.0
T-3	203.8 ± 55.3	27.1	283.5 ± 33.5	11.8	168.0 ± 46.7	27.8
T-4	226.8 ± 105.6	46.6	238.0 ± 46.9	19.7	160.5 ± 61.4	38.3
T-5	175.3 ± 41.7	23.8	176.8 ± 25.5	14.4	174.0 ± 27.6	15.9
T-6	211.5 ± 50.4	23.8	231.5 ± 56.4	24.4	138.0 ± 46.4	33.7
			Mn			
T-1	74.25 ± 20.71	27.89	70.00 ± 13.04	18.63	89.50 ± 6.81	7.61
T-2	70.25 ± 22.82	32.49	65.50 ± 17.86	27.27	98.50 ± 9.98	10.14
T-3	81.75 ± 20.76	25.39	79.25 ± 1.26	1.59	98.75 ± 17.15	17.37
T-4	65.75 ± 07.63	11.61	80.00 ± 17.72	22.15	98.00 ± 18.17	18.54
T-5	66.00 ± 16.31	24.71	76.25 ± 14.91	19.55	119.50 ± 14.20	11.88
T-6	67.00 ± 38.04	56.78	66.00 ± 13.29	20.14	122.75 ± 22.23	18.11
			Cu			
T-1	34.3 ± 18.1	52.8	36.0 ± 24.6	68.4	25.3 ± 8.5	33.7
T-2	35.5 ± 17.8	50.2	58.8 ± 33.4	56.8	17.5 ± 5.7	32.8
T-3	17.8 ± 3.4	19.2	15.3 ± 2.5	16.4	17.5 ± 9.7	55.3
T-4	41.0 ± 9.2	22.4	30.8 ± 17.3	56.4	19.3 ± 13.0	67.5
T-5	35.0 ± 12.0	34.4	40.8 ± 20.3	49.9	41.5 ± 8.8	21.2
T-6	22.5 ± 12.4	55.3	20.8 ± 14.5	69.7	51.8 ± 10.5	20.2
			Zn			
T-1	21.0 ± 3.4	16.0	22.0 ± 4.2	19.3	22.0 ± 6.4	29.0
T-2	23.0 ± 3.7	15.9	20.5 ± 3.4	16.7	25.3 ± 8.1	31.9
T-3	27.0 ± 2.9	10.9	26.3 ± 6.1	23.4	24.3 ± 7.1	29.4
T-4	26.0 ± 3.6	13.7	27.8 ± 2.9	10.4	24.0 ± 5.0	20.7
T-5	22.0 ± 4.8	21.6	23.8 ± 3.9	16.3	32.0 ± 9.0	28.1
T-6	23.8 ± 2.2	9.3	23.3 ± 7.9	33.9	33.8 ± 7.9	23.4

SD stands for standard deviation; CV-co-efficient of variations

Table 5: Influence of different nutrient sources on Fe content in surface and sub-surface mango orchard soil

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			Available Fe (ppm) in surface soil			
T-1	6.04 ±0.68	11.2	4.84±1.15	23.7	10.92 ±2.05	18.8
T-2	5.97 ±0.16	2.6	4.65±0.63	13.4	12.73 ±2.55	20.0
T-3	6.72 ±0.20	2.9	6.43±0.44	06.9	12.54 ±3.81	30.4
T-4	6.34 ±0.79	12.5	6.90±0.55	08.0	13.01 ±3.22	24.7
T-5	7.39 ±0.27	3.6	4.97±0.63	12.8	13.10 ±4.19	32.0
T-6	7.18 ±1.07	15.0	5.30±1.10	20.8	13.84 ±2.61	18.9
			Available Fe (ppm) in sub- surface soil			
T-1	2.66±0.06	2.1	2.88±0.12	04.3	8.53±1.27	14.9
T-2	3.21±0.07	2.2	3.21±0.34	10.5	8.76±1.25	14.2
T-3	2.92±0.14	4.8	3.41±0.78	23.0	9.46±0.97	10.2
T-4	3.07±0.13	4.1	4.15±0.24	05.7	9.35±1.39	14.9
T-5	3.30±0.06	1.7	3.31±0.68	20.4	9.98±1.80	18.1
T-6	4.66±0.40	8.5	3.53±0.53	09.6	9.95±0.66	6.6

SD stands for standard deviation; CV-co-efficient of variations

Table 6: Influence of different nutrient sources on Mn content in surface and sub-surface mango orchard soil

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			Available Mn (ppm) in surface soil			
T-1	8.59±1.80	20.9	10.77±2.29	21.3	15.61±3.12	20.0
T-2	9.21±3.78	41.0	7.74±1.36	17.6	17.55±9.19	52.4
T-3	9.92±1.05	10.5	8.83±1.12	12.7	18.28±7.15	39.1
T- 4	10.28±0.99	9.6	11.59±2.60	22.4	18.77±8.60	45.8
T-5	12.19±3.13	25.6	12.70±0.71	05.6	19.26±4.22	21.9
T-6	12.79±0.04	0.3	08.43±1.13	13.4	21.48±7.98	37.2
			Available Mn (ppm) in sub-surface soil			
T-1	5.76±0.03	0.5	7.36±1.69	22.9	11.21±7.13	63.6
T-2	6.85±1.00	14.7	6.88±0.70	10.1	11.95±5.61	47.0
T-3	7.50±0.51	6.8	05.3±1.71	22.2	12.10±4.66	38.5
T- 4	8.40±0.31	3.7	5.96±1.28	21.5	14.37±4.26	29.7
T-5	8.53±0.49	5.8	8.73±0.66	07.6	15.55±8.37	53.8
T-6	10.14±1.27	12.5	7.29±0.61	08.3	16.89±9.18	54.3

SD stands for standard deviation; CV-co-efficient of variations

Table 7: Influence of different nutrient sources on Cu content in surface and sub-surface mango orchard soil

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			Available Cu (ppm) in surface soil			
T-1	1.39 ±0.16	11.2	3.14±0.47	15.0	5.90±0.41	6.9
T-2	2.58 ±0.37	14.3	2.62±0.79	30.2	6.71±0.31	4.7
T-3	1.73 ±0.52	30.2	2.31±0.27	11.6	7.37±0.64	8.7
T-4	2.51 ±0.30	11.8	2.65±0.60	22.7	7.44±0.67	9.0
T-5	3.31 ±0.33	9.8	2.09±0.20	9.6	7.83±0.64	8.2
T-6	2.20 ±0.40	18.0	1.85±0.41	22.4	7.92±0.73	9.2
			Available Cu (ppm) in sub-surface soil			
T-1	0.76 ±0.20	26.1	1.30±0.21	15.9	3.07±0.67	21.9
T-2	0.89 ±0.24	27.0	1.36±0.09	6.9	3.01±0.48	15.8
T-3	1.12 ±0.37	32.8	1.15±0.31	27.2	3.45±0.51	14.7
T-4	1.01 ±0.35	35.0	1.47±0.38	25.7	3.66±0.47	13.0
T-5	1.50 ±0.51	33.9	0.94±0.18	19.2	4.47±0.80	17.9
T-6	1.58 ±0.34	21.5	0.85±0.21	25.3	4.81±0.44	9.3

SD stands for standard deviation; CV-co-efficient of variations

application (Table 10-11). Higher available K content of 232.45 ppm in surface soil and 199.44 ppm was recorded in NPK+GM than 175.71 and 152.98 ppm in control plots relating the fact that for quality fruit production, the importance of K was measurable. In order to improve the sustainability in soil production system and to maintain a satisfactory level of production, application of organic sources or green manuring is essentially needed particularly for soils with low SOC content and sandy in nature.

CONCLUSIONS

Restoring soil health for future cultivation is urgent need to feed the mouth of millions of populations of our country. During the processes of soil restoration, organic and inorganic sources are applied to improve the soil health conditions. Soil physical, chemical and biological properties

Table 8: Influence of different nutrient sources on Zn content in surface and sub-surface mango orchard soil

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			Available Zn (ppm) in surface soil			
T-1	0.35±0.04	12.1	0.35±0.07	20.9	0.96±0.09	9.6
T-2	0.44±0.06	12.9	0.39±0.04	10.7	1.35±0.24	17.8
T-3	0.48±0.06	11.8	0.35±0.03	7.4	1.60±0.37	22.9
T-4	0.46±0.08	18.4	0.36±0.05	13.0	1.21±0.27	22.1
T-5	0.54±0.11	21.0	0.43±0.05	12.5	2.02±0.15	7.5
T-6	0.45±0.01	3.1	0.39±0.04	9.8	2.14±0.32	15.1
			Available Zn (ppm) in sub-surface soil			
T-1	0.29 ±0.01	4.9	0.29±0.04	14.4	0.48±0.09	13.9
T-2	0.28 ±0.03	10.1	0.31±0.07	22.3	0.66±0.10	14.5
T-3	0.32 ±0.03	8.8	0.25±0.04	16.9	0.72±0.06	7.2
T-4	0.30 ±0.06	18.9	0.28±0.06	20.2	0.77±0.15	16.1
T-5	0.34 ±0.03	8.3	0.24±0.04	11.8	0.87±0.12	14.2
T-6	0.35 ±0.01	4.0	0.31±0.02	09.4	0.93±0.10	20.5

SD stands for standard deviation; CV-co-efficient of variations

Table 9: Influence of different nutrient sources on soil organic carbon content in surface and sub-surface mango orchard soil

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			Soil organic carbon content (%) in surface soil			
T-1	0.418±0.07	17.1	0.457 ± 0.04	8.2	0.414 ± 0.05	12.7
T-2	0.496±0.04	8.3	0.506 ± 0.06	11.4	0.448 ± 0.04	8.0
T-3	0.554±0.07	12.6	0.506 ± 0.04	7.5	0.487 ± 0.07	14.5
T-4	0.515±0.01	2.9	0.486 ± 0.04	7.4	0.530 ± 0.03	5.8
T-5	0.515±0.01	1.8	0.564 ± 0.02	2.7	0.589 ± 0.07	11.3
T-6	0.457±0.07	14.2	0.467 ± 0.06	12.5	0.613 ± 0.03	5.5
			Soil organic carbon content (%) in sub- surface soil			
T-1	0.214 ± 0.03	12.9	0.247 ± 0.01	3.7	0.204 ± 0.02	9.4
T-2	0.273 ± 0.03	10.1	0.292 ± 0.04	15.3	0.263± 0.03	9.6
T-3	0.292 ± 0.03	9.5	0.311 ± 0.03	8.4	0.258 ± 0.04	16.7
T-4	0.263 ± 0.01	5.1	0.311 ± 0.04	12.7	0.267 ± 0.04	15.0
T-5	0.311 ± 0.01	0.0	0.311 ± 0.01	2.9	0.326 ± 0.04	12.3
T-6	0.341 ± 0.01	3.9	0.253 ± 0.01	2.1	0.345 ± 0.03	9.6

SD stands for standard deviation; CV-co-efficient of variations

become supportive to enhance the productivity both for soil and tree. Application of nutrition at critical fruit developmental stages improves the yield and quality of the fruits. The present study showed majority percent age of SYI in low productivity range. There is a need to improve the situation. The response of different treatment combinations were recorded and inclusion of green manuring or FYM or even other locally available and economically viable like vermicompost should be treated in mango orchard soils having poor fertility status.

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Table 10: Influence of different nutrient sources on P content in surface and sub-surface mango orchard soil

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			Available P (ppm) in surface soil			
T-1	11.00 ± 0.14	1.3	15.0 ± 1.31	8.8	13.00 ± 0.53	11.7
T-2	11.90 ± 0.14	1.2	19.8 ± 0.82	4.1	16.18 ± 0.23	7.6
T-3	11.55 ± 0.49	4.3	23.2 ± 0.63	2.7	17.95 ±0.65	3.6
T-4	16.05 ± 0.92	5.7	18.0 ± 2.33	12.9	18.80 ±0.64	3.4
T-5	27.25 ± 2.06	7.6	20.5 ± 0.78	3.8	19.28 ± 0.57	3.0
T-6	16.25 ± 0.94	5.8	18.0 ± 1.21	6.7	23.00 ± 0.82	7.9
			Available P (ppm) in sub- surface soil			
T-1	11.40 ± 0.85	7.4	14.00 ± 1.24	8.8	9.08 ± 0.01	11.1
T-2	11.95 ± 0.92	7.7	14.00 ± 1.52	10.5	10.23 ± 0.44	14.0
T-3	13.85 ± 0.16	7.7	15.40 ± 2.01	13.1	11.93 ± 0.87	15.7
T-4	15.65 ± 0.03	5.8	10.40 ±1.93	18.5	12.18 ± 0.75	14.4
T-5	18.00 ± 0.03	6.3	13.90 ± 1.28	9.2	13.48 ± 0.53	18.7
T-6	19.75 ± 0.66	4.1	14.60 ± 1.91	13.1	16.13 ± 0.93	12.0

SD stands for standard deviation; CV-co-efficient of variations

Table 11: Influence of different nutrient sources on K content in surface and sub-surface mango orchard soil

	1st Season crop		2nd Season crop		3rd Season crop	
Treatments	Mean ± SD	CV (%)	Mean ± SD	CV (%)	Mean ± SD	CV (%)
			Available K (ppm) in surface soil			
T-1	106.10 ± 5.59	5.3	143.0 ± 29.7	3.3	175.71 ± 8.44	4.8
T-2	121.25 ± 5.87	4.8	136.0 ±1.31	8.3	192.58 ± 3.69	1.9
T-3	109.50 ± 1.41	1.3	160.5 ± 5.52	3.4	199.56 ± 7.60	3.8
T-4	151.00 ± 4.24	2.8	170.5 ± 5.16	3.0	206.03 ± 5.61	2.7
T-5	141.85 ± 7.00	4.9	149.0 ± 7.25	11.6	212.20 ± 2.99	6.1
T-6	109.60 ± 7.64	7.0	179.0 ± 4.24	2.4	232.49 ± 4.33	1.9
			Available K (ppm) in sub- surface soil			
T-1	78.85 ± 0.49	0.6	150.0±33.94	22.6	152.98 ± 9.77	6.4
T-2	88.00 ± 4.95	5.6	162.5±41.72	25.7	159.49 ± 6.06	3.8
T-3	85.10 ± 4.10	4.8	150.5 ± 9.19	6.1	164.54 ± 6.41	3.9
T-4	97.75 ± 1.77	1.8	215.5±3.44	6.2	175.51 ± 7.29	4.2
T-5	104.35 ± 1.91	1.8	167.0±35.36	21.2	186.91 ± 2.94	1.6
T-6	110.95 ± 6.61	5.4	144.5±17.68	12.2	199.44 ± 3.12	1.6

SD stands for standard deviation; CV-co-efficient of variations

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Bioremediation: A Key to Managing Soil Health in Heavy Metals Contaminated Municipal Solid Waste

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INTRODUCTION

Municipal solid waste (MSW), also called urban solid waste, is the most complex solid waste stream, as opposed to more homogeneous waste streams resulting from industrial or agricultural activities. MSW is defined to include refuse from community activities, such as residential households (domestic wastes), commercial and business establishments, fresh markets, institutional facilities, construction and demolition activities, and to exclude hazardous and infectious wastes. The burgeoning human population with rapid urbanization, industrialization and agricultural intensification are accompanied with generation of huge volumes of urban wastes (Gupta *et al.,* 2015). The presence of heavy metals in the urban waste contributes potential risk to soil health and is a major cause of ecological degradation. In many countries, the MSW are still disposed most unscientifically on open low-lying areas or landfill sites around the cities. These dumping sites also emit foul odors and turn out to be potential breeding grounds for house flies, insects, rodents and disease causing pathogens. The situation is going to further worsen in the near future with the increasing urbanization and the growing constraint of availability of land for landfill sites. The urban population in many Asian countries including India is going to be almost doubled in the next two decades. Most of the metropolitan cities of India have generated on an average of 73.4 M t of city refuse during the year 2015, which has a potential of 10.3 M t of compost and it is expected to increase to 107 M t during 2030 (Manna *et al.,* 2018; Sharma *et al.,* 2006). These wastes contain about 40% biodegradable matter, but only 14% (10.3 M t) of the MSWs were composted during the year 2015, which may go upto about 15 M t during the year 2030. MSW generally includes degradable (paper, textiles, food waste, straw and yard waste), partially degradable (wood, disposable napkins and sludge) and non-degradable materials (leather, plastics, rubbers, metals, glass, ash from fuel burning like coal, briquettes or woods, dust and electronic waste) (Jha *et al.,* 2011). Management of such a heterogeneous mixture of biodegradable and non-biodegradable fractions of MSW becomes a problem for the municipalities from the perspectives of collection, safe disposal and recycling. Heavy metal content in MSW is one of the non biodegradable and most dangerous soil pollutants because this heavy metal may easily move from soil to food plants through bioaccumulation (Huang *et al.,* 2015). Furthermore, heavy metals have a toxic effect on the soil microbial communities, which play an important role in soil nutrient cycling and, therefore, in soil fertility and overall soil health.

Threats of MSW and possible solution

Improper management of MSW is one of the sources for environmental pollution in towns, cities and municipalities. Most of the cities do not enforce MSW regulations properly particularly in developing countries.

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The improper handling of MSW can lead several public health risk (Table 1) to nearby residents 'owing to its appearances as infectious, or toxic nature. Additional environmental impacts are damage of the environmental system by pollution of air, water and soil. Such improper management of MSW poses a high risk to human health (Cointreau, 2006; Lee and Lee, 1994).

Worldwide, large quantities of heavy metals and several hazardous organic compounds are discharged to nearby land surfaces and into the aquatic bodies due to anthropogenic activities. In the recent years, soil is facing numerous challenges for the maintenance of its health due to soil pollution with emerging contaminants. Besides the natural ways of soil contamination, various anthropogenic sources and agricultural activities have been found as potential threat to soil health and crop productivity (Chibuike and Obiora, 2014). Thus, soil contamination through heavy metals and hazardous organic pollutants are vigorously investigated for conducting risk assessment and developing remediation protocols in order to make the soil and aquatic systems safe for the use of agriculture and animal husbandry. The effects of metal pollution on local environments and organisms may be substantial and long lasting in spite of an extensive remediation effort. Considerable research has been carried out in developing countries for heavy metal removal techniques. Physicochemical methods, such as chemical precipitation, coagulation, chemical oxidation or reduction, filtration, electrochemical treatment, application of membrane technology (ultra filtration and reverse osmosis, electrodialysis etc.), evaporation recovery, solvent extraction and ion-exchange processes, have been traditionally employed for heavy metal removal from solid waste/or from industrial wastewater/ sewage water, but these techniques are highly expensive. Remediation by using biological resources is generally called bioremediation whereas using plants is called phyto-remediation. Bioremediation is a process in which the effective microorganisms and plants may play a vital role for the degradation/decontamination of the pollutants into harmless products. Important strategies of biormediation like biotransformation and biosorption by microorganisms are used to transform or adsorb metals. Intact microbial cell, live or dead and their products can be highly efficient bioaccumulator. Besides bacteria, mostly fungal biomass contains a relatively high percentage of cell wall materials that are excellent metal binder. Suitable biotechnological method and proper configuration may enhance bio-absorption of heavy metals and the degradation of toxic compounds from the MSW. Stringent regulations are increasing the demand for new

Table 1: The Public health risk via different contaminated environmental components due to improper management of MSW (Lee and Lee, 1994; Selin, 2013)

Ways of exposure	• These pollutants can be found in various environmental media such as, air, soil and water, and possibly will find their way to reach human body through ingestion, inhalation or absorption.
Public health effects	• Skin problem: - fungal infection, allergic dermatitis, and skin cancer. • Respiratory problem - bacterial upper respiratory tract infections (such as: pharyngitis, laryngitis and rhinitis), chronic bronchitis and asthma. • Intestinal problems - bacterial enteritis, helminthiasis, amoebiasis, liver cancer, kidney and renal failure. • Skeletal muscular systems problem - back pain. • Central nervous system problem - impairment of neurological development, peripheral nerve damage and headaches. • Eye problem - allergic conjunctivitis, bacterial eye infections. • Others problems - septic wounds and congenital abnormalities, cardiovascular diseases and lung cancer etc.

technologies for metal removal from solid or liquid waste to attain today's toxicity-driven limits. Another process, the phytoremediation may be defined as an *in-situ* remediation strategy that uses vegetation and associated micro-biota, soil amendments, and agronomic techniques to remove, contain, or render environmental contaminants harmless. Though plants are known to sequester and degrade some classes of organic contaminants in soils, *in-situ* contaminant degradation by root associated *rhizosphere microflora* is likely to be the most effective mechanism during the phytoremediation process. This method is easy to execute and capable of permanently treating a wide range of contaminants under different ecological environments. Therefore, for effective and efficient removal of major contaminants in MSW compost, a efficient microbial consortium is needed to develop and apply for the degradation/removal of heavy metals.

Soil pollution is very diverse, and a comprehensive database is still unavailable to figure out the actual status of soil pollution in India. The data reported in various studies demonstrate that the metal concentrations in soil generally reflect the influence of various local industrial activities which include metal mining, chemical and petrochemical, textile, leather, cement, and ceramic industries, etc. (Table 2). Evaluation of soil metal data indicates that the maximum level of heavy metals occur in relation to industry types, for example, Pb, Zn, Ni, Cu, Fe, and As in smelter and metal industries, Mn and Cd in the textile industry, and Cr in leather industry. Amongst the different heavy metals, Cu, Cd, Pb and Zn were most frequently encountered in Indian soil-plant-animal continuums.

Bioremediation Technology to minimize heavy metal toxicity from contaminated waste

Bioremediation is a process in which the potential microorganisms and plants play important roles for degradation of the pollutants into harmless products or restore the natural soil condition (Ayangbenro and Babalola, 2017). The microbes cannot degrade heavy metals directly but they can change the valence states of metals rendering them immobile or less toxic. Microorganisms destroy the organic contaminants in the course of using the chemicals as nutrient or

Table 2: Sources of heavy metal for soils of India

Name of the contaminant	Source
Arsenic (As)	Geogenic/natural sources, anthropogenic activities, semiconductors, petroleum refining, wood preservatives, animal feed additives, coal power plants, herbicides, volcanoes, mining and smelting.
Cadmium (Cd)	Geogenic sources, anthropogenic activities, metal smelting and refining, fossil fuel burning, phosphate fertilizers, sewage sludge.
Chromium (Cr)	Electroplating industry, sludge, solid waste, tanneries
Copper (Cu)	Electroplating industry, smelting and refining, mining, biosolids
Lead (Pb)	Mining and smelting of metaliferous ores, burning of leaded gasoline, municipal sewage, industrial wastes enriched in Pb, paints.
Manganese (Mn)	Fertilizer
Mercury (Hg)	Volcano eruptions, forest fire, emissions from industries producing caustic soda, coal, peat and wood burning.
Molybdenum (Mo)	Fertilizer, spent catalyst
Selenium (Se)	Coal mining, oil refining, fossil fuels combustion, glass manufacturing industry and chemical synthesis (*e.g.* varnish, pigment formulation).
Nickel (Ni)	Volcano eruptions, landfills, forest fire, bubble bursting and gas exchange in ocean, weathering of soils and geological materials.
Zinc (Zn)	Electroplating industry, smelting and refining, mining biosolids.

Source: Gautam, S.P. 2011. Central Pollution Control Board, New Delhi (http://www.insaindia.org/pdf/Hazardous_Metals.pdf).

energy source for their own growth and reproduction utilizing carbon for cell building materials. Bioremediation in combination with phytoremediation and rhizoremediation contribute significantly in the removal of unwanted compounds from the biosphere. Besides bacteria, fungi also play an important role for remediation of contaminated soil and water bodies. In biotransformation and biosorption, microorganisms are used to transform or adsorb metals. Intact microbial cells, live or dead, and their products can be highly efficient bioaccumulator. The fungal biomass contains a relatively higher percentage of cell wall materials that are excellent metal binder. Suitable biotechnological method and proper configuration may enhance bio-sorption of heavy metals from the MSW. The highly expensive physiochemical methods such as chemical precipitation, coagulation, chemical oxidation or reduction, filtration, electrochemical treatment, membrane technology (ultra filtration and reverse osmosis, electrodialysis etc.), evaporation recovery, solvent extraction and ion-exchange processes, have been traditionally employed for heavy metal removal from solid or industrial wastes. In search of eco-friendly techniques, an efficient consortium of fungi acting as biofilter to remove contamination from the polluted land with organics and heavy metals are being evaluated for their further practical application.

The mechanisms of removal of heavy metals includes the efflux of metal ions outside the cell, accumulation and forms complex of the metal ions inside the cell of microbes and later reduce the toxic metal ions to a non-toxic state. Potent metal biosorbents under the class of bacteria includes the genera of *Bacillus*, *Pseudomonas* and *Streptomyces.* Among microbes, fungal biomasses were very effective due to higher percentage of cell wall material, which may have the excellent metal binding capacity. Many fungi and yeast such as *Rhizopus*, *Aspergillus* and *Sacchromyces* have excellent biosorption potential. For endurance under metal-stressed environment, plant growth promoting *rhizobacteria* have evolved several mechanisms by which they can immobilize, mobilize or transform metals and preventing the uptake of heavy metal ions by plants. In general the immobilization and mobilization are the two main techniques used for the bioremediation of metals by microbes. Bioremediation by microbes mainly involves two important mechanisms that includes (i) Immobilization This remediation approach can utilize microorganisms to reduce the mobility of the contaminants by changing the physical or chemical characteristics of the contaminants, and (ii) Mobilization- Microorganisms can mobilize metals through autotrophic and heterotrophic leaching, chelation by microbial metabolites and siderophores, methylation, and redox transformations.

Removal of heavy metals from MSW using selected mesophilic fungi

Heavy metal content in MSW is one of the most hazardous soil pollutants as it may easily move from soil to plants through root absorption, and fairly large amounts can accumulate in their tissues. Furthermore, heavy metals have a toxic effect on the soil microbial communities, which play an important role in soil nutrient cycling and, therefore, in soil fertility. Biofiltration techniques was employed to remove heavy metals from sample MSW (Plate 1) from city waste dumping site, Bhopal, using mesophilic fungi. The main mechanisms of heavy metal removal by fungi are basically a biosorption and biofiltration method. In this experiment selected mesophilic fungi were grown in specific broth with graded level of heavy metals. The six mesophilic fungi were evaluated for heavy metal removal potential that acts as a biofilter to counteract heavy metals from the MSW (Manna *et al.,* 2014).

- Six mesophilic fungi have been screened namely *Trichoderma viride, Aspergillus heteromorphus, Rhizomucor pusillus, Aspergillus flavus, Aspergillus terrus* and *Aspergillus awamori.* The fungal growth of all these selected fungi was highly susceptible

Plate 1. The MSW contaminated site (a, b and c) and strategies to remove heavy metal using customized biofilter harboring fungi (d).

to Cd (>5 ppm). The fungi *Trichoderma viride, Aspergillus awamori* and *Rhizomucor pusillus* were highly susceptible to Cu (> 50 ppm). The result also showed that *Aspergillus flavus* and *Aspergillus heteromorphus* were highly susceptible to Cr at 50 ppm. The Zn was found toxic to *A. heteromorphus* at 200 ppm.

- The biosorption capacity of living fungal cells has been studied in a compact perforated stationary phase biofilter (Plate 1). Individual fungus was grown and multiplied with standard media at 30^0C. After 30 days, maxium removal of Pb (52%) was observed by these fungi followed by Ni (37%) and Zn (33%) (Table 3). Further it was observed that among six fungi *Trichoderma viride* performed better for removal of Pb, Ni, Zn and Cd followed by *Aspergillus flavus.*
- The functional groups were mainly observed in the cytoplasmic membrane of isolated fungi which included amide group (-NH), hydroxyl group (-OH), carboxylate anions (-COO), carbonyl groups (-CO), C-F and C-Br were

mainly responsible for biosorption of heavy metals. In present study it was found that the four fungi *viz.*, *Aspergillus flavus*, *Aspergillus terrus*, *Aspergillus awamori* and *Rhizomucor pusillus* having these functional groups. The functional groups ligands with heavy metal like Cd, Cu, Ni, Cr and Zn.

CONCLUSIONS

Bioremediation is considered to be very safe, economic and green technology as it relies on biological agents that occur naturally in the planet and pose no threat to the environment. Even though various bio-resource such as bacteria, archaebacteria, yeasts, fungi, algae and plants are available, the biological treatment alone is not sufficient enough to treat the pollutants at contaminated sites. Every biological agent has a different growth requirement. The optimum biomediation protocol can be developed in the case of proper examination of the conditions of the contaminated soil and the pollutants. As for example, several sites can be contaminated with numerous heterogeneous pollutants, it is important to integrate techniques for remediation systems in order to improve the remedial action.

There is a need to isolate the most suitable agent which can be cultured easily in the lab, with minimal requirement and can be useful in treating variety of pollutants. Use of genetically engineered microorganisms is probably not needed in most cases because of the wide availability of naturally occurring microbes. There is an urgent need to study the effect of various microorganisms in combination against various pollutants for the conservation of natural resources and environment management. Recycling of wastes containing inorganic toxic metals and organic pollutants needs to be given greater emphasis not only from environmental and health considerations but also as a resource conservation measure. Finally, up-scaling the technology of these bio-approaches for rehabilitation of contaminated soils needs to be fully demonstrated in the fields for wider acceptability.

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Efficacy of Bori-Bunds (Sand Bags) Towards Sediment Load Arresting for Gully Bed Stabilization- A Case Study from Gujarat

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INTRODUCTION

Gully erosion is a foremost problem in certain parts of India, explicitly along three notorious rivers (Yamuna, Chambal and Mahi), where about 4 million hectares (M ha) of ravine lands adversely affects the overall agrarian productivity with greater sensitivities towards losses from floods and inundations. Most severe form of ravines is concentrated in the States of UP, MP, Gujarat and Rajasthan under few basins of above cited rivers. Out of total ravine lands in the country, as high as about 2.7 M ha are located in these 4 States, where Gujarat remains one of the dominating representative zone. It encompasses vast stretches of ravenous lands across districts of Banaskantha, Sabarkantha, Mehsana, Gandhinagar, Ahmedabad, Kheda, Vadodara, Panchamahals, Bharuch and Surat. Here, the gullied lands and ravines have been formed all along the banks of major rivers (Mahi, Sabarmati, Narmada, Tapti) and their tributaries (Banas, Saraswati, Meshwo, Watrak, and others). Typical ravines of Gujarat are known for their enormous size with almost vertical sides having V-shaped cross-sectional configurations. Rivers Mahisagar, Narmada and Watrak account for largest ravine areas; being 61888, 58142 and 56497 hectares, respectively. Researchers have amply proved the utility as well as positive influences of various soil and moisture conservation measures for controlling the runoff and soil loss on variety of degraded lands including above mentioned gullied lands (Gaur and Singh, 1995; Kale *et al.,* 1993). Moreover, the exact characterization of gullied lands remained entirely inimitable in dissimilar zones having varied conformations (size, cross sections, shapes, physiographic distributions/linkages).

Present case study pertains to Mahi river basin, which indeed extends over an area of 34482 km^2 and constitutes about 1.1% of total geographical area of the country. Red and black soils being the important soil types in the basin with Mahi river that passes through the Kheda, Anand, Vadodara and Panchmahal districts of Gujarat.Various organizations/agencies including ICAR-IISWC Research Centre at Vasad; Foundation for Ecological Security (FES) at Anand, Gujarat State Watershed Management Agency (GSWMA), Gujarat State Land Development Corporation (GSLDC), State Departments of Forest and Agriculture; have consistently functioned to visualize, assess and control the extent of gullied soil erosion and sediment dynamics in such areas. A sample but informal ground effort in this direction was laid by authors to evolve and visualize the benefits of some traditional approaches on gully erosion control evolving and espousing low cost measures and re-vegetation activities (accommodating about 150 hectares of common property and 410 hectares agrarian lands) in Vadodara district.The writeup incorporates few glimpses of practical significance, from a real field operational evaluation study in deep ravines of Mahi river, by being more focussed towards impact assessments of Bori-Bunds (sand bags) which were used to rehabilitate the gullied lands with vegetative reinforcements (bamboo and other grasses).

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Focus of present study was identifying and propagating such low-cost local technology for making it familiar to nearby farmers and thus generating confidence in them to adopt or absorb the technology by applying a blend of traditional and scientific know-how. The strategy remains to identify lower order streams and prioritize their treatment by using empty cement bags (filled with sand therein), and thereafter using them as an effective temporary gully plugs, by adhering an appropriate structural and locational configuration. These gully plugs were appropriately reinforced by planting vegetation (mostly bamboo seedlings), offering ample soil moisture and stability to vegetation. Once the vegetation establishes, the roots grasped the soil together against eroding forces.

Complexity of Gullied Lands

Gullied lands have greater number of complexities in regards to their components like gulley beds, gully side slopes (lengths and degree), meandering characteristic of lower order streams, vegetative coverage, and several other managerial practices of in and around gullied streams specifically the riparian zones and sub zones. Gully formulations together with associated hydrological and geomorphologic facts are of immense importance, whenever an integrated ravine reclamation plan needs to be conceived (Simon and Rinaldi, 2006). Gujarat occupies one of the highest gullied areas in the country, which is mostly located along banks of Mahi river and its tributaries, typically at their downstream reaches. Several R&D efforts have been performed by encompassing plethora of conservation measures and strategic interventions at varied scales in time and space domain (Singh *et al.,* 2014). Above complexities pertaining to prevailing cohesive gully beds was suitably investigatedin the region being more attentive towards gully formations and gully bed treatments.

Findings from various formal and informal experimental as well as operational research on such lands has delivered enormous pools of knowledge (Rao *et al.,* 2013), where causes and effects of gully erosion are well identified, defined and quantified along with a vast spectrum of conservation measures (mechanical as well as vegetative). Majority of findings had very clearly revealed that preventing the formation of a gully is much easier and favourable option as compare to controlling it once it has already happened. In most of the situations observed in the region, whenever the incipient gullies are not stabilized, they become longer, larger and deeper. Under prevailing sets of climatic and geological conditions, at many locations vertical gully banks can easily become as high as 20-25 meters or more. Such type of gully networks can engulf adjacent steep lands/farming areas, grass lands, riparian lands, and even most parts of the forest landscapes. In most cases, it is not possible to stabilize those gullies because it often led to further hazardous leading or facilitating mass erosion like landslides and thus chocking and degrading streams (physically, biologically, ecologically) after heavy rains.

Gully Bed Stabilization

Greater magnitude of managerial complexities of gullied lands could be easily diluted by planning an adequate level of gulley bed stabilization. In such gully control, temporary physical measures like, woven-wire, brushwood, logs, loose stone, boulder check dams etc remains most popular options to halt the gulley bed scouring at one hand, while facilitating arresting of sediment loads on other hand. When such sediment loads (already released from upstream segments of gullied catchments) are effectively trapped with ample magnitude of runoff volume, they altogether facilitate the growth of nearby vegetative elements, reducing net porosities of these temporary structures hence capturing more runoff and enhancing infiltration opportunity times. These loose materials remain excellent because of economics in cost of construction and also the simplicity in its tailor-made designs and other configurations. Adopting these structures, the well-established concept of check dams can be nicely applied to harness its benefits with least inputs (cost of construction, operation and maintenance, simplistic designing and environment friendly nature). Most of such temporary kind of check dams are often constructed across the gully bed to cut the lengths of gulley beds and thus plugging their cross sections for stopping/ reducing erosion from stream banks and lateral regions. By reducing the original gradient of the gullied channel, such plugs very easily diminish the flow velocity of sediment laden runoff flows and their erosive power. Once the vegetative reinforcement is well attained, even in severe most peak runoff events, the runoff responses of gullied catchments are effectually regulated by gully plugs to convey peak flows in a desired level of safety. Such temporary check dams, generally have a life-span of three to eight years, and they fruitfully collect and hold soil and moisture in the bottom of the gully. Tree seedlings, as well as shrub and grass cuttings planted in gullies can grow without being washed away by flowing water, offering a permanent vegetative cover in a short time.

Role of Vegetation

Integration and Re-integration of degraded ravine lands with numerous kinds of flora is hugely important to increase forest cover and to meet the necessities of ever-increasing populace in the country. Bamboo is considered to be one of the probable species most suitable for such gullied lands (Rao *et al.,* 2013). It is one of the fastest-growing plants having widespread fibrous root system, linked rhizome system, condensed foliage, and yielding adequate quantity of leaf litter. A research and development project entitled "Hydrologic and economic evaluation of bamboo plantations in gullied lands under major ravine systems (Mahi, Chambal, Yamuna) of India" was implemented in the region where authors remained the lead actors to conceptualize, plan, implement and assess the ultimate effect of bamboo-based interventions for sustainable natural resource management in degraded gully lands. The high stemflow amount and funnelling ratio of bamboo plants in comparison to deciduous and coniferous plants made it better rainfall absorbing and hydrologically best-suited plantation in such degraded gullied lands, with higher economic returns, offering cost: benefit ratios nearing 1:2. Bamboo based resource conservation in the Chambal ravines, Yamuna ravines and Mahi ravines have amply improvised hydrologic and economic aspects of gullies/ gullied catchments. Though variety of temporary structures (staggered trenches, continuous trenches, loose boulder check dams, bamboo live check dams in different planting configurations, Bori-bunds *i.e.* sand bags etc.) were intervened by the authors; however, in present writeup the salient verdicts from Bori-bund based interventions are shared herein.

Conductance of An Operational Case Study

Ravine reclamation work on a small natural ravenous catchment of Vadodara district was undertaken, basically under Foundation for Ecological Security under UNDP-SGP collaborative R&D project. Treatment of associated ravines were accomplished during 2006 by constructing numerous Bori-bunds (sand bag dams) adopting formal ridge to valley treatment approach at catchment scale. The variability of ultimate siltation pattern was observed, critically analysed and presented herein to reflect the end performance of these low-cost temporary gully plugs.

Description of Study Area

Baseline survey was conducted for the study area to know the ground realities before initiation of the above said implementations. Benchmark status of natural as well as socioeconomic pattern of study area revealed that there exists, about 501 household comprising people/families of varied community with total population of 2812 (986 male, 846 female and 983 children). There was 53% income from agriculture, 18% from agriculture labour, 16% form livestock and 13% from other income source. Benchmark survey shows 89% household under agriculture while only 10% household under agriculture labor. Secondary occupation covers livestock (41% household) and agriculture (28% household) for income source. The majority of farmers being marginal landholders, agricultural labor become a major source of secondary income with almost 31% of households' dependent on it. Major livestock population were buffalo (62%), goat (15%), cow (9%), bullock (10%) and sheep (5%). A total of about 195404 liter milk was being collected per year, out of which, 58% sold to co-operative and 17% to outside, keeping merely 25% kept for household consumption. Soil analysis showed that the soil had medium nitrogen level, poor in phosphorous and rich in potash. The pH of the soil in gullied catchment was ranging from 7.38 to 7.69. All above configurations of gullied lands, established the prime socio-economic importance of these ravines, which deserves conservation treatments.

Gully erosion represents an imperative sediment source in a range of environments where gullies remain effectual links for transferring runoff and sediment from uplands to valley bottoms and permanent channels yielding aggravated off-site belongings of water erosion. Many cases of damage (sediment and chemical) to watercourses and properties by runoff from agricultural land relate to ephemeral gullying with increased connectivity in the landscape. Consequently, there emerges a simultaneous importance towards not only imposing variety of gully control measures but also effectively monitoring and evaluating their performance in real field conditions. The main objective of present study was to assess and understand the functional utility of certain low cost temporary earthen gully plugs made of empty sand bags. A representative gully network at Village Tansiya was adopted for generating intended valuable information under the UNDP-SGP sponsored Project for Ravine Stabilization, where about 23 ha of ravine lands were treated through the TGCS (Tree Growers' Cooperative Societies) on the bank of river Mahi in Savli Taluka of Vadodara district. For the purpose, a typicalravenous micro-catchment of about 4 ha area (Fig. 1) was randomly selected for the purpose. Mapping of the drains, gulley beds, and adjacent ridges/up-stream areas was accomplished by utilizing hand held GPS instrument and repetitive physical surveys (reconnaissance and engineering) of predominant longitudinal and cross-sectional profiles.

Scheduling and Primacies of Observations

A ridge to valley approach was adopted while locating, selecting and adopting candidate structures for evaluation purposes. During re-connaissance, random selection of Bori-bunds was made in such a manner that three specific segments of study catchment (1/3rd upper, 1/3rd middle and 1/3rd lower reaches) are well represented. Comprehensive land treatment plan

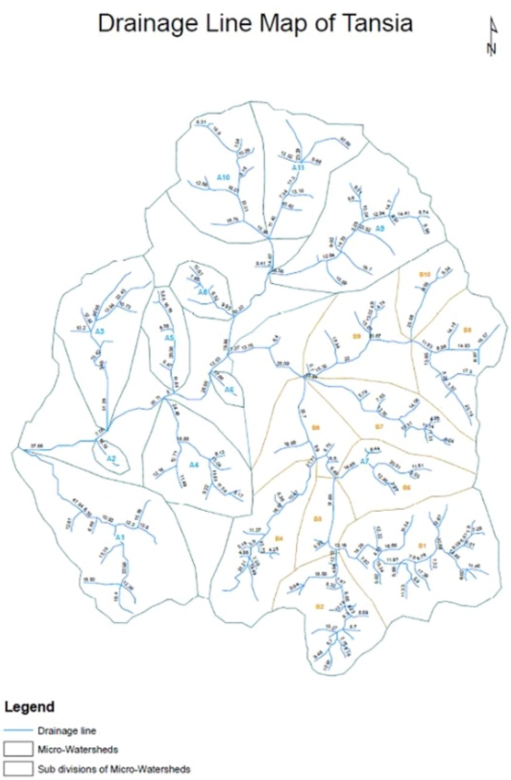

Fig. 1. Locations of representative sand bag gully plug on streams of varied orders inside catchment

was based on intensive transects and discussions with the community, followed by digitally marking all the gully beds with locations for intended sandbag dams. Major priorities remainto check and visualize the root cause of location specific gully formation, possible options for stabilizing the slopes, degree of needs for protecting the adjacent table lands, best utilization option for land parcels according to their capabilities, involving traditional knowledge and views of farmers for specific site/s and over all possible best economic versions. After planning, dimensional decisions, and creations of Bori-bunds at about 100 locations. Out of these100 Bori-bunds (made of sand filled bags), positions (coordinates and location) of 83 structures were precisely determined and documented. Fig. 2 depicts an average design configuration for such gully plugs. Vegetative reinforcement was another new component which was integrated in the said interventions. Major species utilized were *Bamboo (D. strictus)*, *Acacia senegal*, *Acacia leucophloea*, *Prosopis cineraria*, *Acacia jacquemontii*, *Holopteleaintegrifolia*, *Acacia nilotica*, *Azadirachtaindica*, *Madhucaindica*, *Manilkarahexandra*, *Pithecellobium dulce*, *Borassusflabellifer*, *Ailanthus excelsa*, *Limoniaacidissimia*, *Syzygiumcumini* and *Embelica officinalis.* The periodic observations (before and after monsoon seasons) on silt

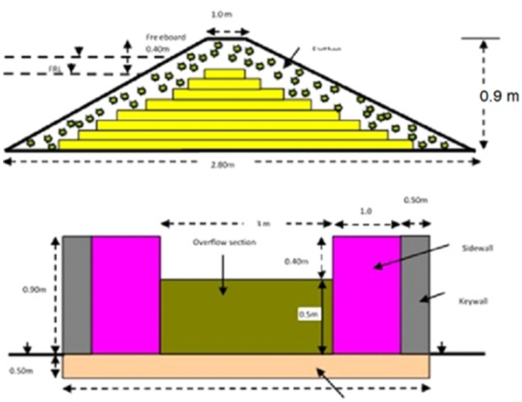

Fig. 2. Cross-sectional and longitudinal Sections of a sample Bori-bund (sand bag gully plug)

arrested by these structures were undertaken by involving farmers too. Precise magnitudes of net siltation (coverage areas and magnitudes of arrested silts) were worked out by utilizing the precious observations taken at randomly selected structures; followed by relevant vegetation surveys. Analysis on spatial distribution of arrested sediment loads was accomplished and some of the preliminary inferences are made part of this technical writeup, which are offered in subsequent paragraphs.

Major Verdicts from Present Study

Effectiveness of sand filled bags as temporary gully plugs was best established in study area. Even in first year of its implementation, the Bori-bunds offered tremendous paybacks in terms of huge arresting of valuable nutrient enriched sediments eroded from upper reaches of gullied catchment. Though these temporary gully plugs were not formally and meticulously designed; as only basic principle of catchment treatments and site demanding conditions were meet by selecting cross-sectional elements (being flexible enough), but maintaining a stabilized condition for its stabilizations and true functioning to capture incoming sediment laden runoff in a manner to get settled the suspended and bed load constituents of sediments. Basic considerations remains to limit the side slopes of embankments up to 1.5 :1 (H:V ratio), foundation of at least 50 cm, effective weir openings of 0.4 to 0.5 m^2, effective heights of gully plugs well below 1 m, and base widths of embankments up to 3 m; all depending upon local site conditions and on the views and advises from farmers who have seen the flows in past years at those particular locations (Fig. 2). Some of the crisped and concluded inferences from elementary observations of this preliminary ground study are offered as follows:

- It was a tough job to exactly measure the exact quantities of the sediment that was detained by temporary gully plugs in real ground conditions, especially with regards to differentiating silt from the other soil deposits and also with regards to measuring the exact depth of the silt cover. However, both the problems were resolved using the traditional know-how and on-field experience of technicians and farmers in conjunction by detecting horizontal as well as vertical spreads of silt arrests at up-stream locations of specific plugs. Depths of the entire silt layer, deposited during first year after construction were appropriately measured by visual and digging operations and then averaged to arrive at the annual deposition magnitudes.

- Average silt arrest was varying from 4 to 7 m^3 of sediments in Bori-bunds which are located in lower 1/3rd segment of treated catchment. Though the number of randomly observed structures in such downstream locations were relatively low, but the relative dimensions of the structures were big enough. Results (Fig. 3) showed that amount of silt deposited in the structures of steeper slope area is more as compared to the silt deposited in the structures of moderate and gentle slope area. From the above observation, it may be safely deduced that the distance between the two structures should be finalized only after analyzing the slope of the drain *viz.,* where the slope of the drain is steeper more structures are required as compared to the drains in moderate and gentle slope area.

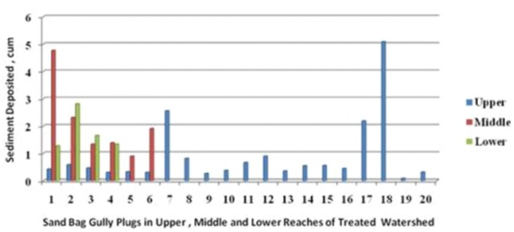

Fig. 3. Variability of siltation at different watershed reaches treated with sandbag gully plugs

- It was observed that increases in amount of silt depositions behind structures were not simply dependent or proportional to contributing catchment area; rather these magnitudes remained equally and some times more dependent on conditions of adjacent sides of gullies and channel meandering conditions.
- In lowest one third area of gullied catchment, the average volume of sediment arrests remained in an around 1.4 to 1.5 m^3 per gully plugs, which indeed was a function of so many factors. Similar arrests for middle 1/3rd segment of same study catchment showed an averaged silt capturing to the tune of about 2 to 2.5 m^3 per structure as influenced by location and other upstream characteristics of particular gully plugs. The magnitude of sediment captured by Bori-bunds located in upper one third portion of the catchment (Table 1), were found minimum (0.85 to 1 m^3). Since highest number of observation points were laid in upper 1/3rd segment, the estimates so arrived may be taken relatively more representative.
- Drainage density was found relatively more in gullied segments having higher slopes as compared to the moderate and low slopes area. Accordingly, the local release of sediment was more in such steeper slope area as compared to the gentle and moderate slope areas. By looking at such physiographic settings, it can be easily and safely deduced that the total no

Table 1: Average extents of siltation for various Bori-bunds located in varied reaches of catchment

Relative location of Bori-bunds inside catchment	Length (m)			Width (m)			Height (m)			Siltation (cm)		
	Min	Max	Av	Min	Max	Av	Min	Max	Av	Min	Max	Av
Upper 1/3rd (20)	2	7.1	4	1.2	7.1	4	0.02	0.18	0.1	0.09	5.09	0.9
Middle 1/3rd (6)	4.5	10.6	6.6	1.3	2.1	2.1	0.11	0.2	0.15	0.9	4.77	2.1
Lower 1/3rd (4)	6	8.4	7	1.4	2.1	1.8	0.12	0.16	0.14	1.28	2.82	1.8

of Bori-bund structures, and their locations needs to be planned according to slope of drain and contributing catchment.

- In all the horizontal and vertical spread of silt deposited in the middle and lower reaches were more than the upper reaches. We further surveyed the selected plot and try to found out the reason for that difference of silt deposition, it was observed that the soil in the catchments of upper reach's bori bandh have more clay content compare to middle and lower reaches.
- Vegetative analysis was also performed to establish the predominant architecture and density of trees, shrubs, herbs or grasses in visibility of Bori-bunds. In its first instance, such vegetative densities of trees were found to be inversely proportional to prevailing density of grass and shrubs at same location *i.e.* near to gully plugs. Moreover, the reason for it was never a stress of soil moisture of soil health, rather it looks to be the variability in sunlight. Similarly, where the density of shrubs was more, the net deposition of silt before Bori-bunds were noticed of lesser magnitude. Though the reason for this was not absolutely visible, but based upon local conditions and discussion with farmers the foremost reason was presence of denser vegetative ground cover, with which lower realises of local sediments looks to be a phenomenon from physical process points of view. It altogether established a fact that whatever the mode of gullied streams, the prevailing density of shrubs and herbs hold a greater significance to regulate soil erosion and silt arresting capabilities of gully plugs.
- Having measured and relatively compared the total quantity of silt, it was found that about 150 cubic meters silt got deposited via all the Bori-bunds across 4 ha natural gullied catchment. Average total weight of the deposited soil was supposed to be about 250 metric tons (M t) or so with highly varied proportions of silt releasing from different parts of the catchment. As high as 30 to 40 tonnes per hectare per year could be the ultimate silt arresting by sand bag filled gully plugs in study reason.
- “Ridge to Valley” approach was found extremely beneficial and important for ensuring the positive outcomes from simplistic soil and moisture conservation treatment in the ravine, as adopted in this case study. From cost of treatment point of view, there is a need to systemically evolve such ready reckoners for varied regions and locality, which ultimately depends and is governed by ease of availability of local materials and other socio-economic elements where such informal kind of soil conservation structures are planned and executed. In present study the cost involved was almost at its least level; where the major portion was labour cost. Most of the materials were devised by farmers as per their own options and materials. For example, the unutilized empty bags (polythene or jute) available in home or local/rural junk stores were arranged and instead of silt, the local soils were filled inside the bags for using them in construction of temporary gully plugs at predetermined locations on gulley beds. It offered to fold benefits, as owing to digging of local soil, an additional water storage capacity was created at upstream of such gully plugs. It altogether offered benefits to capture additional volumes of runoff and silts and thus not only arresting more silt but also offering more soil moisture for nearby vegetation to grow and better reinforcement of gully plugging system.
- Contrarily, the Bori-bunds were found not to be considered a totally dependable solution for their intended purposes. This is because of the fact that empty cement bags filled with earth only, gets disintegrated (*i.e.* powered) even in first year itself. This could be considered as a threat for this technological option of gullied land treatments. Moreover, after discussion with farmers, one of the

solutions (to at least dilute such issues) was originated. It includes using selective earth mass and its pre-determined layering during filling of bags; which ultimately could enhance or prolong the life of filled bags (at least for additional one year).

- Most of the structures were found safe enough against sliding, overturning or any other kind of failures (hydraulic, hydrologic, or structural).
- There existed a tremendous variability in magnitude as well as patterns of siltation in various cement bag gully plugs (83 nos) as evident from graphical comparison of results for three specific reaches, which are self-explanatory.Such varied capturing of sediments offered additional advantages of improvements in longitudinal slope profiles of gullied beds of smaller streams of different orders; which I turn was a sound hydrological improvement to regulate the dynamics of surface runoff and sediments in an optimum manner involving least possible costs.

It was a very useful study for understanding the impacts of soil and moisture conservation activities for the stabilization of Mahi ravines. The major achievements remain initiation of a ground based scientific database, which would be used as a future reference tool for understanding the impact of locally devised low-cost gully control measures, specifically temporary small size gully plugs. It would also serve as a useful reference tool at a later stage for further conducting the before and after impact assessments of catchment treatments, to facilitate in-depth understanding of the gullies and ravines in the region. The technical and functional descriptions in regards to Bori-bund based gully treatments are merely a location specific on-ground study with simplistic field-based observations. These were not so systematic or intensive following the exact methodological protocols, moreover the observations are real field outcomes which are difficult to get challenged, at least for the locations and conditions where they are generated/evolved. The findings as indicated in important inferences, clearly vindicate the facts, opportunities and scope for a wider replication of this technological option in the region. It could be an extremely effective option for reclaiming gullied and ravenous lands offering better vegetative covers, huge sediment arrests, stabilized banks and beds of gullies and smaller drains in a gullied catchment, and above all a true confidence to stakeholders or farmers in ravenous areas for better management of degraded gullied land parcels at their own, without being much dependent upon formal federal or governmental sources. These earths filled bags not only offered ample capturing of sediment but also positively influenced the soil-vegetation-cover complexes in and around the gully beds and banks, which in turn moderated the net surface runoff responses of contributing catchment. The Bori-bunds based soil conservation approach needs its location specific evolving to make it a truer and effectual intervention, which could be widely and deeply replicated in nearby (but similar) areas.The writeup has enough scope for its further enrichment from scientific point of views and considerations, as in its present form it involves only a set of preliminary real ground results from a case study; compromising with formal experimentations and experimental conditions /pre-requisites. It advocates line of operational R&D for future in this specific aspect.

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Plug Tray Production of Cucurbit Seedlings for Better Economic Returns in Riverbed Lands of Haridwar District

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INTRODUCTION

Haridwar is one of the prominent holy districts of the Uttarakhand where different kind of vegetables are cultivated by the farmers of the different vegetables cucurbits are more widely cultivated by the farmers in the villages situated on the bank of river Ganges where they are involved in the riverbed farming. Usually these lands are available only for a short period (October to May), and landless, small and marginal farmers cultivate these lands for seasonal vegetables. Riverbed cultivation is also known as *Diara* land farming (*plase* in local language) and is an age old practice of cultivating vegetable crops on the bank or basin of Ganges river after the flood water recedes (Fig. 1).

Mostly cucurbitaceous vegetables by virtue of their long tap root system are extensively grown in riverbeds. Different cucurbits like water melon (*Citrulluslanatus* T.), bottle gourd (*Lagenariasiceraria*), cucumber (*Cucumi sstivus* L.), summer squash (*Cucurbita pepo* L.), bitter gourd (*Momordica charantia* L.), pumpkin (*Cucurbita moschata* D.), pointed gourd (*Trichosanthes dioica* R.) and sponge gourd (*Luffa cylindrical* R.) are commonly cultivated in these systems. These *diara* lands are formed and subjected to alluvion and diluvion action of perennial Himalayan Rivers and due to inundation caused by rivers during the monsoon

Fig. 1. ***Diara*** **land farming of cucurbits on the Ganga river bank**

which deposits fresh silt and clay every year these lands are very much suitable for growing vegetables crops. Even though upper layers of land (largely containing sand) apparently seems unsuitable for cultivation, the subterranean profile moisture seeped from adjacent river streams makes it suitable for cultivation of cucurbit vegetables. Because of adverse condition of *diara* land, except cucurbits, most of the crops are not suitable for these types of lands. It can be treated as a kind of vegetables forcing where in the cucurbits are grown under sub-normal conditions facilitating off season production of cucurbitaceous vegetables. Mainly during winter months from October to May, after the river water recedes, vegetables can be planted in ditches dug into the seasonal sand banks, and the crops harvested before the onset of the next monsoon.

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The cucurbitaceous crops on these sandy soils along river bid also acts as a mulch during summer months and prevents the sand from blowing away and thus, acts as an good conservation measure. This type of cultivation is practiced on low priced sandy soils along the beds of the rivers, on bare, active sand-dunes in sandy regions gives protection to dunes and no sand blowing takes place with their vines mulching the soil during summer months. About 65% of total cucurbit cropped area of the country falls under riverbeds.Climate change induced floods and the encroachment of riverbeds and silting over arable land is steadily increasing the area under sandy riverbeds.

Early seedling development-big Step to fetching higher income: Case study at Shivalik foot-hills of Himalayan region by ICAR-IISWC, Dehradun

The team of ICAR-IISWC, under the DST sponsored project "Ensuring Sustainable Agricultural Development and Livelihood Security in lower Shivalik Range of Uttarakhand" has selected *Kabulpuri Raighati* village of Laksar block in Haridwar district of Uttarakhand. The village is situated on the bank of river Ganges where most of the farmers are engaged in off season (ahead to their normal season) cucurbit cultivation in the riverbed system for fetching high price of the off-season produce. After selection of village, baseline agro-ecosystem analysis was done using semi-structured interview schedule supported with PRA tools. Problem-cause analysis was also carried out. In the survey,different problems encountered by farmers during the cucurbit vegetable cultivation in *diara* land were recorded. The major challenges faced by farmers are enlisted below:

1. High seed cost of hybrid cucurbit vegetables.
2. Poor germination of seeds due to abiotic and biotic stresses.
3. More time taken for production of vegetable seedling because of low temperature during January and Februry.
4. High risk of seedling mortality due to exposure to adverse weather condition during early phase of establishment in the field.
5. Poor quality/unhealthy seedling availability.
6. Poor establishment and growth of plant/vine consequently leading to low productivity.
7. Higher incidence of pest and diseases mainly viral diseases.
8. Mechanical damage to the root system and shock during transplanting.
9. When the nursery is located far from the main field, the chances of transportation shock is more resulting in a lower rate of survival.
10. Fetching low market price to produced vegetables due to market gluts.

To address these problems, introduction of seed plug/pro tray (Fig. 2-3) was done for healthy and early production of vegetable seedlings using artificial media (coco peat media) in *Kabulpuri-Raighati* village. Generally, the cucurbits are sown by seeds in nursery followed by transplanting in the field. These seedlings are sensitive to slight damage to root and shoot system when pulled out from the soil at time the time of transplanting in main fields. But in the plug-tray nursery raising technology, when the seedlings of these cucurbits are raised in multi-celled plug-trays the roots are proliferated mostly on the outer periphery of the root media ball and they can be removed very easily without causing any kind of damage to root or shoot of the seedling. In addition to this, the root development under this system is more vigorous compared to grown in seedlings soil medium grown. This technology is efficient and suitable for growing off-season nursery of these cucurbits for advancing their crop (7-12 days) ahead to the normal season.

Coco peat is prepared from the waste of coconut husk or coir dust. This medium has good porosity, improved drainage and air movement

Fig. 2. Successful seedling production ahead of normal sowing season of cucurbits

Fig. 3. Successful cucurbit production ahead of normal season of cucurbits

activity. This medium is completely free from infestation of any pest or pathogen. It is commonly used under commercial nurseries for production of healthy vegetable and flower seedlings/ saplings. Use of coco peat media has several advantages such as the homogeneity of medium which makes it possible for the seedlings germinate and grow uniformly. Further, it has good moisture retention capacity and provides appropriate degree of drainage. Besides, it also easy handling and transportation as they are available in compact bricks of different weights.

Plug/pro tray technology details:

- This is the preferred method for seeds that are very fine, expensive or slow to germinate.
- Use healthy and improved seed from a reliable seed source. If the seed is not already treated, mix 2-3 g thiram per kilogram of seed. Alternatively, seed may also be treated with *Trichoderma viride* and *Pseudomonas flourescens*. Mix 10g of formulation per litre of cow dung slurry for treatment of 1 kilogram of seed before sowing.
- Use clean trays with cell holes 4 cm deep and 4.5 cm in diameter.
- Prepare the growing media by mixing coco peat and vermi-compost in the ratio 1:2 .
- Fill the cell holes tightly with the pre-moistened media.
- A small depression (0.5 cm) is to be made with finger- tip in the centre of the cell of pro tray to sow the seed.
- Sow one seed in the center of each cell, about 0.5-1.0 cm deep. Cover the seeds with the same mixture.
- Water at the rate of 15 ml per hole during first irrigation, subsequently giving 7-10 ml per hole daily each morning. Avoid watering late in the afternoon to minimize the occurrence of foliar diseases. Moistening the entire plug promotes root growth to the bottom of the plug.
- To promote initial germination, keep 8-10 trays stacked on top of each other and cover the entire stack of tray with a black polyethylene sheet. This ensures fairly uniform temperature and moisture for facilitating good germination. No irrigation is required till seeds germinate. Care must be taken to separate the trays when the seedlings are just emerging, to prevent them from becoming thin and weak.

- Seeds start emerging at about 3-6 days after sowing depending on the season in which crops are sown. Shift the trays to a net house and lay them on a seedbed covered with a polyethylene sheet or on a table.
- Before transplanting, seedlings should be hardened by withholding irrigation and are taken out from the plug-trays without any damage to roots or shoots of seedlings.
- The seedling would be ready in 21-25 days for transplanting.
- Seedlings of required cucurbit crop can be raised according to required date of transplanting in the field or under protected structures but two important factors considered before raising the seedlings are the quality of soil-less media and size of cell of the multi celled plastic plug-trays.

The advantages of using plug/pro trays:

- Provides adequate space for each seedling to grow.
- Improves germination percentage and uniformity in germination.
- Saves 30-40% seed in comparison to conventional nursery raising.
- Drastic reduction in seedling mortality or damping off because of sterilized growing media.
- Uniform, healthy growth and early readiness of seedlings.
- Ease in handling and cheaper transportation.
- Better root development and less damage while transplanting.
- Good field establishment and improved uniform crop stand.
- Early planting is accomplished by raising seedlings under pro tray.
- Seedling can be raised under adverse climatic conditions.
- Healthy seedlings can be raised in short period as compared to the time taken in open field condition.

Training of farmer

To expose the farmers about vegetable seedling production using root plug tray one-day field training programme was organized at the Kabulpuri Raighati village on 17th March 2018. Total 51 farmers'/vegetable growers participated in the programme. Detail exposure and demonstration for preparation of coco peat media and seed sowing in plug tray for cucurbit vegetable seedling production was given, afterwards cocopeat media and plug trays were distributed to farmers (Fig. 4-5).

Impact of Technology

Initial feedback of farmers' was very

Fig. 4. Training on plug-trays to needy farmers

Fig. 5. Distribution of plug-trays to needy farmers

encouraging, as more than 90% of root plug tray recipient farmers were convinced and accepted the benefit of raising nursery of cucurbit vegetables though root plug tray technique. They experienced the early and uniform germination of seedlings besides saving the 30-40% expensive hybrid seeds. Furthermore, because of better establishment of seedlings, farmers felt that gap filling is much minimized as protray seedlings established welland also came to yield early. Besides, farmers got success in advancing production of cucurbit vegetables for 7-15 days that in turn provides better price to produce. There is wide scope to extend this technology among the growers of this area to improve their economic conditions by taking the advantage of high price of off-season produce of these cucurbits.

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Land Degradation Status of the North East States of the Country and Steps Essential for Improvement

Prafulla Kumar Mandal*

Father of the Green Revolution of India and world famous Agricultural Scientist Prof. M.S. Swaminathan alerted "Among the troubles of the real world, land degradation and increasing diversion of prime farm land for nonfarm purposes, are among more serious ones, since they affect the future of food and water security. There is currently well justified concern for oil prices, but it is not commonly understood that while coal or renewable energy can stand in for oil, there is no substitute for top soil" (ICLRMFEES 2000-New Delhi, India).

The United Nation (UN) has forecasted that the world human population of current 7.6 billion is expected to reach to 8.6 billion in 2030 to 9.8 billion in 2050 and to 11.2 billion in 2100. The number of hungry people in the world is around 795 million (m). The Food and Agriculture Organization (FAO) is of the view that to feed this larger population, food production must be increased by 70%. Annual cereal production will be needed to rise to about 3 billion tonnes from 2.1 billion of today and annual meat production from 200 million tonnes (mt) to 470 mt. Thus alongwith the increase of population, the demand of the food (cereals and pulses), fruits, vegetables, sugar and jaggery, tubers, commercial crops, fodder and forage, oil seeds (edible and non-edible), medicinal plants, aromatic plants, plantation crops, flowers, raw materials of agri-based industries, structural wood and timbers, bamboos, spices and condiments etc many others are in the rise day by day. To ensure food security, the annual production should be at the quantity to meet the demand and buffer stock. It has been spelt out that, "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). All these should be produced on the arable land with productive soil and optimum fresh water. But, the arable land has been subjected to various kinds of degradation and accelerated soil erosion and the arable land area is decreasing for use in various non-agricultural sectors and urbanization. Soil not only is the foundation of plants but filters and clean tens of thousands of cubic kilometers of water each year. Let us have an exercise of the present state and the efforts needs to combat the situation as introduced herein before for our country India and particularly for the North Eastern states.

Geographical area of India – 328.73 m ha; Reported area 326.25 m ha.

Annual receipt of natural water per year - 400 million ha-m. Annual eroded soil 5334-6000 mt.

Eroded spoils - (i) laden 61% on down situation land and water course, (ii) 10% water bodies that reduces water storage up to 1.2% annually, (iii) 29% goes to sea that is deposited in the estuary (Mohana).

Soil degradation in India is estimated to be occurring on 147 m ha of land, (including 94 m ha water erosion, 9 m ha wind erosion, 16 m ha acidification, 14 m ha flooding, 6 m ha salinity, and 7 m ha a combination of factors).

Nutrients removal by soil erosion - up to 8.4

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m t of NPK (N- 2.5 + P 3.3 + K 2.6 m t), Micro-nutrients to be added.

Due to erosion, Crop loss or less production:

Estimates of 8 Cereals + 10 Oil Seeds + 9 Pulses is 13.4 m t. Cereals- 8.844 + Oil Seeds 2.814 + Pulses 1.742 m t. (V.N. Sharda and P. Dogra 2012). Statement of loss of production some of the crops caused by soil erosion (in tones) shown in table below:

Maize	18,57,442
Rice	43,08,786
Wheat	5,64,680
Groundnut	9,02,233
Rape and Mustard	2,97,963
Sesame	1,04,070
Sunflower	1,06,510
Bengal Gram	4,94,108
Greengram	68,400
Horsegram	2,33,348

(V.N. Sharda and P. Dogra, 2012)

North-East Region, Status and Importance of Soil and Water Conservation

North-Eastern Region of the Country constitutes of the states - Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura.

Disasters of these states exhibited by both flood-drought incidences, degradation of land by accelerated soil erosion and vulnerable too, that reflects negative consequences on the farming of the area. The area of arable land is comparatively less than that of other states of the country. All kind of erosions, *viz.,* splash, sheet, rill, gully, ravine, land slip/slide in fragile hills, stream bank erosion, river bed shallowing for excessive siltation are evident at high magnitude due to high rainfall intensity, undulating/sloppy topography, stony/ rocky loose soil. Top soil is scrapped. The Region is the treasure of bio-diversity of the country, but vulnerable to stresses due to the land degradation caused by the erosion. The data so far available, depicts the broad land use of the Region shown in then table below:

From the aforesaid available data on land degradation, it is seen highest (93.49%) in Nagaland and lowest 25.72% in Arunachal Pradesh and average is 53.7% of the region. As to the broad land use data, it appears that the cultivable area of the individual State is as least as 13.66% and as high as 47.08%, average is 25.41% of the geographical area correspondingly net sown area is as least as 2.69%, as high as 36.04%, average 17.48% of the geographical area of the region. Sizeable cultivable area is not sown due to various reasons, mainly being unsuitable land topography and erosions. Soil erosion rate is very high.

It is the integrated soil and water conservation, that can only halt the degradation and upgrade the degraded lands, bring lands under cultivation by development measures adopting appropriate location specific technologies. Also soil conservation based farming is essential. The North Eastern states of the Country need location specific

Name of North-East States	Geographical area (ha)	% Degraded	Cultivable land		Net sown land		
			Area (ha)	% of geogra area	Area (ha)	% of geogra area	% of cultivable area
Arunachal Pradesh	83,74,000	25.72	4,23,000	5.05	2,25,000	2.69	53.19
Assam	78,44,000	58.27	33,64,000	42.89	28,27,000	36.04	84.04
Manipur	22,33,000	79.18	3,90,000	17.47	3,83,000	17.15	98.21
Meghalaya	22,43,000	77.23	10,56,000	47.08	2,86,000	12.75	27.08
Mizoram	21,08,000	55.17	3,67,000	17.41	1,45,000	6.88	39.51
Nagaland	16,58,000	93.49	6,94,000	41.86	3,84,000	23.16	55.33
Sikkim	7,10,000	36.9	97,000	13.66	77,000	10.55	79.38
Tripura	10,49,000	77.03	2,72,000	25.93	2,55,000	9.53	93.75
Total	2,62,19,000	53.47	66,63,000	25.41	45,82,000	17.48	68.77

continuous specialized soil and water conservation research to standardize appropriate measures and its dissemination through training. The necessity calls priority from the status of denudation of the physiographic, climatic, vegetation.

Integrated Soil and Water Conservation Measures

Three groups of measures are needed for integrated soil and water conservation. (1) Disintegrate raindrop energy, (2) Decrease sediment yield, (3) Halt rain water in each elevation and rest surplus safe disposal, (4) Intercept the direct flow of run-off water, (5) Arresting eroded soils *in-situ*, (6) Enforce recharge of ground water, (7) Storage of surface water in surface water bodies, (8) Transparent surplus water, (9) Increase the time of concentration of run-off water in the drainage net works, (10) Prolongation of stream flow in the natural drainage system, (11) Restoration of degraded land, (12) Development of micro climate suitable for habitation, (13) Prevention of flood and drought, (14) Halt of degradation of environment and replenishment of degraded environment, (15) Protection of bio-diversity, (16) Protection of micro flora and fauna, (17) Ultimately maintain and regain of soil fertility status that will enable step up of annual, biennial perennial crops' productivity and allied sector like fishery, animal resources, raw materials of bio & agro-industries.

1. **Mechanical Measures**: Erection of barriers by works on the field to intercept the run-off and safe disposal of surplus. New works and maintenance of contour bunding, field bunding, compartmental bunding, bench terracing, gully plunging, graded terracing (inward and out ward), conservation bench terrace, staggered contour trench cum ridge, small dam, de-siltation basin, silt detention dam, waste wire, Inlet drops, chute, diversion channel, land shaping, land levelling, field bunding, plot to plot drainage, sluice gate, percolation tank, impoundment ditch, dug out, farm pond, cause-way, vented cause-way, course training spur), surface reservoirs , torrent control structures, land slip and land slide resisting structures, culverts with weir or without weir, wire net binded loose boulder/ stone gabion, etc.
2. **Vegetative Measures:** Raising grasses and legumes (non-weed) cover (Agro-stological) on the non-arable lands, contour vegetative hedge (vetivar, lemon grass and vitex), grassed water ways, agro-forestry, farm forestry, shelter belt (two storied), eyebrow vegetation in hill terrace risers, etc.
3. **Cultural Practices:** Farming operations like contour ploughing, contour cropping (row), strip cropping with erosion resisting and erosion permitting crops at appropriate ratio of the cover of the strip along the contour, inter-cropping at appropriate ratio of rows of erosion resisting and erosion permitting crops. Detailed soil survey report based replenishment of macro and micro-nutrients through green manuring, organic and Inorganic manures and fertilizers combination, etc.

Watershed Management

Now almost each country of the Globe has taken up Watershed management programmes. It is a strategy, the subjects are land, soil and water conservation. Watershed is a geo-hydrological unit of land, that drains to a single outlet of the drainage system. The outlet may be a surface water body or a natural drainage system. It may be compared with a leaf that all its venation networks join with its mid rib, then to its peteol. Thus Watershed is a natural hydrologic entity governed by the terrain topography from where runoff flows to a draining point. The term watershed is a general phenomenon, its size and area depends on the areal expanse of the unit .

Watershed Networks of India

Name of the smallest revenue unit is Mouza having a Jurisdiction List number (J.L. No.). Number of Mouzas constitute a Police Station, number of Police Stations constitute a Sub-division/Taluka, number of Sub-divisions constitute a district, number of district constitute a State/ Union Territories, number of States / Union Territories constitute the Country India. According to the spread of the Watershed, one may be intra Mouza, inter Mouzas, inter Police Stations, inter sub divisions, inter districts. Inter States/Union Territories and international according to its spread over as full or part. Soil and Land Use Survey of India under the Ministry of Agriculture and Farmers Welfare has prepared National Watershed Atlas. Different nomenclatures have been assigned to the watershed as a single and consisting of more than one. Whole country has been delineated into 6 Water Resource Regions, 37 Basins within it, 117 Catchments within Basins, 588 Sub-catchments within Catchments and 3851 Watersheds within Sub catchments. All are synonymous. Surface field water of 3851 watershed flows to 588 Sub-catchments, from these flows to 117 Catchments, from these to 37 Basins and from these to 6 Water Resource Regions. Water from these 6 Water Resource Regions drains to the Arabian Sea, Indian Ocean, Bay of Bengal. For working convenience, according to the geo-hydrological unit size smallest is Mini Watershed (1-100 ha), then Micro Watershed (100-1000 ha), then Milli Watershed (>1000-10000 ha) and then Sub Watershed (>10000-50000 and then Watershed (>20000-150000 ha). The water drains from Mini → Micro → Milli → Sub → Full Watershed sequentially, respectively. The objective of Watershed management is that after touch of rain water the field water should be retained and distributed in these net works. It has upper reach, middle reach and lower reach. All the mechanical and vegetative conservation works starts from the upper reach. The geo-hyrological unit of land is sect by natural boundary that after downpour (rainfall), the field water of the unit moves onwards to the drainage lines of that unit. It may be within a smallest revenue unit, adjacent more units, inter district, inter province, inter countries, international.

Increasing Farmers' Income:

1. **Integrated Soil and Water Conservation and its scope:** Restarting of discontinued Central Govt's schemes for integrated soil and water conservation so long implemented under the Department of Agriculture, Cooperation, Farmers Welfare of the Ministry of Agriculture and Farmers welfare, Govt. of India, like (1) Soil Conservation in the catchments of River Valley Project (RVP), (2) Soil Conservation in the catchments of Flood Prone Rivers (FPR), (3)Reclamation of Alkali Soil and (4). Watershed Development Project in Shifting Cultivation Areas have been discontinued. While these need be restarted vigorously with enhanced rate, new scheme like plot to plot soil conservation and land shaping in coastal saline areas need be launched. The suicidal per hectare ceiling of cost norm should not be again recurred. It should be on the basis of estimates as per SSR. No jumble of huge number of report/ information clerical works should be re-introduced.
2. Creation, strengthening and deployment of official human infrastructure with technologists for evolving, refreshing, disseminating and materializing technologies by education, research, training and extension methodologies. Human infrastructure should have direct hierarchy from grass root level to national level *viz.,* Village, Block, Sub-division, District, State/ Union Territory, National.
3. Strengthy official extension infrastructure should be established starting from the grass root level to the national level. Till time there are enough number of agro-technologies evolved and standardized through research, yet to be materialized. Enough number of agricultural technologists come out from the Agricultural Education and Research Institutions are well conversant of those. They should be deployed for planning and materialization of the evolved and standardized agro-technologies. Today

without adoption and application of the advanced technologies by the experts, no positive achievement is possible. Hence, Strengthy official extension infrastructure at grass root, Block, Sub-division, District, State, National level is indispensable.

4. Establishment of Research and Training Centre for the NESR exclusively for the Soil and Water Conservation, Watershed Management. While under the ICAR-Indian Institute of Soil and Water Conservation, Dehradun has other Regional centres but not in the vast area of NESR. Actually more than one is very much necessary. But it is remaining un-attended, probably with the argument that complex research station is existing there. This is not a creative concept. Justification for its necessity in the North Eastern Region with the ground of existing few ICAR Centres, that may have undertaken miniature similar activities will not be enough. The evidence of necessity of subject specific research Stations/Centres, even in a same geographical location is self justified by the establishment of series of many research Stations/Centres in Hyderabad under the ICAR, even inspite of existing ICRISAT.
5. Inclusion of Soil and water Conservation i.e. Agriculture as a whole under the concurrent list of the 7th schedule of the Constitution of India.
6. Constitution of different statutes, bodies, committees in Agriculture and allied sectors from Block to national level with the principal position of the Graduates in Agriculture and Allied subjects and the farmers representatives .
7. Rapid Reconnaissance Soil Survey, Detailed soil survey to determine Land Capability Class, Land and Soil Irrigability Class. LCC, LSIC based land use planning on the principle of use the land according to its capability.
8. L.&S.I.C. based application of irrigation technologies.
9. Extensive Soil and Water Conservation works on plot to plot by reviving closed schemes and augmenting new schemes both Centrally sponsored and State / Union Territory sector at 100 % subsidy.
10. Adoption of mass scale multiple use of land under crops *viz.,* Farm forestry, Agri-forestry, Agri-horti, Pasto-horti, Horti-forestry, Pasto-horti.
11. Agro-stology (grasses and legumes) with preference to industrial raw materials in non-arable lands.
12. Fish-cum-paddy cultivation in low lands.
13. Production and use of organic manures as much as possible.
14. Preference of construction and strengthening of multipurpose surface water reservoirs, dams, barrages. Completion of incomplete projects and schemes of this category. (Generation of electricity, irrigation, fishery, navigation, industrial use, drinking water by purification, flood control and drought resistance).
15. Restriction of use of ground water for industries and urban areas.
16. Treatment of industrial effluents before spreading on farm lands and mixing with surface water bodies and recharge.
17. Stopping alluring rural youth to non-farm profession with misleading propaganda against agricultural profession.
18. Non-transfer of farm lands to non-farmers by sale, lease, gift, donation .
19. No more urbanization, no use of farm land for non-farm activities.
20. Budget and actual expenditure in farm sectors atleast 50% of the total Budget both in Centre and in States/ Union -Territories.

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Remote Sensing Approach for Water Spread Mapping of a Reservoir: A Case Study of Tehri Dam Reservoir

Deepak Kumar* and Vaibhav Deoli

INTRODUCTION

Water bodies are key features on earth and essential for all form of life on earth (Kelly-Quinn *et al.,* 2017; Biggs *et al.*, 2017; Acharya *et al.,* 2016). Water is equally important for hydrological cycle, nitrogen cycle, carbon cycle etc. as well as for forest and grassland of the world. Hence identification and estimation of water bodies is important for water conservation and management of water bodies. Estimation may include spread area of the water bodies, depth of water bodies, volume of the water spread areas, sessional changes in water level and so on.

For these purposes remote sensing may play a key role (Sheng *et al.,* 2016; Palmer *et al.* 2015). The advantage of remote sensing is that it is macroscopic, real-time, dynamic access to the land surface information. So it is suitable in change detection in land as well as in water bodies. For water bodies mapping there are lot of satellite present which may be used to detect a water body and for gathering information about them after applying suitable index to extract water bodies.

All over the world different researcher working on water bodies features extraction and change detection in water bodies. Hui *et al.* (2007) used Landsat-8 imagery for modelling Spatial-temporal change of Poyang Lake in China. Normalized difference vegetation index (NDWI) and modified normalized difference vegetation index MNDWI index are used by them and conclude the images can be used to accurate mapping of water spread area. Du *et al.* (2012) used Landsat data imagery for water bodies mapping of Quingjiang River in China by NDWI and MNDWI index. Mishra and Parshad (2014) used Landsat imagery to extract water bodies by perceptron model with NDWI index and MNDWI index. Jiang *et al.* (2014) extracted lakes and river from Landsat imagery in China by NDWI and modified NDWI index. They conclude that Modified NDWI method is more improved to water bodies mapping than NDWI and NDVI method.

Basic principle of remote sensing for water body mapping

In general, remote sensing means assessing the features of any place from a distance. In satellite based remote sensing, cameras are fitted to the orbiting satellite which is focused towards the surface of earth. Cameras are sensitive to wavelengths of the electromagnetic spectrum.

In water resources, for water body mapping, remote sensed data play an important role to locate as well as to extract water bodies like dams, rivers, lakes etc. Radiation which is incident upon water is not reflected back; rather it is either transmitted or absorbed. Water bodies absorb near infra-red and longer visible wavelength radiation more than visible wavelength. Thus, clear water appears dark in color on an infrared image. Therefore, delineation and location of water bodies from remotely sensed data can be done very accurately by higher wave bands.

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Satellite useful for water body mapping

There are different satellite, which spectral images can be used for water bodies extraction and mapping. Among them Landsat Satellite, HJ-1A/B, MODIS are broadly used for water body mapping. The detail of these satellites is given in Table 1. Swath of Landsat-8 imagery is minimum (185 km) whereas the MODIS swath is maximum to 2200 km. The swath of HJ-1A/B is 360 km. Landsat-8 Imagery and HJ-1A/B imagery have equal resolution of 30 m and resolution of MODIS is 250 m or 500 m. Frequency of MODIS satellite is higher as compared to other. It's frequency is 2 time a day whereas frequency of HJ-1A/B is 2 days. Landsat imagery has minimum frequency of 16 days.

Band rationg indices for water bodies extraction

There are various ratioing indices used by researcher to extract water body and used to estimate different water features from satellite images. NDWI, MNDWI, WRI, NDVI etc. are some indices which has been used to water body extraction, conservation and management.

Normalized difference water index (NDWI)

NDWI is used to monitoring changes in water surface area with help of green and near Infra-red (NIR) wavelength. Range of NDWI is between -1 to +1 with positive value for water and negative value for all other features in satellite imagery. Mathematically, NDWI index is given as:

$$NDWI = \frac{Green - NIR}{Green + NIR} \quad ...(1)$$

For landsat-8 imagery band-3 (B3) and band-5 (B5) represent Green and NIR color. Hence for Landsat-8 imagery NDWI index is given as:

$$NDWI = \frac{B_3 - B_5}{B_3 + B_5} \quad ..(2)$$

Modified Normalized Difference Water Index (MNDWI)

MNDWI is modification in NDWI which is also suitable to extract water bodies from satellite imagery. In MNDWI water has greater positive values than NDWI because it absorbs less Near Infra-red (NIR) and more Medium Infra-red color (MIR). MNDWI is calculated as:

$$MNDWI = \frac{Green - MIR}{Green + MIR} \quad ...(3)$$

For Lansat-8 imagery MNDWI is given as:

$$MNDWI = \frac{B_3 - B_7}{B_3 + B_7} \quad ...(4)$$

Water Ratio Index (WRI)

WRI is mathematically defined as:

$$WRI = \frac{Green + RED}{NIR + MIR} \quad ...(5)$$

For Landsat-8 imagery it is given as:

$$WRI = \frac{B_3 - B_4}{B_5 + B_7} \quad ...(6)$$

Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index

Table 1: Satellite useful for water body extraction

Satellite	Landsat Imagery	HJ-1A/B Imagery	MODIS
Swath (km)	185	360	2200
Resolution (meters)	30	30	250 or 500
Frequency (days)	16	2	0.5
Resolution (micro-meters)	Band 1 (0.45-0.52)	Band 1 (0.43-0.52)	Band 1 (0.62-0.67)
	Band 2 (0.52-0.6)	Band 2 (0.52-0.6)	Band 2 (0.84-0.88)
	Band 3 (0.63-0.69)	Band 3 (0.63-0.69)	Band 3 (0.46-0.48)
	Band 4 (0.76-0.9)	Band 4 (0.76-0.9)	Band 4 (0.55-0.57)
	Band 5 (1.55-1.75)		Band 5 (1.23-1.25)
	Band 6 (10.4-12.5)		Band 6 (1.63-1.65)
	Band 7 (2.08-2.35)		Band 7 (2.11-2.16)
	Band 8 (0.51-0.89)		

(NDVI) is a technique used to estimate land cover area, built-up area, water cover area, open area, forest by combination of few band of satellite imagery. The value of NDVI vary from -1 to +1. In general, NDVI is calculated as per eq. 1.

$$NDWI = \frac{NIR - RED}{NIR + RED} \quad ...(7)$$

Where, NIR stand for Near Infra-Red; RED represent the red spectrum.

Landsat-8 imagery band 5 represent NIR and Band 4 represent RED. Thus, eq. 8 can be used for NDVI estimation.

$$NDWI = \frac{B_5 - B_4}{B_5 + B_4} \quad ...(8)$$

Case study of tehri dam reservoir

Tehri Dam reservoir is one of the highest dam in India constructed on Bhagirathi River near Tehri Garhwal, Uttarakhand. This dam is situated at longitude of $30^0$23'N and $78^0$26'E with an altitude of 1750 m above mean sea level. The dam was mainly built for provides electricity of around 1000 MW. Beside electricity generation, this dam is used for irrigation and drinking water purpose for nearby areas.

In this case study, Tehri reservoir water spread mapping, during the pre-monsoonal season, has been done from 2016 to 2018. For this study, Landsat-8 imageries have been used. Cloud free Landsat-8 imagery has been taken for pre-monsoon session. In pre-monsoon session water level of dam will be minimum.

The objective of the study was to estimate water spread area by remote sensing technique after applying different ratioing indices. For this purpose three indices has been used namely NDWI and MNDWI. The location map of Tehri reservoir is shown in Fig.1.

Water spread mapping for the pre- monsoon season of 2016, 2017 and 2018 has been shown in Fig. 2. In this study, for each year, water spread mapping has been done using NDWI and MNDWI ratioing index. While extracting the water features, threshold value to the ratioing index is important. Threshold value of 0, 0.2 has been used while extracting water features using NDWI and MNDWI, respectively. The selection of threshold value was based on overlying and comparing the original image with the extracted water body image. Water spread area for the same period using aforesaid ratioing index has been tabulated in Table 2.

In an average, water spread area was 17.6 km^2, 16.12 km^2 and 24.89 km^2 for pre-monsoon period of 2018, 2017 and 2016, respectively. Since the study period was pre monsoon season, the water spread area was low during this period. The information of water spread area can be used to calculate real time capacity of the reservoir, if the depth of water in reservoir will be coupled with the water spread area. SARAL ALTika may be used to measure depth of water in a reservoir. The information hence collected can be used for precise water budgeting.

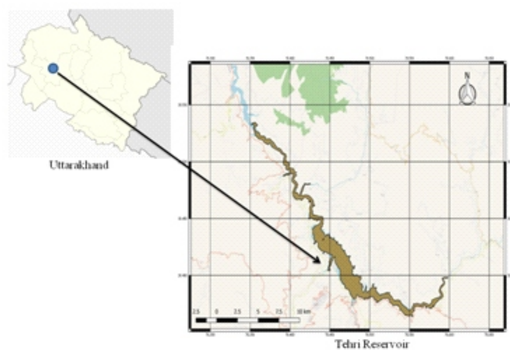

Fig. 1. Location map of Tehri Dam in Uttarakhand

Table 2: Water spread area in pre-monsoon session in Tehri Dam by different water indices

Study Area	Year	Water Index	Threshold value	Calculated area (km^2)
		NDWI	0	18.12
	2018	MNDWI	0.2	17.08
		NDWI	0	16.37
Tehri Dam	2017	MNDWI	0.2	15.88
		NDWI	0	25.43
	2016	MNDWI	0.19	24.35

CONCLUSIONS

Among several applications, remote sensing techniques can be used for water body feature extraction, further this information can be used for water resources management. The band ratioing technique, which is a part of image processing, is suitable for feature extraction. Normalized Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI), Normalized Difference Vegetation Index (NDVI) and Water Ratio Index (WRI) can be suitably used for estimating the water spread area. Using NDWI and MNDWI, a case study of water feature extraction has been done for Tehri reservoir. The results remarkable provide the

Fig. 2(a). Water spread mapping in 2016 based on NDWI

Fig.2(b). Water spread mapping in 2016 based on MNDWI

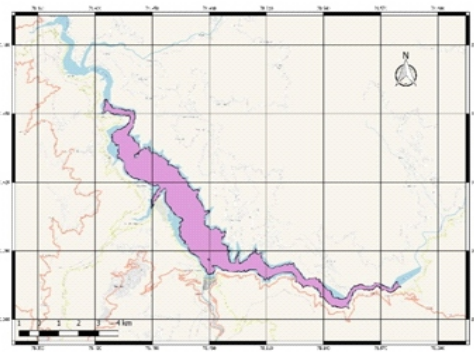

Fig. 2(c). Water spread mapping using NDWI (2017)

Fig. 2(d). Water spread mapping using MNDWI (2017)

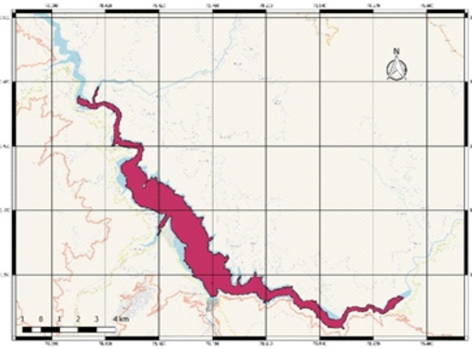

Fig. 2(e). Water spread mapping using NDWI (2018)

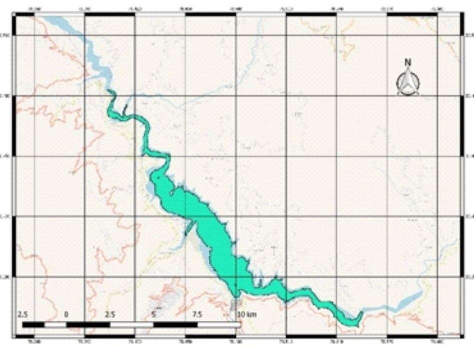

Fig. 2(f). Water spread mapping using MNDWI (2018)

Fig. 2. Water Spread Mapping of Tehri reservoir during pre-monsoonal period

spatial and temporal variation of water spread for the said reservoir.

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Biochar as Soil Amendment for Sustainable Agriculture

Praveen P.*

INTRODUCTION

In the present scenario, carbon sequestration is gaining importance to mitigate climate change. Sequestration of carbon can be done by afforestation, biomass management, making use of alternate energy such as solar, wind, biogas etc. Biomass can be converted into energy source through several methods. The most common is direct combustion of biomass material, such as agricultural waste or woody materials. Thermo-chemical technology such as pyrolysis, gasification and hydrothermal conversion are used to produce energy with less carbon emission. Biochar is the carbon-rich by-product obtained by heating biomass under pyrolysis process. Under this process biomass is heated in a closed system under limited supply of oxygen. Products obtained during this process are syngas, bio-oil and biochar. Direct combustion systems feed a biomass feedstock into a combustor or furnace, where the biomass is burned with excess air to heat water in a boiler to create steam. Instead of direct combustion, some developing technologies gasify the biomass to produce a combustible gas, and others produce pyrolysis oils that can be used to replace liquid fuels. Boiler fuel can include wood chips, pellets, sawdust, or bio-oil. Steam from the boiler is then expanded through a steam turbine, which spins to run a generator and produce electricity. This process is very simple and adopted for thousands of years. Traditional earthen and brick kilns were replaced by modern pyrolyzers as the former technology produce charcoal by releasing large amount of volatile substances to the atmosphere which cause air pollution. Modern technology is designed so as to capture the volatile compounds for the production of bio-oil and syngas. One of the by-products obtained during this process can be used as soil amendment that is biochar.

The char obtained from pyrolytic process can serve as a sorbent, has greater sorption ability than natural soil organic matter due to its greater surface area, negative surface charge and charge density (Liang et al., 2006.). Biochar can be used directly as a soil amendment and it has been reported that using it improves soil quality by raising soil pH, increasing moisture holding capacity, attracting more beneficial fungi and microorganism, improving cation exchange capacity and retaining nutrients in soil (Lehmann, 2007). One more advantage of using biochar as a soil amendment is it may persist in soil for many years due to its resistant for microbial decomposition and mineralization. Effective utilization of biomass have synesgistic effect as syngas obtained from the biomass turned to be an alternate energy source and has got many benefits to mitigate the use of fossil fuel, besides the biochar obtained from the pyrolytic process can be used as soil amendment to improve quality of soil.

The modality of biochar in its ability to act as an effective soil amendment is similar to the traditional "slash and burn" fertilization method, where farmers remove the vegetation and release a pulse of nutrients to fertilize the soil. But the slash and burn practice has an unfavourable environmental reputation because it is associated with deforestation and air pollution. In contrast, biochar production under a controlled system may provide a higher yield and have fewer detrimental effects on the environment. These

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characteristics make biochar an exceptional soil amendment for use in sustainable agriculture (Lehman and Joseph, 2008).

Power of Biochar

Biochar being by-product of pyrolysis process enhances crop growth by increasing the quality of soil and sequestering C in soil and providing other environmental advantages. As such, it represents a tool for managing the quality of soil over long period, alongwith climate change mitigation. Presently, scientific research, on the environmental advantages and agricultural scope of biochar is being published at growing rate. However, biochar is the main ingredient in a new carbon-negative strategy which has the potential to resolve various critical current ecological, economic and energy problems. If properly made and used, biochar can relieve climate change and other environmental effects.

Environmental Benefits and Impacts

Shareef and Zhoa, 2017 reviewed some of the works with respect to biochar as a soil amendment to highlight the ability of char and also to provide scientific reference for the biochar application. They observed that through the pyrolysis process the structure of molecular biomass is reorganized which is extremely stable in the soil system. Carbon that was in the atmosphere gets combined into biomass by plant wastes, plants are pyrolyzed, and biochar placed in soil. By reviewing research works with respect to application of biochar as a soil amendment, they found that biochar can be employed as an instrument to sequester or seize carbon in soil in a safe system. The carbon in biochar has least possibility to "escape or lease" in the atmosphere and also has additional advantage of improving the soil quality and these can actual an amendment for sustainable agriculture.

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Some Lesser Known Facts about Sukhomajri Project of ICAR: The Foster Mother of Watershed Management in North India

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The Integrated Watershed Management Project Sukhomajri of the Central Soil and Water Conservation Research and Training Institute Dehradun funded by Ford Foundation is perhaps the only Operational Research Project of ICAR on watershed management which was visited by largest number of administrators, scientists, planners, politicians, students and IAS and IFS probationers. The list of distinguish visitors include the then Union Minister of Agriculture and Cooperation Rao Birinder Singh, the then Union Minister of Forests and Environment Smti Menka Gandhi, the then Director General of ICAR Dr. M.S. Swaminathan, the then Member Planning Commission of India C. Hanumantha Rao. Sukhomjri in north and Ralegan Siddhi in south were referred to in the speech delivered from Red Fort by Shri Atal Bihari Bajpai, the then Prime Minister of India and gave the famous slogan *khet ka pani khet mein, gaon ka pani gaon mein* highlighting the urgent need of water harvesting. It also got maximum coverage in the mass media of that times including Illustrated Weekly.

At the instance of Dr. M.S. Swaminathan, two documentaries were prepared to commemorate the Silver Jubilee Year of ICAR. One complete film was made on Sukhomajri and second covered small bits from all ICAR institutes. The film was translated in 14 languages and shown in cinema halls of the country. Perhaps NRM agenda was very high in the mind of this great visionary. A full page D.O. letter was written by a senior IAS officer from the Planning Commission to all the Chief Secretaries of States appreciating the Sukhomajri concept and requested them to visit this project and replicate this concept in their respective states. The response was so quick that in no time the then Chief Secretary of Haryana, Financial Commissioner of Agriculture, Punjab and Director, Agriculture, Himachal Pradesh visited the project.

Sukhomajri gradually became a concept of participatory and integrated natural resource management for poverty alleviation. It emerged as the solution to the problem of rapid siltation of Sukhna Lake. It became an answer to the serious problem of floods, droughts and deforestation. The communities started protecting the forest watersheds to which they were devastating before due to the flow of direct, visible and substantial benefits to each and every family through rainwater harvesting. After seeing the glow on the faces of poor farmers whose thirsty rain-fed farm lands were being irrigated through sprinklers in 1978 with rainwater harvested from a hilly forest watershed and visualizing the prospects of its large scale replication, Dr. M.S. Swaminathan spontaneously remarked at Sukhomajri in October, 1977: **"The future of Himalayas is hidden in Sukhomajri"**. At the ICAR Director's conference held at Shimla next day, he motivated the Directors to visit Sukhomajri on their way back. He asked Dr. D.R. Bhumbla, DDG (Soils) to construct another water harvesting dam as requested by Sukhomajri farmers.

It was named as a model of self sustaining rural development by a foreign correspondent of Economic Times. Dr. Hanumanantha Rao,

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Member, Planning Commission, was so impressed after his visit that he sent Kanchan Chopra to camp at Sukhomajri and bring out the complete story of transformation. The late Sh Anil Aggarwal and his colleague madam who is now heading his institution visited Sukhomajri and Nada and gave maximum coverage in the very first chapter of **Citizens Report on India's Environment.** Madhu Sarin an environmentalist joined the band wagon and highlighted the potential of this model in Joint Forest Management. While Mr. Caprihan, the Chief Secretary of Haryana made rich contribution by promoting this program in Haryana, Mr. P.H. Vaishnav, the then Financial Commissioner Development, Punjab first experimented the model at Parchh Village and then got it replicated in Punjab Shivaliks.

Sukhomajri became a passion with Dr. D.R. Bhumbla, the then DDG, ICAR. Mr. Mishra who went to the extent of madness to propagate the collective power of hills and the people, called it cyclic system of development and vehemently held that development is possible without destruction of forests. He advised foresters to consider water as a product of forest in addition to timber and fuel wood. He painfully felt that India is developing but its natural resources are depleting and degrading fast. His quest for learning more and more from farmers, down trodden and deprived became so strong that he named Daula, an old but wiser farmer of Sukhomajri as his Guru. Sondi Ram a landless labourer of Nada became his subject of interest because his wife ran away when he fell sick and could not earn for his daily meals. The scientists who worked in this project never worried about their assessment/ promotions because everybody was aware of the success of Sukhomajri project. The author worked for 12 years in this project at grass root level.

Author worked for 12 years (1977 to 1989) at the grass root level in and around Sukhomajri and Nada and worked for replication of the Sukhomajri model for almost 30 years (1977-2007). While whatever Mishra said and felt was published either in press or in papers, the research experiences were encapsulated in technical bulletins of the Institute and large number of research, technical, popular and seminar papers were published by the fellow workers of the Institute. Yet there were certain lessons of experience which are very important but never became the subject of discussion. As the nation is preparing for a much bigger fight on rural poverty, resource degradation and community participation in land and water management, such experiences are likely to be useful to all stakeholders.

No irrigation pipe outlet was originally installed through the body of 12m high earthen dam (Sukhomajri-II). Efforts were made to operate a siphon system made of jointed RCC Pipes over the dam to draw water, but it did not work (Looks blunder now). After visiting Damodar Valley Project near Ranchi in Bihar during 1978, a slit was opened in the dam body and pipe outlet with sluice valve was laid out. The idea from DVC worked well.

The total cost of the main dam at 1978 prices was around ₹ 50000/-. Another ₹ 16000/- was spend on RCC conveyance pipeline. This system worked well, though water use efficiency was low as compared to drip and sprinkler system now prevalent. The services of Dr. Jack Kellar, an authority on sprinkler irrigation were hired by the Ford Foundation to plan a sprinkler irrigation system for more efficient use of limited irrigation water. His plans neither convinced me, nor Mishra and much less Daula and villagers. But even then ₹ 40,000/- was spent by Ford Foundation on complete set of sprinkler system off loaded in the village. Mr. David, one of the M.Sc. students of Dr. Jack Kellar was sent for a month from USA to get the system installed as part of his M.Sc. Thesis work. The main pipeline was laid below the surface, but laterals were laid on the surface and system was made operational.

A freely moving buffalo bull crushed few aluminum pipes under its foot during night couple of days later. The size of an individual field can be imagined from fact that 44 farmers owned 20 ha of command area. The half hectare land owned was divided into six irregular rectangles. Farmers could not irrigate the whole rectangular field as sprinklers coverage was in a circle. The nozzles covering circular areas could not fit into the small rectangular fields of so many farmers. The sprinkler system did not operate even for 10 days and everything was dismantled after the departure of Mr. David, put in store and never used. However, all sloping lands were leveled and border irrigation was preferred. Many farmers sold their goats to invest on land improvement. A *barabandi* system of water sharing was planned and implemented by Sh. S.P. Malhotra, a retired Enginner-In-Chief of Haryana hired by Ford Foundation.

Several farmers were given saplings of mango and guava for planting. They were planted but not even one could reach the fruiting stage as wild life damage was beyond control. Papaya plants were planted on the field bunds of some farmers. Few farmers saved them and nurtured to fruiting stage. Jethu Ram was photographed with Papaya plants. So was the case of ORP Nadha. Large number of Papaya plants reached maturity. In less than 2 years, all Papaya plants disappeared and no new one was planted by the farmers themselves as marketing became a big problem of perishable fruit. Hybrid maize seed was given to the farmers and several demonstrations were also laid out. The crop yield of hybrid maize was better than local maize. But the colour of grains was white. No farmer raised hybrid maize again as local maize was their staple food. But they changed the entire wheat and sugarcane varieties in no time.

The Village Resource Management Committee (VRMC) decided ₹ 2/- hour of water supply as water rent. Gradually some farmers started delaying the payment. Then few more followed and slowly arrears started accumulating. Many beneficiaries became defaulters. When VRMC changed, the cashier could not give the full amount of water rent to the new cashier. New committee decided to stop water supply to those who were in arrears. On this a big quarrel started. The matter was resolved with great difficulty and ultimately the decision was taken to auction the reservoir stored water by open bid system to a local contractor who would collect the water rent. This system worked well and subsequently followed in several water harvesting projects.

The underground pipeline was being laid in Sukhomajri. In order to bring the entire area near the village under the command, it was planned to take the pipeline to the highest point close to the houses. The alignment was decided by the villagers themselves. One villager, Puran stopped the work of pipeline layout when it reached close to the target point. He took the plea that he wanted to construct his out house on his piece of land which incidentally came exactly in the centre of alignment. All villagers persuaded him, but he did not agree. More he was persuaded, more adamant he became. There was no way out as pipeline had already reached the boundary of his field. Giving bends would mean loss of hydraulic head which was barely sufficient to get full discharge. This issue of head limitation was made clear to everyone including Puran and was well understood by all, but Puran did not budge. There was no alternative. Daula said "*Laton Ke Bhoot Batoon Se Nahin Mantye"*. He suggested the solution in my ears. The SHO of Pinjore was known as he visited Sukhomajri whenever any dignitary visited. Problem was put before him. He devised his own way and asked us to intensify the work tomorrow and finish it in one day. He sent a constable to Sukhomajri to call Puran to police station. SHO thrashed him, kept him sitting there for one full day and one full night without registering any case. Pipeline was laid in one day through his field. His wife gave choicest abuses from her roof top to field man, forest guard and labourers. The pipeline was refilled before Puran came back next morning. He remained cool and calm thereafter. This technology worked because whole community was with us. I never took food in any body's house and never got any produce home from the village. The Tiffin system was followed.

Sukhomajri does not exist as a revenue village. It was mentioned as "be charagmauja" (lamp less settlement) of Dhamala village in revenue record. A '*choe*' divided the arable land of Dhamala and Sukhomajri. There also existed a divide in the adjoining non arable forest land in the form of main drainage line of a small forest watershed on which the main earthen dam was constructed to store the runoff from 9.2 hectare forest watershed. As a result, the reservoir, which formed, fell half in Dhamala and half in Sukhomajri land. But pipeline was laid to irrigate the land of Sukhomajri and not of Dhamala. Dhamala farmers remained silent for some time, but when they saw that Sukhomajri people who used to come to Dhamala for fetching drinking water from their well (incidentally Sukhomajri had not even a single well) are enjoying huge benefits because of irrigation from common reservoir, they started raising the issue of sharing water. In many functions, when high dignitaries visited Sukhomajri, they started putting their claim. They started saying that someone from Sukhomajri is distantly related to Dr. D.R. Bhumbla (who was then DDG, ICAR) and he is favouring the Sukhomajri people. Dhamala was mainly Jat Sikh community dominated and Sukhomajri by Gujjar community.

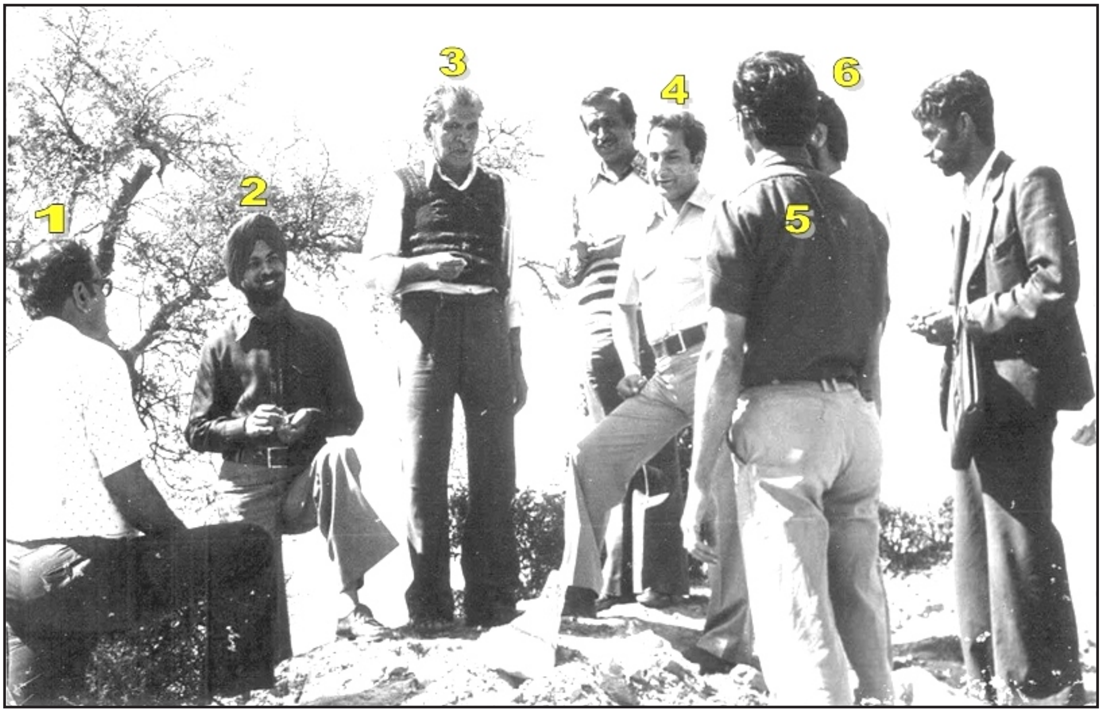
Dr. Bhumbla arranged a complaint from Dhamala against Sukhomajri addressed to Secretary Agriculture, Govt. of India, New Delhi and got a copy of it. He persuaded the Agriculture Ministry to sanction one similar dam for Dhamala village. Incidentally a good site existed by the side of Sukhomajri dam. The funds came from the Govt. of India through Department of Agriculture, Haryana and that is how Dhamala also got a similar facility.

When at the intervention of Haryana Forest Department, the lease for extracting Bhabar grass from forest area was given to Sukhomajri VRMC by eliminating prevalent contractor system, Dhamala people again raised the issue of sharing the revenue. The division of forest land among two villagers became a big issue and this was reported with adverse comments on Sukhomajri in news papers. How this was sorted out is a long story, but fact remains that conflicts emerged but proper handing by the committed and well meaning authorities amicably resolved the conflicts.

When at the instance of some senior officers, Haryana Forest Department raised a barbed wire fence between the forest and private land of Sukhomajri; Mr. Mishra opposed it tooth and nail and termed it as "wall of distrust". His experiment on social fencing (people themselves protecting forest because it was a source of water which acted as a catalyst to improve their economy) got vitiated. He tried to convince everybody and ultimately succeeded in getting barbed wire fence removed.

When we were working in Nadha village, plantation of fodder trees on 11 hectare degraded land was taken up to augment fuel wood and fodder supplies. Bhabar grass was also planted to improve the livelihood opportunities of 12 *harijan* families as almost all of them were engaged in rope making from Bhabar grass. Mishra took five of us (S.K. Dhar, R.D. Jakati, Deep Joshi then FF consultant but after that formed NGO, Pardhan, Mr. R.K. Mukherjee from DVC and myself) to the hill top and made us to stand around a pit (Photo).

He gave one 'Patasa', a common sweet, to each of us and asked to bow our heads, throw your patasa with folded hands in the pit and swear to have buried our egos in the pit and that we would work throughout our life for the bleeding hills and the hungry people. We all did what he suggested and the pit was filled in our presence, he started calling us Sukhomajrians. We salute to the departed soul. Mishra is no more with us. The success of this project stems from four major factors:



1. Sh. R.K. Mukherjee, 2. S.S. Grewal, 3. P.R. Mishra, 4. S.K. Dhar, 5. R.D. Jakati and 6. Deep Joshi on hill top in village Nadha, District Ambala of Haryana State

- The guidance, support and encouragement from the top emanating from Dr. D.R. Bhumbla, the then DDG, Soil and Agronomy ICAR, New Delhi.
- The dedicated efforts of Mr. P.R. Mishra, who made Sukhomajri a mission of his life and died replicating Sukhomajri in Bihar and got Padam Shree for his relentless efforts on poverty eradication through natural resources management.
- The energetic team of workers at the grass root, who faithfully implemented the directions and adopted participatory mode of development ensuring active involvement of the community.
- Excellent relations with the Haryana State Forest Department which replicated Sukhomajri model.

(A Tribute to Dr. D.R. Bhumbla and Late Shri P.R. Mishra)

“Save Soil Campaign”

> *“Upon this handful of soil our survival depends. Husband it and it will grow our food, our fuel, and our shelter and surround us with beauty. Abuse it and the soil will collapse and die, taking humanity with it”*
>
> **From Atharvavedas (Sanskrit Scripture) – 1500 BC**

"I pledge to intensify our endeavours to protect and improve soil resources that surround us in order to restore and maintain a sound ecological balance in land, air, and water. I commit myself to promoting public awareness and education on the “Save Soil Campaign” as well as the public reporting of the environmental impact of various activities being taking place on the thin layer of SOIL. I believe it is our responsibility to take care of soil and land resources so that it remains available in good condition to my children and grand children (for generations). I also pledge to continue promoting the benefits of soil conservation for the sake of human's well being”.

Facts and Popular quotes about the importance of soil resources

- It can take more than 1,000 years to form a centimeter of topsoil
- In a handful of fertile soil, there are more individual organisms than the total number of human beings that have ever existed
- There are over 100,000 different types of soil in the world
- Five tonnes of animal life can live on one hectare of soil
- SOIL is “*Soul of infinite life*”
- Listen to soil, if you have ears - *Jesus*
- Soil is a storehouse of Carbon to mitigate Climate change
- A land without a Farmer becomes barren
- Agriculture connects Farmer, Land and Nature
- Soil sustains all life on the Earth
- Farmers are the Human factors in soil Management
- Farmers first in soil and water conservation: Beginning the Journey towards a new vision
- Farmers heal the land

Indian Association of Soil and Water Conservationists

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