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Science-led interventions in integrated watersheds to improve smallholders' livelihoods

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ABSTRACT

Existing large crop yield gaps between farmers' fields in rainfed areas and the achievable yields are abridged through integrated watershed management during 2002-2007, while improving farmers' livelihoods also. In addition to water shortages, emerging widespread deficiencies of multiple micro- and secondary nutrients such as sulphur (S), boron (B) and zinc (Zn) along with nitrogen (N) and phosphorus (P) are holding back the productivity potential through inefficient utilization of limited available water. Soil test-based balanced nutrient application of deficient SBZn plus NP in fields in watersheds recorded 70 to 119% (2100 kg ha^{-1} in maize, 660 kg ha^{-1} in groundnut, 640 kg ha^{-1} in mungbean and 1070 kg ha^{-1} in sorghum) improvement in crop productivity along with additional returns varying from Rs 16,050/- to Rs 28,160/- ha^{-1} over the farmers' practice (only NP). Landform management to alleviate waterlogging proved effective intervention to manage high clay Vertisols for higher soybean and groundnut productivity by 13 to 27% (340 to 350 kg ha^{-1} in soybean and 160 to 250 kg ha^{-1} in groundnut) over the farmers' practice. However, the integrated approach of balanced nutrition and landform management plus improved cultivar was the best option in increasing sunflower productivity by 182% (1600 kg ha^{-1} in sunflower) over farmers' management (control). Adoption of these soil-water-crop interventions in target watersheds abridged yield gaps by 12 to 96% in groundnut (160 to 1280 kg ha^{-1}), 29 to 100% (240 to 1130 kg ha^{-1}) in pigeonpea and 0 to 100% (0 to 1175 kg ha^{-1}) in chickpea. The impact of watershed interventions was seen in farm-based activities like improved milk production and incomes. The watershed programs alleviated migration in the catchments by improving the five capitals viz. human, financial, social, physical and natural.

1. Introduction

1.1. Rain-fed regions, our hope to future food security

World population of 9.2 billion by 2050 mostly in developing countries in Asia and Africa (5.3 and 1.7 billion, respectively) would need increased water withdrawal from 2500 km^3 in 2000 to 3200 km^3 by 2025 by agriculture to achieve needed food production [1,2]. One third of the world's population (especially in the developing countries) is expected to face severe water scarcity by 2025 [3]. To achieve food security, minimize the water conflicts and reduce poverty, it has become essential to harness potential of rainfed systems [4], as globally 80% of agriculture is rainfed and current productivity on farmer' fields is lower by two to four folds than achievable potential [5–9].

In India, rainfed agriculture constitutes 67% of the net cultivated area [10] and is the hot spot of poverty and malnutrition as it was bypassed during the green revolution era in 1960's. Researchers and policy makers have now realized importance of rainfed agriculture to meet the demand for food which would continue to rise with the growing population expected to reach 1.6 billion by 2050 and also to uplift socioeconomic conditions of the farmers [11,12].

1.2. Harnessing the potential of rainfed agriculture

A long-term study since 1976 at ICRISAT center at Patancheru, India demonstrated a virtuous cycle of persistent yield increases with an average annual productivity of 5.1 t ha^{-1} through improved watershed management (land, water and crop management etc.) in rainfed agriculture as compared with 1.1 t ha^{-1} (Fig. 1) in the farmers' practice [4,13]. Both management practices are sustainable

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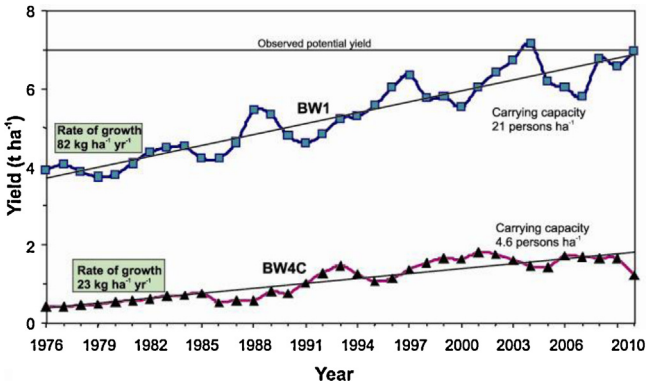

Fig. 1. Three-year moving average of crop yields in improved (BW1) and traditional (BW4 C) management systems *during 1976-2010 at ICRISAT, Patancheru, India*. Source: Wani et al. [10].

in the long run, but have different carrying capacities - farmers' practice having a low carrying capacity of 5 persons ha^{-1}, while improved watershed management can support 21 persons ha^{-1}. Currently, rainfed agriculture suffers from a number of biophysical and socioeconomic constraints, which limit the productivity of crops. There is an urgent need to understand and break the unholy nexus of drought, land degradation and poverty for improving livelihoods, food security through sustainable intensification of natural resources using science-led, holistic watershed scale development approach (5, 13, 14, 15).

1.3. Watershed programs in India–key learning

A meta-analysis of watershed projects in India [14,15], showed a benefit to cost (B:C) ratio of 2 and internal rate of return (IRR) of 27% with rural incomes enhanced by 58%, agricultural productivity increased by 35% and additional environmental and social benefits. However, 68% of projects performed below average in terms of economic, production and social indicators pointing out a large scope for improvement [14,15].

Watershed programs were conspicuously more remunerative and impact oriented in the low income regions with higher B:C ratio of 2.25:1 and 164 person days employment generated per year per ha as compared to the high income regions with 1.75:1 B:C ratio and 91 person days employment generated per year per ha (Table 1). Moreover, returns on investment in inputs as well as research were higher for dryland areas than for irrigated areas [16].

Integrated watershed development is a community approach [17,18] with a positive relationship between people's participation and benefits from watershed program (Table 2). The B:C ratio was greater (2.63) in watersheds where people's participation was higher in comparison to the watersheds with lower participation (1.42). The prominent drivers of success were integrating the needs of all stakeholders particularly women, landless laborers and other vulnerable groups through targeted activities [19,20], knowledge-based entry point activities to build rapport with the community [21,22], tangible economic benefits to individual farmers [23,24], agroecoregion specific technologies [20], consortium (of multiple institutions) approach to harness multidisciplinary strength [25], capacity strengthening of the stakeholders [4,18], and making watersheds a business case by transforming subsistence farming in to marketable surplus farming.

In rainfed areas, management at watershed scale is one of the most trusted approaches to manage rainwater and other natural resources for increasing food production, improving livelihoods, protecting environment, addressing gender and equity issues along with biodiversity concerns [4,13,17,18,24,26–29]. Therefore, integrated watershed management is recognized as a potential engine for agricultural growth and development in fragile and marginal rain-fed areas in India [17,22,26,28].

2. Materials and Methods

2.1. Details of case study watershed sites

The present study was conducted in the selected watersheds in 5 states in India implemented by ICRISAT-led consortia in the areas of soil, water, crop and nutrient management (Table 3). The

Table 1
Summary of benefits from the sample watersheds in India according to income status of the region.

Parameter	Particulars	Unit	Per capita income of the region		
			High*	Medium**	Low***
Efficiency	Benefit to cost (B:C)	Ratio	1.75 (15.3)	1.96 (28.2)	2.25 (9.36)
	Internal rate of return (IRR)	Per cent	24.6 (7.23)	27.9 (6.89)	30.6 (6.02)
Equity	Employment	Persons days ha^{-1} $year^{-1}$	91.1 (7.23)	159.7 (9.16)	164.3 (6.76)
Sustainability	Increase in irrigated area	Per cent	48.5 (12.5)	45.8 (8.09)	76.0 (6.71)
	Increase in cropping intensity	Per cent	31.4 (10.8)	34.1 (14.4)	43.8 (10.3)
	Runoff reduced	Per cent	43.2 (9.32)	43.3 (6.81)	49.3 (5.28)
	Soil loss saved	t ha^{-1} $year^{-1}$	1.18 (36.2)	1.10 (41.1)	0.87 (12.3)

Figures in parentheses indicate t-values; *, **, and *** include the states having per capita Ag GDP greater than Rs. 4000, between Rs. 2000 to Rs. 4000, and below Rs. 2000 per annum, as in Joshi et al., 2005. Source: Joshi et al. [14]

Table 2
Summary of benefits from the sample watersheds in India according to people's participation.

Parameter	Particulars	Unit	People's participation		
			High	Medium	Low
Efficiency	Benefit to cost (B:C)	Ratio	2.63 (16.0)	1.60 (29.7)	1.42 (16.4)
	Internal rate of return (IRR)	Per cent	38.3 (10.2)	22.3 (4.74)	17.3 (8.21)
Equity	Employment	Persons days ha^{-1} $year^{-1}$	165.2 (5.29)	118.7 (4.31)	105.4 (9.97)
Sustainability	Increase in irrigated area	Per cent	77.4 (8.23)	56.2 (8.07)	29.4 (10.3)
	Increase in cropping intensity	Per cent	44.6 (9.37)	25.0 (10.2)	32.0 (14.2)
	Runoff reduced	Per cent	43.2 (6.03)	40.4 (4.22)	69.0 (7.19)
	Soil loss saved	t ha^{-1} $year^{-1}$	1.18 (43.2)	1.10 (18.2)	0.87 (22.3)

Source: Joshi et al. [14]