Agricultural Water Management 176 (2016) 55–66

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Farm level rainwater harvesting across different agro climatic regions of India: Assessing performance and its determinants

Shalander Kumar[a,*], Thiagarajah Ramilan[b], C.A. Ramarao[c], Ch. Srinivasa Rao[c], Anthony Whitbread[a]

[a] International Crop Research Institute for the Semi-Arid Tropics, Patancheru 502 324, India
[b] Insitute of Agriculture and Environment, Massey University, Palmerston North 4474, New Zealand
[c] Central Research Institute for Dryland Agriculture, Hyderabad 500 059, India

ARTICLE INFO

Article history:
Received 19 August 2015
Received in revised form 28 March 2016
Accepted 11 May 2016
Available online 26 May 2016

Keywords:
Rainwater harvesting
Farm pond
Impact
Performance
Determinants supplemental irrigation

ABSTRACT

Rainwater harvesting and its utilization have a very important role to play in harnessing the production potential within dryland systems. This study assesses the performance of small rainwater harvesting structures (farm-ponds) in 5 major rainfed states of India over the period 2009–2011 using data from multiple sources and stakeholders. Rainwater which is harvested using structures of varying types and sizes was used for either supplemental irrigation or recharging open-wells. In many cases, the farm level rainwater harvesting structures were highly effective for rainfed farming and had a multiplier effect on farm income. In some situations however, it was viewed by farmers as a waste of productive land. The use of farm ponds in Maharashtra, for example, resulted in a significant increase in farm productivity (12–72%), cropping intensity and consequently farm income. In the Chittoor district of Andhra Pradesh, farm pond water was profitably used for supplemental irrigation to mango plantations, vegetables or other crops and animal enterprises with net returns estimated to be between US$ 120 and 320 structure^{-1} annum^{-1}. Despite such examples, the adoption of the farm ponds was low, except in Maharashtra. A functional analysis of the reasons for high adoption of water harvesting structures indicated that factors such as technical support, customized design, level of farmer participation, age, existing ownership of open wells, annual rainfall and household assets were the major determinants of performance of farm-level rainwater harvesting structures. Based on this countrywide analysis, different policy and institutional options are proposed for promoting farm-level rainwater-harvesting for dryland agriculture.

1. Introduction

In the rainfed arable systems of India which account for about 55% of the total sown area (Shankar, 2011), capturing and efficiently using rainfall is the most critical component for profitable and resilient rainfed systems. The successful production of rainfed crops largely depends on how efficiently soil moisture is conserved *in situ* or by harvesting the surplus runoff and recycling it for supplemental irrigation. Recycling of waste water is the another potential source to tap for rainfed regions but needs greater investment, sensitization of stakeholders and capacity to ensure safe to use standards for recycled wastewater (Regli et al., 1991; Shuval et al., 1997; Lopez et al., 2006). The Comprehensive Assessment of Water Management in Agriculture (CA, 2007) describes a large untapped potential for upgrading rainfed agriculture and calls for increased water investments in the sector. Over the recent decades, interventions around rainwater harvesting have been an important component of rural and agricultural development programmes in India. The importance of rainwater harvesting for agriculture is now more urgent with increased climatic variability and higher frequency of extreme weather events (Rao et al., 2009; IPCC, 2014). High rainfall variability (AICRPDA, 1991-2011) in the selected seven study districts further makes an important case for rainwater harvesting for agriculture. Research institutions have worked on designing efficient rainwater harvesting structures for different rainfall regions and soil types, effective storage of harvested water and methods for its efficient use in the Indian context (Kumar et al., 2011; Reddy et al., 2012). According to Sharma (2009), many more community managed rainwater harvesting initiatives have resulted in failure than success with most programmes fail-

* Corresponding author.
E-mail addresses: k.shalander@cgiar.org, shalanderkumar@gmail.com (S. Kumar), t.ramilan@massey.ac.nz (T. Ramilan), carrao@crida.in (C.A. Ramarao), cherukumalli2011@gmail.com (Ch.S. Rao), a.whitbread@cgiar.org (A. Whitbread).

http://dx.doi.org/10.1016/j.agwat.2016.05.013

ing to include effective strategies for maintaining the communal water harvesting structures beyond the project life (Shah, 2007). Despite its obvious potentials, many communities fail to overcome collective action challenges in sustaining the ecosystem services over time (Joshi et al., 2005; Falk et al., 2012). Individual control over available water enables farmers to better plan agricultural operations; use water resources more efficiently and productively, and maintain structures for long term use (Takeshima et al., 2010; Molle et al., 2003). The community based initiatives have their own limitations which are usually related to institutional failure (Shah, 2007). This has led to government's increased investment priority for promoting rainwater harvesting at the farm level (Govt. of India, 2007). However, despite of the technical potential of these technologies, the adoption and performance these efforts have "*. . .not been very satisfactory especially in enhancing agricultural productivity and farm income*" (Rao et al., 2009). There in need to generate more information on economic viability of farm level rainwater harvesting, factors influencing its performance and implementation under different agro-ecologies would be helpful in guiding the future investments. The study presented in this paper makes a comprehensive assessment of performance of rainwater harvesting at the farm level in five major rainfed states of India representing semi-arid and arid regions to better understand the drivers and conditions under which previous initiatives have been successful or which factors led to failure.

2. Materials and methods

2.1. Data

The study uses data from various sources including a survey and focus group discussions (Table 1) to assess the performance of farm level rainwater harvesting under different agro-climatic conditions in semi-arid and arid regions in India. The surveys were undertaken in single districts of five major rainfed states (Districts) namely; Andhra Pradesh (Chittoor), Maharashtra (Akola), Karnataka (Bangalore rural), Tamil Nadu (Vellore) and Rajasthan (Bhilwara) with reasonable density of farm ponds, all representing semi-arid agro-ecologies. Two more districts, Jodhpur from Rajasthan and Anantapur from Andhra Pradesh (AP) were also included in the study to represent major hot arid agro-ecologies in India. This selection used advice from national scientists of Dryland project of Central Research Institute of Dryland Agriculture (CRIDA) as well as the published sources (Rao et al., 2009). In the selected districts annual rainfall varied from 327 to 949 mm and has diverse soil types (Table 4). In the randomly selected clusters of 3–4 villages from each district (Fig. 1) a rapid rural appraisal was undertaken covering about 100 households selected randomly from each cluster. It revealed that a very low proportion of farmers (<10%) possessed rainwater harvesting structures (RWHS) for agricultural purposes. From this sample of farmers with and without RWHS, 2 groups of 20 farm households/district were randomly selected. Thus the study sample of n = 200 farm households (HHs) represented a wide range of rainfall, soil and cropping systems. The data were collected for the year 2010–2011 through interviews using structured questionnaire administered in June–July 2011. Although construction of RWHS was partially funded by various government programmes, structures were largely constructed and maintained by farmers. The data were collected on socio-economic profile of the households, characteristics and utility of RWHS and initial investment and operational cost of RWHS, adoption and awareness levels of farmers' about rainwater harvesting techniques and benefits, for example, increased cropped area and productivity, increased income due to diversification to high value enterprises. We also collected information through structured discussions with programme implementing agencies (district water development agency in Andhra Pradesh, agriculture and soil & water conservation departments in other states), research scientists from CRIDA and Agricultural Universities in respective states, relevant non-governmental organizations (NGOs): Foundation for ecological security (FES) in Rajasthan and AP; DHAN foundation in AP and Tamil Nadu, local panchayats, policy makers (Director watershed programmes)as well as on-site observations.

To further assess the impact of rainwater harvesting on agricultural productivity and farm income, a second data set was collected from projects undertaken by a federally agricultural research funded agency, the Central Research Institute for Dryland Agriculture (CRIDA). Data from a network of on-farm trials conducted by CRIDA and collaborating agricultural universities' scientists in different regions of India representing diverse agro-climatic situations (rainfall 500 to >1000 mm), soils (Aridisols, Alfisols, Vertisols, Inceptisols, Antisols, Oxisols) and cropping systems. Some common characteristics of the rainwater harvesting structures include: structurally farms ponds are not covered structures, except in Jodhpur (arid Rajasthan), where RWHS was much smaller in size and covered to avoid high evaporation losses during hot times (Seethapathi et al., 2008). In Jodhpur, the rainwater was harvested in an underground cistern made of concrete and locally known as Tanka (Goyal and Issac, 2009). The rainwater harvested and stored through farm ponds on individual fields was recycled mainly for supplemental irrigation during dry spells in the growing season. In some villages in Tamil Nadu and Andhra Pradesh these structures were dug in the vicinity of open wells (most of these open wells dried up earlier) and were used as percolation ponds for their recharging. All the sample households were rainfed and did not have access to underground water through bore-wells except around 20% households in Anantapur and Vellore who had owned shallow open wells. These open well owning households accounts only for 6% of the total sample households. For the open well owning households, the benefits were calculated as additional area irrigated because of recharging of the open wells. We assessed the impact of farm level rainwater harvesting on cropping pattern, cropping intensity, diversification to high value crops, crop and livestock productivity, net returns and perception of farmers to risk.

2.2. Data analysis

The farmers' contribution to the initial investment on RWHSs was about 50%, but the benefit-cost analysis was carried out for both the scenarios; scenario I. considering total cost (farmers contribution + government contribution), which included the fixed costs (depreciation, interest, opportunity cost of land (lease cost) where structure is constructed) and variable costs such as annual maintenance cost at the rate of 2% of capital cost (Palmer et al., 1982) and operational expenditure such as labour, pump hire charge and diesel cost for irrigation. For those households who had access to pump sets, the hire charges of 3 hp diesel pump set using plastic pipe or sprinkler as delivery systems were included in the cost. Such hire charges for pump set varied from US$ 8 to US$ 10 per day. A few farmers in Chittoor district also used a traditional device to lift pond water manually engaging two persons and accordingly the cost was accounted. Scenario II, where 50% government support for initial investment was not included in benefit cost analysis, wherein the analysis considered all costs but only 50% of the fixed cost in terms of depreciation and interest on initial investment. The internal rates of return (IRR) were estimated to reflect long term performance of RWHS following Gittinger (1982) and assuming 15 year life of farm ponds (Reddy et al., 2012; Malik et al., 2013). The annual net current benefits due to farm pond were calculated for each farmer and then mean for each district. However the IRR was